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IMPLICATION DE LA RÉTENTION FORESTIÈRE EN AMÉNAGEMENT ÉCOSYSTÉMIQUE DANS LA CONCILIATION DES BESOINS ÉCOLOGIQUES ET SOCIAUX

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CYNTHIA PATRY

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AVANT PROPOS

La présente thèse est le fruit d'un travail de collaboration entre mes directeur et co-directeur Christian Messier et Daniel Kneeshaw, ainsi que l'aide inestimable de mon comité de thèse incluant Stephen Wyatt et Isabelle Aubin. J'ai été en charge de l'élaboration des objectifs et hypothèses de recherche, de la planification des chapitres, de l'échantillonnage terrain, ainsi que de l'analyse des données et de la rédaction des articles. Mon comité de thèse a été à mes côtés à chaque étape pour discuter du contenu scientifique et des approches méthodologiques et analytiques à adopter. Je tiens à souligner que Frank Grenon ainsi que Stephen Wyatt ont participé aux discussions concernant la premier chapitre ainsi qu'à son amélioration. Pour le second chapitre Isabelle Aubin, Timo Kuuluvainen et Anneli Uotila ont grandement contribué au raffinement des idées, aux analyses statistiques, ainsi qu'à la relecture du manuscrit. En ce qui concerne le troisième chapitre Stephen Wyatt, ainsi que Nicolas Milot ont participé au brassage des idées, ainsi qu'à la relecture et aux corrections du manuscrit. Cette thèse est présentée sous la forme de trois articles scientifiques rédigés en anglais. Au moment du dépôt de cette thèse le premier chapitre est publié dans le Forestry Chronicle du mois de juillet/ août 2013, le second chapitre est en cours de préparation pour sa soumission à la revue Forest ecosystem and management et le troisième chapitre pour soumission à Forest Policy and Economics.

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"Nous changeons la terre plus rapidement que nous la comprenons"

(Vitousek *et al.*, 1997)

In culture, as well as in nature, diversity holds the potential for innovation and opens the way for creative, non-linear solutions.

(Wolfgang, 1999)

TABLE DES MATIÈRES

LISTE DES FIGURES

LISTE DES TABLEAUX

RÉSUMÉ

Un élément important et récurrent des stratégies d'aménagement écosystémique est la rétention d'une certaine proportion du couvert forestier, comme héritage biologique, et cela, autant au niveau du peuplement que du paysage, ainsi que dans le temps. Une rétention plus élevée (bois mort au sol, chicots, arbres vivants, corridors, bandes riveraines, larges ilots, vieilles forets et aires protégées) est-elle le gage d'une meilleure conciliation des besoins écologiques et sociaux?

Tout d'abord, quels sont les besoins écologiques reliés au maintien de la rétention forestière? L'impact d'un gradient d'intensification forestière sur la composition fonctionnelle (trait fonctionnel) de la strate herbacée a été testé. Une tendance vers la perte des traits de persistance (espèces sur la liste rouge) est observée avec l'intensification de l'aménagement. Cette perte est d'autant plus grande quand l'intensification s'effectue à différentes échelles spatiales et dans le temps.

Ensuite, un questionnaire internet a été administré à des parties prenantes de différentes affiliations (utilisateurs non industriel, les représentants des ONG en environnement et industriels) impliquées dans un processus décisionnel et des chercheurs en écologie afin de tester comment les parties prenantes acceptent les bases théoriques et priorisent la rétention forestière. Tous les répondants s'entendent sur les bases scientifiques (différentes échelles spatio-temporelles). Par contre, les industriels ont des préférences divergentes sur l'opérationnalisation de la rétention, adoptant le status quo vs une amélioration des pratiques actuelles.

Finalement, dans le but de mieux comprendre comment est opérationnalisé la rétention forestière, une revue des différentes stratégies de rétention forestière utilisées dans les guides en aménagement écosystémique à été réalisée. Le cadre théorique (émulation des perturbations naturelles ou non) et les échelles spatio-temporelles utilisées pour opérationaliser la rétention ont été comparés. Tous les guides, sauf le plus ancien, basent leur cadre théorique sur l'émulation des perturbations naturelles. Par contre, ils n'adaptent pas le contexte historique aux changements globaux actuels. L'aspect temporel de la rétention est très peu abordé, avec une grande majorité des stratégies sur le court terme. Une plus grande justification écologique ainsi qu'une meilleure interrelation des échelles spatiales seraient également souhaitable. Dans un contexte d'aménagement écosystémique, il est crucial d'arriver à proposer des stratégies de rétention concrètes qui sont pertinentes écologiquement et endossées par la majorité des groupes d'intérêts constituant les parties prenantes.

INTRODUCTION

La délimitation entre les systèmes sociaux et écologiques est de plus en plus remise en cause avec l'augmentation de la population mondiale (Folke, 2006). L'humain est maintenant bien implanté dans la majorité des systèmes écologiques (Vitousek *et al.*, 1997); en effet, il constitue dans bien des cas une espèce clé ("key species") dans la modification de l'environnement et ce, à plusieurs échelles spatiales (Zurlini *et al.*, 2006). Plusieurs auteurs suggèrent de briser les frontières et d'aborder les problèmes environnementaux selon une approche plus intégratrice portant sur les socio-écosystèmes ou encore les systèmes socio-écologiques (SES) (Glaser *et al.*, 2008).

Dans le socio-écosystème que constitue la forêt, il est maintenant reconnu que la création d'aires protégées est insuffisante pour assurer le maintien de la biodiversité forestière (Daily et Huang, 2001 ; Deal, 2001 ; Fischer *et al.*, 2006 ; Heller et Zavaleta, 2009 ; Wiersma et Nudds, 2009) et satisfaire les multiples usagés de la forêt. Considérant que 92% des forêts mondiales sont hors réserve (FAO, 1999 cité dans (Lindenmayer *et al.*, 2006)), une attention particulière doit être apportée à la matrice forestière aménagée qui devrait contribuer au maintien du plus grand nombre d'espèces (Folke *et al.*, 1996 ; Lindenmayer et Franklin, 2002 ; Rayfield *et al.*, 2008) et à l'harmonisation des usages. Depuis l'émergence de la foresterie industrielle, la matrice forestière a subi des changements majeurs en composition et structure qui menacent actuellement la survie des espèces les plus vulnérables (FAO, 1992). De façon générale, elle a été grandement simplifiée, menant entre autres à des forêts ayant une composition et une structure beaucoup plus homogènes à l'échelle du site (Puettmann *et al.*, 2009) et à des proportions de vieilles forêts bien en dessous des seuils historiques (Cyr *et al.*, 2009b). Plusieurs études suggèrent que la perte des attributs des forêts anciennes, tels que le bois mort (Ehnstrom, 2001 ; Jonsson *et al.*, 2005), a un effet non négligeable sur la biodiversité et est parmi les enjeux les plus critiques en foresterie (Freedman *et al.*, 1996 ; Gauthier *et al.*, 2008a ; Hanski, 2000 ; Noss, 1999 ; Whitman et Hagan, 2007). La connectivité du territoire a également grandement été modifée par rapport à la matrice forestière naturelle (Wedeles et Sleep, 2008). Dans certaines régions du monde, une restauration des écosystèmes forestiers est même nécessaire car on'y retrouve pratiquement plus de forêts naturelles (Kuuluvainen, 2002).

Les problèmes issus du mode de gestion conventionnelle des ressources forestières ont mené à une perte de confiance de la part du public envers les gestionnaires de la forêt (Shindler *et al.*, 2002). Cette pression sociale grandissante a stimulé un changement de paradigme forestier, passant d'une exploitation basée sur le libre marché de la ressource ligneuse et la productivité des usines, vers le paradigme de l'exploitation durable des ressources forestières (Bengston, 1994 ; Kimmins, 2002).

Avec l'engouement pour le développement durable des ressources, plusieurs concepts connexes gagnent actuellement en popularité, tels que l'aménagement écosystémique. Ce concept récent provient de la Conférence mondiale sur l'environnement humain à Stockholm de 1972 et de la Convention des Nations Unies sur le droit de la mer de 1982 (FAO, 2003). Il a rapidement été repris en foresterie (Grumbine, 1994) et abondamment discuté depuis. Les définitions de l'aménagement écosystémique sont nombreuses. Toutefois, une revue de la littérature par Grumbine (1994) indique que dans l'atteinte du maintien de l'intégrité écologique, certains sous-objectifs sont récurrents, tels que: " (1) maintenir des populations viables in situ de l'ensemble des espèces indigènes; (2) représenter dans les aires protégées l'ensemble des types d'écosystèmes à travers leur aire de variabilité naturelle; (3) maintenir les processus évolutifs et écologiques (ex; perturbations naturelles); (4) aménager sur une période de temps suffisamment longue pour maintenir le potentiel évolutif des espèces et des écosystèmes; et (5) accommoder les besoins humains et leur occupation du territoire à l'intérieur de ces contraintes. "

Les forêts résiduelles, qui sont définies comme tout élément naturel retrouvé à une ou plusieurs échelles spatiales qui sera maintenu pour un certain temps dans la matrice forestière après une coupe ou une perturbation naturelle (incluant bois mort au sol, chicots, arbres vivants, corridors, bandes riveraines, larges ilots, vieilles forêts et aires protégées), se sont révélées être un élément central dans l'atteinte des objectifs soulevés par la gestion écosystémique. Elles jouent un rôle potentiellement crucial dans la résilience de ces écosystèmes après perturbation, contribuant avec le temps au maintien des attributs de forêts naturelles (Beese *et al.*, 2003 ; Crête *et al.*, 2004 ; Deans *et al.*, 2003 ; Drapeau et Imbeau, 2006 ; Mitchell et Beese, 2002 ; Perron *et al.*, 2008). Les seuils écologiques concernant la quantité, la disposition et la qualité des forêts résiduelles demeurent incertains (Lindenmayer et Franklin, 2002 ; Rosenvald et Lohmus, 2008).

Bien que les connaissances scientifiques soient encore partielles concernant l'impact de la rétention forestière sur la biodiversité et les fonctions des écosystèmes (Rosenvald et Lohmus, 2008), la majorité des études concluent qu'il faudrait faire davantage d'efforts afin de maintenir une portion plus importante de rétention forestière et ce, à plusieurs échelles temporelles et spatiales (Letres *et al.*, 1999 ; Lindenmayer et Franklin, 2002). Les échelles spatiales sont souvent interdépendantes (Levin, 1992) car certains phénomènes à une échelle donnée dépendent de ce qui arrive à d'autres échelles sans toutefois être visible à toutes les échelles (Franklin, 1993). Par exemple, trop longtemps la connectivité du territoire était assurée par une stratégie de rétention à l'échelle du peuplement, soit par le maintien de bandes riveraines. Les bandes riveraines risquent de ne pas satisfaire les besoins de connectivité aux échelles spatiales supérieures car leur répartition n'est pas nécessairement en fonction de lier les différentes parcelles de forêt. La temporalité de la rétention est également très importante car la faune et la flore ont des besoins écologiques très variables. Des espèces habituées à des perturbations fréquentes ne nécessiteront pas la même continuité dans la rétention forestière que des espèces issues de milieux très stables (Armstrong *et al.*, 2003 ; Hunter, 1999). Le principe de précaution (Matsuda, 2003) est de mise quand les besoins de continuité dans la rétention ne sont pas bien définis pour l'ensemble des espèces. Il est suggéré que l'analyse des patrons de distribution dans le temps et l'espace des éléments de rétention suite aux perturbations naturelles serait une manière prometteuse d'opérationnaliser la rétention forestière dans les limites de la variabilité naturelle des forêts (Armstrong *et al.*, 2003).

Quoique la réduction de la rétention forestière dans le temps et l'espace risque d'affecter de nombreux taxons (Rosenvald et Lohmus, 2008), la présente étude propose d'évaluer l'impact des forêts résiduelles sur la dynamique végétale de sous-bois utilisant une approche par traits fonctionnels. Les études sur l'impact des aménagements forestiers sur la strate de sous-bois sont souvent fragmentaires car elles se déroulent sur des échelles de temps et d'espace restreintes (Alexandter *et al.*, 2007 ; Beese et Bryant, 1999 ; Dovciak *et al.*, 2006 ; Drever et Lertzman, 2003 ; Halpern, 2005 ; Macdonald et Fenniak, 2007 ; Rosenvald et Lohmus, 2008 ; Sullivan et Sullivan, 2001 ; Sullivan *et al.*, 2008 ; Temesgen *et al.*, 2006 ; Vanha-Majamaa et Jalonen, 2001). Peu évaluent l'impact sur une échelle de plus de 10 ans (Deal, 2001 ; Rose et Muir, 1997 ; Traut et Muir, 2000). De plus, l'influence du paysage sur ce taxon est peu documentée (Wilson et Puettmann, 2007). Généralement les recherches qui tentent d'évaluer l'impact des nouvelles pratiques forestières sur la biodiversité végétale se limitent à l'analyse de la richesse et de l'abondance, alors que les traits fonctionnels fournissent des informations complémentaires et cruciales sur le fonctionnement global de l'écosystème (Lavorel et Garnier, 2002 ; Naeem *et al.*, 2012). Les traits fonctionnels sont également utiles car ils permettent une comparaison de différents écosystèmes qui ont une composition en espèces potentiellement différente, mais où les processus sont les mêmes (Bernhardt-Römermann *et al.*, 2011).

L'aménagement du territoire à travers plusieurs échelles spatiales et temporelles est un idéal écologique qui est susceptible de poser plusieurs problèmes de nature humaine/sociale, tels que des problèmes de valeurs, de conception, de compréhension et d'opérationnalisation (Byron *et al.*, 2011). En effet, le maintien de forêts résiduelles pose un problème de taille car cette action est en opposition avec le paradigme de la marchandisation de la forêt dans un contexte de libéralisme économique par le fait que le bois laissé représente des pertes financières et peut être perçu comme du gaspillage de la ressource ligneuse par certaines parties prenantes .

En aménagement écosystémique l'élaboration de stratégies passe de plus en plus par un long processus impliquant plusieurs acteurs du milieu forestier (Betts et Forbes, 2005 ; Coast Information Team, 2004 ; USDA et USDI, 1994). En effet, l'approche par parties prenantes ("stakeholder theory"), qui divise la prise de décision entre plusieurs acteurs du milieu (Freedman et McVea, 2001), est davantage favorisée en aménagement écosystémique que par le passé où les pouvoirs étaient concentrés au sein de l'industrie forestière et des gouvernements (Chiasson et Leclerc, 2013). Toutefois, en pratique certains groupes, tels que l'industrie forestière qui possède davantage de moyens, semblent encore dominer les débats (Houde et Sandberg, 2003). L'arrivée de nouveaux acteurs dans le processus décisionnel est susceptible d'améliorer la résilience du socio-écosystème, bien que ce ne soit pas systématiquement le cas. La justification étant que ceux-ci, en voulant défendre leurs idées et leurs intérêts, contribuent à enrichir le débat lorsque des perturbations surviennent, ce qui potentiellement va influencer positivement la capacité d'innovation et de renouvellement du système (Lebel *et al.*, 2006). Certains chercheurs affirment que les décisions prises par voie de consensus et par une diversité d'acteurs locaux risquent d'être plus acceptées localement et durables dans le temps, que des décisions prisent par des autorités centralisées (Brunson *et al.*, 1992 ; Glasmeier et Farrigan, 2005).

Dans un monde où les parties prenantes ont de plus en plus de poids dans les décisions, il est capital de mieux comprendre comment ils comprennent les concepts scientifiques et intègrent la science dans leurs pratiques forestières. L'acceptabilité des nouvelles pratiques forestières doit être intégrée dans le processus de mise en œuvre de l'aménagement écosystémique. Cependant, cette question est moins fréquemment abordée dans la littérature (Brunson, 1996 ; Dekker *et al.*, 2007 ; Slocombe, 1998) et plus difficilement intégrée dans la pratique (Butler et Koontz, 2005). Il est également important que les alternatives proposées par les parties prenantes, s'il en est, contribuent réellement aux enjeux écologiques qui ont motivé leur élaboration.

Le développement de concepts scientifiques, tels que l'aménagement écosystémique et la rétention forestière, ainsi que leur opérationnalisation représente tout un défi mais est essentiel à la bonne gestion de nos ressources naturelles (Harris, 2012). L'implication d'un nombre accru de parties prenantes différentes dans le processus décisionnel issues par exemple d'affiliations ou de niveaux d'éducation différents, complexifie d'autant plus ce transfert de connaissances. Les concepts risquent de ne pas être compris par tous de la même manière, mais également les délais en vue de l'obtention de bénéfices découlant de l'opérationnalisation de ces concepts sont souvent mal compris (Harris, 2012). Par exemple, le concept d'aménagement écosystémique a pris plusieurs années pour être compris et accepté par la majorité aux États-Unis (Bengston *et al.*, 2001). Récemment certains scientifiques ont commencé à réclamer plus de "translational ecology", un terme qui signifie plus de transfert de la science vers les milieux pratiques. L'objectif étant que les praticiens (politiciens, fonctionnaires, industriels, etc.) soient à même d'intégrer à leurs prises de décision la meilleure science disponible (Schlesinger, 2010).

Toutefois, pour réduire le fossé entre la science et la société il faut entre autres que les scientifiques s'impliquent dans la vie publique et utilisent d'autres moyens de communication (Bartonova, 2012).

0.1 Objectif général

La présente thèse vise à mieux comprendre comment les connaissances scientifiques sont intégrées dans les pratiques de gestion. Les trois chapitres représentent chacun une des étapes menant à la mise en œuvre d'un concept théorique. La première étape consiste en la création des connaissances scientifiques suite à l'étude du système ciblé. La seconde étape comprend le processus décisionnel qui va agir comme filtre au niveau des connaissances disponibles pour, au final, ne retenir que les éléments qui satisferont aux priorités et valeurs des agents décisionnels. Et finalement, la dernière étape consiste en la création de mesures concrètes afin de mettre en œuvre le concept théorique, soit l'aménagement écosystémique, basé sur les décisions prises à la seconde étape. Puisque ce concept est très large et implique plusieurs facettes de l'aménagement, j'ai choisi de privilégier plus spécifiquement la rétention forestière. Une emphase particulière est portée sur l'efficacité des forêts résiduelles à maintenir à plusieurs échelles de temps et d'espace la résilience des socio-écosystèmes forestiers en assurant le maintien de la biodiversité et en favorisant l'acceptabilité des parties prenantes. D'où découle la question de ma recherche:

0.1.1 Question et sous-questions de recherche de la thèse :

Comment la rétention forestière dans un contexte d'aménagement écosystémique contribue à concilier les besoins écologiques et sociaux?

1) *Quels sont les besoins écologiques reliés à la rétention forestière?*
2) *Comment ces besoins sont compris et priorisés par les parties prenantes?*

3) Comment la rétention forestière est mise en œuvre dans les stratégies d'aménagement écosystémique?

Pour y répondre, trois sous-objectifs ont été élaborés : (1) analyser l'impact d'un gradient d'intensification de l'aménagement forestier (dans le temps et l'espace) sur la composition fonctionnelle de la strate de sous-bois ; (2) tester comment les parties prenantes impliquées dans un processus décisionnel acceptent les bases théoriques et priorisent la rétention forestière; et (3) faire la revue des différentes stratégies de rétention forestières utilisées dans les guides en aménagement écosystémique de la forêt tempérée en Amérique du Nord afin de déterminer si l'émulation des perturbations naturelles est une base scientifique dans les guides et si la rétention forestière est opérationnalisée à différentes échelles spatiales et temporelles. L'atteinte de ces objectifs permettra de mieux comprendre globalement comment la rétention forestière peut aider à la conciliation des besoins écologiques et sociaux lors de l'opérationnalisation du concept d'aménagement écosystémique. L'ordre des chapitres suit la logique expliquée plus haut concernant les étapes de la mise en œuvre d'un concept théorique, soit le développement des connaissances (chapitre 1), la prise en compte ou non de ces connaissances scientifiques (théorie) dans le processus décisionnel (chapitre 2) et finalement la création de stratégies concrètes d'opérationnalisation du concept (chapitre 3).

CHAPITRE I

INTENSIVE FORESTRY FILTERS NEGATIVELY PERSISTENCE UNDERSTORY VEGETATION TRAITS OVER TIME AND SPACE

Cynthia Patry,
Centre d'etude de la Foret, Departement des Sciences Biologiques, Universite du Quebec a Montreal, C.P. 8888, Succ. Centre-Ville, Montreal, Canada, H3C 3P8
patry.cynthia@courrier.uqam.ca

Daniel Kneeshaw
Centre d'etude de la Foret, Departement des Sciences Biologiques, Universite du Quebec a Montreal, C.P. 8888, Succ. Centre-Ville, Montreal, Canada, H3C 3P8.
kneeshaw.daniel@uqam.ca

Isabelle Aubin
Service canadien des forêts, Centre de forestrie des rands Lacs, 1219 Queen St. East Sault Ste. Marie, Canada, P6A 2E5
Isabelle.Aubin@NRCan.gc.ca

Timo.Kuuluvainen
University of Helsinki, Department of Forest Sciences
Faculty of Agriculture and Forestry, P.O.Box 27 (Latokartanonkaari 7), Finland, FI-00014 Timo.Kuuluvainen@helsinki.fi

Anneli Uotila
Faculty of Forestry, University of Joensuu, P.O. Box 111, FI-80101 Joensuu, Finland.
anneli.uotila@kolumbus.fi

Maija Salemaa
The Finnish Forest Research Institute, Vantaa, Finland, PO Box 18, FIN-01301
maija.salemaa@metla.fi

Christian Messier
Centre d'etude de la Foret, Departement des Sciences Biologiques, Universite du Quebec a Montreal, C.P. 8888, Succ. Centre-Ville, Montreal, Canada, H3C 3P8.
messier.christian@uqam.ca

1.1 Abstract

Protected areas alone cannot maintain biodiversity. Therefore, it is necessary to create conditions appropriate for plants and wildlife in managed landscapes. We compared effects of different levels of historical forest management intensities at stand- and landscape-scales on functional responses of understorey plants. A gradient in intensity of forest management, spanning natural forests and extensively managed forests (naturally regenerated cuts) in Canada to intensively managed forests (plantations) in Canada and Finland was analysed on the basis of functional traits of the understorey species present. Traits characteristic of red-listed Finnish understorey species were also used. Results showed strong trait filtering along a gradient of forest management intensity. In natural forests and extensively managed forests, where forest retention was high throughout time and space, persistence traits were maintained, i.e., perennial geophytes or chamaephytes with non-leafy stem foliage structure. At the opposite end of the gradient, in intensively managed plantations, where forest retention elements (i.e., dead wood and large forested patches) were reduced, filtering led to selection of species with colonisation traits, e.g., tall species with limited lateral extension. In Finnish plantations, the filter was stronger, with more colonisation traits being selected, e.g. graminoid therophytes dispersed by epizoochory. In both Canadian and Finnish plantations, depleted traits were the same as those on the Finnish red-list. These results show that intensive forestry conducted over a long period of time and over a broad landscape negatively affect understorey plant functional diversity as measured by functional traits.

1.2 Introduction

The historical extent and intensity of boreal forest exploitation has varied greatly geographically. Most European boreal forests have been exploited for centuries, leading to a modification in structure and composition. In contrast, some boreal forests in Russia and North America still possess many characteristics of primary forests, due to their more recent history of colonisation and to less intensive forest industrialisation (Gustafsson *et al.*, 2010). The maintenance of retention elements, such as down woody debris (DWD) and patches of green trees, greatly depends on the degree to which forest management is intensified (Gustafsson *et al.*, 2010). Old forests (> 150-years-old), which had been historically dominant in Finland (Kuuluvainen and Siitonen, 2013), were reduced by the 1800's to a third of the landscape area that they had formerly occupied and now have been practically eliminated (< 1% in Sweden) (Linder and Ostlund, 1998). Currently, most European boreal forests are young and even-aged (Kouki *et al.*, 2001). The same trend is occurring in the boreal forests of Canada, but to a lesser extent (Cyr *et al.*, 2009a). Coarse woody debris (CWD), for example, has been reduced by 90-98% of its historical levels in Fennoscandia (Siitonen, 2001) and by 30% in Canada (Pedlar *et al.*, 2002). Forest management intensification has further resulted in a reduction of the hardwood component of the European boreal forest, particularly Eurasian aspen (*Populus tremula* L.) (Kouki *et al.*, 2004). Consequently, many aspen-associated species are now threatened in Northern European countries (Kouki *et al.*, 2004). In North America, the opposite trend is occurring, as poplar species have been increasing in abundance following forest harvesting (Carleton and Maclellan, 1994).

Such structural and compositional changes that are induced by intensive forest utilisation have adversely affected forest biodiversity (Hanski, 2000) and many forest processes (Bengtsson *et al.*, 2000 ; Cardinal and Andrew, 2000). For example, in intensively managed Finnish forests, 2247 species have been classified as threatened and now appear on Finland's red-list. Of this list, about 31 herbaceous species are classified as being threatened by increased forest management practices (Rassi *et al.*, 2010). However, this number varies greatly along the gradient of forest management intensity (IUCN, 2012). To date, no threatened species that are associated with Canada's less intensively managed boreal forest have been found on the IUCN Red-List (IUCN, 2012)

A taxonomic approach has been traditionally used to evaluate the effects of forest management intensification on biodiversity (Díaz and Cabido, 2001). At the site-level, understorey species richness following management prescriptions can equal or exceed that of pre-management conditions, although the species pool is often modified (Haeussler and Bergeron, 2004 ; Hasenauer and Kindermann, 2002 ; Kembel *et al.*, 2008 ; Newmaster *et al.*, 2007 ; Peltzer *et al.*, 2000). More recently, the functional trait approach has been proposed as a method that complements the taxonomic approach, and which allows a more mechanistic understanding to be gained regarding the processes that are involved (Lavorel and Garnier, 2002 ; Naeem *et al.*, 2012). Further, the use of functional traits may provide advanced warning of potential changes in a community prior to actual species losses (Mouillot *et al.*, 2012). For a given species pool within an ecosystem, environmental pressures act as a filter upon species and, consequently, the response of a given species will be determined by its traits (Keddy, 1992). The use of a functional trait approach permits different ecosystems with similar underlying processes, but potentially dissimilar species compositions to be compared (Aubin *et al.*, 2007 ; Bernhardt-Römermann *et al.*, 2011). Such an approach is thus ideally suited for a comparison of many sites across biogeoclimatically similar regions and continents such as the boreal regions of Western Europe and Canada. Yet, it is difficult to find natural forests in the boreal forest of western Europe; conversely, it is difficult to find stands and landscapes within the Canadian boreal forest that have been intensively managed for an extended period of time (> 50 years).

The objective of this study was to compare the effects of an intensity gradient of forest management, as practiced in the boreal forest of Western Europe and Canada, on understorey vegetation functional trait composition at both the stand- and landscape-levels. We hypothesised that as forest management intensifies, traits that are related to processes such as dispersion and persistence will be filtered[1] differently, resulting in the creation of dissimilar syndromes[2]. A syndrome of colonisation traits should increase while a syndrome of persistence traits should decrease with the intensity of forest management (syndrome description, Table 1.1). Forest management intensity is determined by the amount of retention elements that are maintained through time, both at the stand and landscape scales, but also to other factors as site preparation and time between two rotations. To conduct this evaluation, three levels of forest management intensities were compared: high forest retention, which was maintained over time and space (natural forests and extensively managed forests in Canada); low forest retention, which was maintained at the stand-scale (intensively managed plantations in Canada that were surrounded by extensively managed forests); and low forest retention, which was maintained at both stand- and landscape-scales over time (intensively managed plantation landscapes in Finland).

1.3 Material and methods

The effect of the management intensity gradient was tested in two steps. Because strong differences in functional traits between regions (Canada vs Finland) can mask important differences within a region, we first compared naturally

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1Trait filtering: "The process by which abiotic variables determine whether a species has the requisite traits to colonize, establish, and persist in a given environment " (Mouillot et al., 2012)

2Syndrome: A set of functional traits selected by environmental conditions (Lloret et al., 2005) regenerated forests following a natural disturbance in Canada (CN = Canada natural) with naturally regenerated forests following a partial or total cut (CE = Canada extensive), and intensively managed plantations, which had been thinned once or twice (CI = Canada intensive). In extensive management, no further management activities were performed after cutting and a greater amount of retention was left (Gustafsson *et al.*, 2010). In general, cut rotations under intensive management were shorter than in extensively managed forest, i.e., about 70-80 years (Forestry Development Centre TAPIO, 2006)

To extend the gradient of forest management intensity, a second analysis was performed that included Finnish boreal forest, which had a longer and more intensive land use history. This forest served as a proxy for the extreme end of the forest-use intensity gradient. We compared intensive plantations in Canada (CI) with intensive plantations in Finland (FI = Finland intensive). The comparison between naturally regenerated forests in Canada and Finland was not possible, given the lack of naturally regenerated forests in the latter. Results were then compared with the traits of species found on the Finnish Red-List to evaluate whether they included the same traits that were lost in intensively managed forests.

1.3.1 Land use history

The boreal forest of Quebec (Canada) underwent colonisation primarily for logging rather than for agricultural purposes (Blanchet, 2010). Prior to the 19th century, agricultural expansion that was attributable to European colonisation of Canada occurred mainly in the southern regions of the country. Industrial exploitation of the Canadian boreal forest only began in the early 20th century, with a focus on spruce harvesting for pulp and paper (Bouthillier, 2011). During this period, the forest industry began to expand further north into the boreal forest, primarily along the major river networks (Blanchet, 2010 ; Boucher *et al.*, 2009). Yet, forest management in the boreal forest of Canada never reached the intensive level that had been attained in the Fennoscandian countries. Large-scale intensively management of mono-culture plantations in Canada is only practiced on private lands in New Brunswick (Park and Wilson, 2007). For the past 30 years, the main forestry activity in Canada's boreal forest has been clear-cut logging of natural forest (Bock and Van Rees, 2002), which may or may not be followed by planting. In 2010, only 3% of Canada's forest was planted (Commonwealth Forestry Association, 2010).

In contrast, much of the Scandinavian boreal forest has been intensively utilised for many centuries (Kuuluvainen and Siitonen, 2013). In Norway, Sweden and Finland, the forest was greatly modified before the beginning of the forest industry. For example, slash and burn agriculture in Finland had a large-scale effect on forests that began as early as the 17^{th} century and which continued until the 19^{th} century. During this period, tar production using Scots pine (*Pinus sylvestris* L.) as the main raw material, together with cattle grazing in the forests, also greatly affected forest ecosystems (Lilja, 2006). Intensive agricultural expansion concluded after World War II, at the same time as the arrival of the forest industry (Ostlund *et al.*, 1997). Since the 1950's, the previously common practice of selective cutting was increasingly replaced by stand-level clear-cutting and even-aged forestry (Kuuluvainen and Siitonen, 2013). The synergy between agricultural expansion and development of intensive forestry in southern Scandinavia changed the landscape by fragmenting the forest into small patches, typically ranging from 0.5 to 10 ha in area (Kuuluvainen, 2002).

1.3.2 Site descriptions

A total of 63 sites were sampled in Canada and Finland. To cover a gradient of forest management intensity, different types of forest were selected. Because the objective of this study was not to compare different stages of succession, all sites that had been selected were between 30- and 70-years-old. In Canada, sites that had been disturbed before 1960 were excluded from the sampling of sites that were managed using industrial techniques. Unfortunately, naturally regenerated forests on rich soils proved very difficult to find in southern Finland, did not appear in the BioSoil database[3] (Hiederer *et al.*, 2011) and, were not subsequently sampled. More than 80% of all harvested sites had been replanted, mainly with Norway spruce (*Picea abies* (L.) Karst.) and Scots pine (METLA, 2011). Semi-natural forests are only found in the north and northeast (Uotila and Kouki, 2005) or in old stands in advanced states of stand development that were well beyond the 30- to 70-year cut-off (Kuuluvainen *et al.*, 1996). Field work was undertaken in summer 2010 in Canada and in summer 2011 in Finland.

Sites in Canada were located in the boreal or hemi-boreal zone (Brandt, 2009): in the upper Mauricie of Quebec (72°62" W, 47 ° 60"N)[4] for the natural and extensive treatment; and in northeastern New Brunswick on private land (67°64" W, 47°34"N) for the intensive plantations. All sites were located within a radius of 300 km, were on mesic till soils, and were historically covered by mixedwood forests. In naturally regenerated sites, stands were dominated by balsam fir (*Abies balsamea* (L.) Miller), trembling aspen (*Populus tremuloides* Michaux), paper or white birch (*Betula papyrifera* Marshall), and black spruce (*Picea mariana* (Miller) BSP). In Canada, most of the selected plantations were pure stands of white spruce (*Picea glauca* (Moench) Voss), but some were mixed with black spruce or red spruce (*Picea rubens* Sargent). All Canadian plantations received 2 applications of herbicide shortly after trees were planted, after which they were thinned once or twice. It should be noted that 20% of the landscape around plantations was in conservation. Annual precipitation in both regions ranged between 900 and 1100 mm, with a annual mean temperature of 3.3 °C (Environment Canada, 2012).

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[3] . Results of forest soil condition in Europe from a large scale soil survey.

[4] Coordinates represente the midle point of the sampling zone

In Finland, all sites that we had selected were part of the pan-European project BIOSOIL (Hiederer *et al.*, 2011) and were located across the southern boreal vegetation zone (61°82" E, 26 ° 11"N (Ahti *et al.*, 1968). Selected Norway spruce plantations were classified as *myrtillus* sites with mesic till soil, or *oxalis-myrtillus* sites (Cajander, 1926) with mesic to moist nutrient-rich tills (BIOSOIL database (Hiederer *et al.*, 2011)). Silver birch (*Betula pendula* Roth) and Scots pine were frequently found in plantations. While no herbicides were applied in Finland, the plantations were thinned one or two times. All sites were historicaly forest, no sites had been previously used for agriculture or tar production. Annual precipitation in southern Finland is between 600 and 700 mm, and mean annual temperature is 5.5 °C (Finnish Meteorological Institute, 2012).

In their natural state, both regions would have been dominated by over-mature and old-growth stands (Kuuluvainen, 2009 ; Ostlund *et al.*, 1997). The mean fire interval is at least 200 years in spruce-dominated forests of Fennoscandia (Wallenius, 2002) and in the regions that were sampled in Canada (Alvarez *et al.*, 2011 ; Mosseler *et al.*, 2003). The assumption that species evolving under the same environmental pressures are adapted to react to disturbances in the same manner has previously been used to compare similar biomes in different geographical regions, e.g., lichen functional traits across a gradient of land use in Europe (Stofer *et al.*, 2006), understorey plants in various types of plantations (Aubin *et al.*, 2008), or bird functional traits in Latin America under a gradient of coffee culture intensification (Philpott *et al.*, 2008). Therefore, we have adopted the same assumption in this study, viz., that very similar sets of functional traits are normally found in the understorey vegetation of natural forests of similar ecological context in both Canada and Finland.

1.3.3 Environmental variables

We measured key environmental variables that are known to affect understorey vegetation. These included soil texture and fertility, with the latter being expressed in terms of base cation content (Ca, Na, and K), stand structure (canopy opening, basal area, and volume of CWD), and landscape composition (percentage of the landscape occupied by forest and agriculture fields). Environmental variables and species occurrences were assessed in each sample plot. In each of the 63 sites, one sample plot (26m radius) was positioned more than 20 m from an edge to avoid edge effects. Sites were located at least 2 km from one another. The sample plot was delimited by four transects of 26 m that were arranged in a cross aligned along the cardinal compass points. Depending on which variables were being assessed, measurements were taken along and up to 2 m on either side of the transect line.

1.3.3.1 Stand structure

At every 2 m along each of the four transects, canopy openness was measured using a spherical crown densiometer (Ben Meadows Company, Janesville, WI). All trees that had a diameter at breast height (DBH, 1.3 m) > 10 cm and which were within 2 m either side of the transect line were measured to determine stand basal area (m2/ha).

To determine the volume of dead logs (V, m3/ha), line intersect sampling (Van Wagner, 1982) was performed along each transect. Cross-transect diameters (UNITS) were measured at the line intercepts of all logs > 5cm diameter (Angers *et al.*, 2005). The volume of dead logs was then estimated using Van Wagner's revisied formula (Van Wagner, 1982):

$$V = K/L * \Sigma d^2$$

where K is a constant (1.234), d is the cross-transect diameter of log (cm) and L is the transect length that was sampled (m). To calculate the volume of dead snags and stumps, all snags (≥ 1.3 m tall, DBH ≥ 5 cm) and stumps (with diameters ≥ 5 cm at 30 cm above the soil surface) that were within 2 m of either side of the transect line were measured in terms of their diameters and heights. The total CWD volume, which included cross transect down log volumes, and the volumes of stumps and snags, which were calculated as cylinders, was estimated on a per hectare basis for each site.

1.3.3.2 Landscape composition

A landscape analysis was performed using Geobase Land Cover Circa 2000 (Geobase, 2011) for Canada and Corine Land Cover 2000 (European Environment Agency, 2000) for Finland. The percentage of forest and agriculture field was determined within a 2 km radius of each site.

1.3.3.3 Soil sampling

In Canada, 10 volumetric samples of both the organic layer and the first 15 cm of the mineral soil were randomly sampled along the transect lines in each site. Water pH, texture (granulometry) (sand = 53 µm - 2 mm, silt = 2 µm - 53 mm and clay = < 2 µm), Ca, Na and K (cmol/kg) concentration were determined in the laboratory for each mineral soil sample using the methods described by Thiffault et al.'s (2007). In Finland, soil information was available from the BIOSOIL database for all sites and similar analytical methods were used (Cools and DeVos, 2010 ; Hiederer *et al.*, 2011).

1.3.4 Vegetation description

At every 2 m interval along the four 26 m transect lines, species present within a 15-cm radius of this point were identified to the specie level. Within 2 m of either side of a transect, the presence of an understorey vegetation species was recorded, if it had not been recorded at any of the 52 sampling points. To calculate occurrence, herbaceous and woody species at a sampling point were each assigned a value of 1 when a species was present at the sample point, and a value of 0.5 for species that were present in the plot but not at any of the sampling points. The frequency of occurrence (%) for a species was determined from the proportion of points in the plot where the species was present, divided by the total number of sample points (i.e., a total possible score of 52). Calculation also included the score of species that were present in the plot but not at any of the sampling points.

1.3.4.1 Traits

The trait approach that was used in this study focuses on the occurrence of response traits that are related to community structure and dynamics. Response traits are defined as "any trait the attribute of which varies in response to changes in environmental conditions" (Violle *et al.*, 2007). Nine traits and one ecological performance measure (light requirement) were selected for the analysis as they were related to dispersal capacity and traits involving the capacity of a plant to be maintained (persistence) in a disturbed site after perturbation (Table 1.1). Most data on traits were found in the TOPIC (Aubin *et al.*, 2012), LEDA (Kleyer *et al.*, 2008), and BIOFLOR (Klotz *et al.*, 2002) databases. When the information was not available in these databases, a literature search was undertaken.

Tableau 1.1 Description and literature review of 9 vegetation traits and 1 ecological preference positively (+) or negatively (-) associated with forest management intensity

Traits/ecological preference	Class		References
Raunkiaer life form	**Chamaephyte** (herb/shrub, bud 1 mm to 25cm above ground) **Geophyte** (herb with underground bud) **Hemicryptophyte** (herb with bud at the ground surface) **Mega or meso-phanerophyte** (≥8m in height) **Micro or nan-phanerophyte** (25cm to 8m in height) **Therophyte** (annual)	- - - - + +	(Aubin *et al.*, 2007 ; Hermy *et al.*, 1999 ; Royo and Carlson, 2006)
Light requirement	**Intolerant** **Midtolerant** **Tolerant**	+ -	(Craig and Macdonald, 2009 ; Macdonald and Fenniak, 2007)
Life cycle	**Perrenial and biannual** **Annual**	- +	(Brumelis and Carleton, 1989 ; Peltzer *et al.*, 2000)
Flowering phenology	**Spring** **Summer / fall**	- +	(Gachet *et al.*, 2007 ; Graae and Sunde, 2000)
Height	Numeric values (cm) : Tall = >50cm	+	(Bock and Van Rees, 2002 ; Brumelis and Carleton, 1989)
Foliage structure	<u>**Not phanerophyte**</u> **Decumbent stem** **Erect leaves** **Erect leafy stem** **Stem bent in an arch-shaped** **Non-leafy stem** **Umbel-shaped stem** **Rosette** **Semi-rosette** **Graminoid** <u>**Phanerophyte**</u> **Multi-stemmed** **One stem**	 - - - - - - + + + + -	(Aubin *et al.*, 2007 ; McIntyre *et al.*, 1995)
Lateral extension	<u>**Not phanerophyte**</u> **Limited** (Annuals and biennials, but also perennials not propagating vegetatively) **Clonal compact** (Perennials growing in dense tufts from buds on a rhizome or a root storage organ. Horizontal propagation is possible but not extensive)	 + +	(Brumelis and Carleton, 1989 ; Haeussler *et al.*, 2002 ; Peltzer *et al.*, 2000)

	Clonal extensive (Perennials with obvious horizontal propagation, either above or below ground. Includes most species qualified as "phalanx" or "guerilla") **Phanerophyte** **Limited** (No form of vegetative propagation, not even sprouting) **Clonal compact** (Vegetative propagation by sprouting or root collar sprouts) **Clonal intermediate** (May include preceding forms, but also layering and low levels of horizontal propagation by root suckers or rhizomes **Clonal extensive** (May include preceding forms, but also high levels of horizontal propagation by root suckers or rhizomes)	- + + - -	
Seed length	**Very small,** <0.1 mm **Small,** 0.1 to 1.99 mm **Medium,** 2 to 2.99 mm **Large,** 3 to 4.99 mm **Very large,** 5 to 40 mm	+ + - -	(Aubin *et al.*, 2009)
Seed production	**Abundant** (>1000 seed per shoot) **Semi-abundant** (20-1000 seed per shoot) **Few** (1-20)	+ - -	(Rowe, 1983)
Seed dispersal	**Endozoochorous** (animal ingestion including bird) **Epizoochorous** (carried externally) **Anemochorous**(wind)	- + +	(Aubin *et al.*, 2007 ; Bradbury, 2004 ; McLachlan and Bazely, 2001)

Positive sign (+) means that this class of a particular trait is favoured by intensification in forest management and part of a syndrome of colonization traits. On the contrary, a negative sign (-) means that this class is negatively associated with forest management intensity and part of a syndrome of persistence traits. For the seed dispersal vector, a species can have more than one class.

1.3.5 Statistical analysis

One ANOVA followed by Tukey means comparison tests and t-test were used to compare environmental factors among levels of forest management intensity. A ANOVA was done comparing Canada natural (CN), Canada extensive (CE) and Canada intensive (CI), and a t-test comparing CI and Finland intensive (FI). We also performed fourth-corner analysis (Dray and Legendre, 2008) to highlight the functional trait(s) that was significantly associated with each level of forest management intensity. This 'direct' approach relates plant traits to environmental variables by simultaneously analysing three matrices: L = species occurrences that were measured in the field per plot; Q = species by functional traits; and R = plot by level of forest management intensity gradient. Dray and Legendre (2008) have presented five models of RLQ analysis; here, we used model 1, where cell values were permuted (9999 times) within the columns of matrix L. This model tests the null hypothesis that species are randomly distributed with respect to site characteristics. Like Aubin et al. (2009), we applied Hellinger transformation to species occurrences (data table L) prior to the analysis and adjusted the probabilities that resulted from significance tests of the global statistics in the fourth-corner matrix, using Holm's procedure (Dray and Legendre, 2008).

To characterise sensitive species in Finland and to compare their traits with vegetation traits on intensively managed sites, emergent groups (EG) were delineated from the trait matrix of Finnish Red-List herbaceous species that were threatened by forest management. The red-list species were selected for analysis independently of the forest type (Cajander's 1926 classification) to which they belonged, because the objective was not to compare them with sampled plantations in Finland, but with rich forests soil in Canada. This red-list of species (i.e., extinct, critically endangered, endangered, vulnerable, and near-threatened) was prepared by the Ministry of the Environment in Finland and based on IUCN criteria (Rassi *et al.*, 2010). The same hierarchical approach that was used by Aubin et al. (2009) was followed to delineate EG using classification methods. Traits related to phanerophytes were not included in the analysis. Gower's similarity coefficient (Gower, 1971) was calculated. This coefficient can handle both missing values and mixed data types (Legendre and Legendre, 1998). Based on these similarity matrices, species were clustered using Ward's hierarchical method, with cut-offs for defining clusters determined subjectively after visual examination of the dendrogram.

Last, species richness and Simpson's diversity index were calculated for all herbs and phanerophytes by level of forest management intensity. JMP 5.1 (SAS Institute, 2003) was used to perform ANOVA and t-test, followed by Tukey tests. The fourth-corner analysis and EG were performed in R (version 2.14.1), (R Development Core Team, 2011 ; Satake and Iwasa, 2006). Results were declared significant at $p = 0.05$.

1.4 Results

1.4.1 Differences in environmental factors along the gradient of forest management intensity

Agricultural fields were rare in the stands that were studied in Canada (absent in CN and CE, and marginal in CI), while representing a substantial portion of the Finnish territory that was surveyed (15 %). In Canada, forests covered a significantly lower percentage of the landscape in areas of intensive plantation (75 %), compared to CN (87 %) and CE (90 %). This percentage was slightly greater than that observed in Finland (66 %) (Table 1.2).

At the stand scale, basal area (± 35 $m^2 ha^{-1}$) and canopy openness (± 12 %) were similar among all site types. In Canada, the percentage of conifers was greater in intensive plantations (CI), but naturally regenerated (CN and CE) were also largely dominated by conifers (about 70%). Intensive plantations in Finland (FI) had significantly fewer conifers (88 %) than plantations in Canada (96 %). Deciduous trees within the plantations were natural origin not planted. Intensive plantations had lower volumes of CWD (CI = 28 $m^3 ha^{-1}$, FI = 24 $m^3 ha^{-1}$) than forests in CN (123 $m^3 ha^{-1}$) and CE (90 $m^3 ha^{-1}$). The soils of the intensive plantation sites in Canada were more fertile than in other sites, given their significantly higher base cation concentrations (K, Na and Mg). Also, soil fertility of CI was higher than in other sites by mineral soil containing significantly more clay (37%) and less sand (23%), and higher pH compared to other sites (Table 1.2).

Tableau 1.2 Mean values of environmental factors, richness and Simpson's diversity indices by level of forest management intensity for two spatial scales. Statistical tests are performed between Canadian sites and then between CI & FI

		Canada			Canada vs Finland	
		CN N= 10	CE N= 10	CI N= 12	CI N= 12	FI N= 21
Landscape	%Agriculture	0±0.06 [A]	0±0.04 [A]	0.2±0.05 [B]	0.2±3 [A]	15±3 [B]
	%Forest	87±3 [A]	90±2 [A]	75±3 [B]	75±5 [A]	66±4 [A]
Stand	Basal area (m^2/ha)	33±3 [A]	36±2 [A]	36±2 [A]	36±3 [A]	42±2 [A]
	%Conifer	75±5 [A]	67±4 [A]	96±5 [B]	96±2 [A]	88±2 [B]
	%Openess	12±1 [A]	10±1 [A]	11±1 [A]	11±2 [A]	14±1 [A]
	CWD (m^3/ha)	123±14 [A]	90±10 [A]	28±13 [B]	28±6 [A]	24±5 [A]
	pH	3.86±0.1 [AB]	3.72±0.1 [A]	4.12±0.1 [B]	4.12±0.1 [A]	3.80±0.1 [B]
	SB (cmol/kg)	2.50±4 [A]	1.91±3 [A]	13.38±4 [A]	13.38±4 [A]	1.58±23 [B]
	%Clay	14±1 [A]	12±1 [A]	37±1 [B]	37±4 [A]	10±3 [B]
	%Sand	54±2 [A]	57±1 [A]	23±2 [B]	23±7 [A]	52±5 [B]
	Richness	29±2.0 [A]	30±14 [A]	33±1.8 [A]	33±2.1 [A]	27±16 [B]
	Simpson	0.95±0.003 [A]	0.95±0.003 [A]	0.95±0.003 [A]	0.96±0.005 [A]	0.94±0.003 [B]

Two analyses are shown. The first one compared semi-natural forests (CN), extensively managed forests (CE) and intensively managed forests (CI) in Canada. The second analysis compared intensively managed forests in Canada (CI) and in Finland (FI). A different letter indicates a significant difference at $P<0.05$ (one-way ANOVA followed by Tukey tests). Means are presented with their standard error (±). SB= Summ of bases.

1.4.2 Influence of the gradient of forest management intensity in Canada

In Canada, occurrences of functional traits were quite similar between CN and CE, but different from the CI (Table 1.3). Most traits, with the exception of light requirement and traits related to seeds, exhibited significant differences between sites. Occurence of geophytes, chamaephytes, and micro-phanerophytes are reduced in intensive plantations, as are perennials in general. Phanerophytes with limited, compacted lateral extension or with multiple stems were less abundant in CI than in the CN and CE. Among non-phanerophytes, plants with non-leafy stems and semi-rosettes were also less frequent, while hemicryptophytes and summer flowering species were more abundant within intensively managed plantations in Canada. Species were also generally taller in plantations compared to CE. Decumbent, rosette and erect leaves were more prevalent in CI. Species with foliage that was arranged in rosettes were also abundant in CN. In addition, non-woody species with limited compact lateral extension occurred in greater abundance in CI.

Tableau 1.3 Influence of the gradient of forest management intensity on the occurrence of functional traits and traits related to the red-list emergent group

		4th corner Canada			4th corner Canada vs Finland		Red-list emergent groups (n=31)		
		CN	CE	CI	CI	FI	1 (16)	2 (8)	3 (7)
Raunkiaer	Chamaephyte		+	-	-	+			x
	Geophyte		+	-			X		
	Hemicryptophyte	-	-	+	+	-	x	X	X
	Micro-phanerophyte			-	+	-			
	Therophyte				-	+			
Light requirement	Intolerant				-	+	x		
	Midtolerant				-	+	x	X	x
	Tolerant				+	-	X		X
Life cycle	Perrenial	+	+	-			X	X	X
	Annual						x	x	
Flowering phenology	Spring						X	X	x
	Summer		-	+			x	x	X
Height herbaceous	Tall (>50cm)		-	+			x	X	X
Foliage structure	Decumbent	-	-	+	+	-			x
	Erectleaves	-		+	+	-	X		
	Erectleafy stem				-	+	X	X	x
	Stem arch-shaped				+	-			

	Non leafy stem		+	-			**X**		
	Umbel-shaped stem				+	-	x		
	Rosette	+	-	+	+	-		x	
	Semi-rosette	+		-			x		
	Graminoid				-	+	x	x	**X**
	Multi-stemmed			-	+	-			
Lateral extension	Limited		-	+				x	
	Compact	-		+	+	-	**X**	**X**	**X**
	Extensive						x	x	x
	Phanerophyte limited		+	-	-	+			
	Phanerophyte compact			-	-	+			
	Phanerophyteintermediay			+	+	-			
	Phanerophyte extensive		+	-	-	+			
Seedlength	Bigseed (>3mm)				-	+	x	**X**	**X**
Seed production	Abundant (>1000)				+	-	x	**X**	x
	Semi-abundant (20-1000)						**X**	x	**X**
	Few (1-20)				-	+	x	x	x
Seed dispersal	Endozoochorous				-	+	x	x	
	Epizoochorous				-	+	x	x	**X**
	Anemochorous						**X**	x	x
	Entomochorous				/	/	x	x	**X**

Two analyses are shown. The first 4th corner analysis compared semi-natural forests (CN), extensively managed forests (CE) and intensively managed forests (CI) in Canada. The second 4th corner analysis compared intensively managed forests in Canada (CI) and in Finland (FI). A positive sign (+) or negative sign (-) assigned to a level of forest management intensity indicates that this class of trait is positively or negatively influenced compared to others level of the gradient. Only significant differences at the 5% significance level after Holm correction are shown for both analyses. Blank: non-significant relationship and /or mean not evaluated. For the emergent group analysis, big **X** mean that this class of trait dominated for that emergent group and small x mean that this class of trait was present in the group but for only one or few species. Numbers in parentheses are the number of species in each group.

One hundred-fifteen species were found in the Canadian survey. Of this total, 75 species were associated with CN, 81 with CE, and 71 with CI. More than twenty species were specific to CN and CE, including orchids such as spotted coralroot (*Corallorhiza maculata* Raf.), lady's-slipper (*Cypripedium calceolus* L.), dwarf rattlesnake plantain or creeping lady's tresses (*Goodyera repens* (L.) R. Br.), and *Habenaria* sp. Several less common species were also found in CN and CE: Prince's pine or pipsissewa (*Chimaphila umbellata* (L.) Barton), creeping snowberry (*Gaultheria hispidula* (L.) Muhl. ex Bigelow), wintergreen (*Gaultheria procumbens* L.), Dutchman's pipe or pinesap (*Monotropa hypopithys* L.), Indian pipe (*Monotropa uniflora* L.), and painted trillium (*Trillium undulatum* Willd.). In CI, we also found around twenty species that were not encountered in other sites. Most of these were sedges or grasses, such as bladder sedge (*Carex intumescens* Rudge) and drooping woodreed (*Cinna latifolia* (Trevis. ex Goepp.) Griseb.), and early successional species, such as *Circea* sp., *Hieracium* sp., spotted jewelweed (*Impatiens capensis* Meerb.), tall blue lettuce (*Lactuca biennis* (Moench) Fernald), and valerian (*Valeriana officinalis* L.). Diversity indices (richness and Simpson) were not significantly different between levels of forest management intensity (Table 1.3).

1.4.3 Functional traits of understorey species on the red-list in Finland

The Finnish Red-List included some 31 forest herb species that were threatened by forest management. We analysed the functional traits of these species to determine the main characteristics of the species found on the red-list and see if their status could be associated with the intensity of forest management. Cluster analysis revealed three distinct groups (Tables 1.3 and 1.4). The first group (16 species) was dominated by species having the following traits: small-statured, perennial shade-tolerant, geophytes; spring flowering, erect leaves or erect leafy stem or non-leafy stem foliage structure and lateral dispersion that is mainly compact. The seeds are mainly of small length, produced in semi-abundant quantity and dispersed principally by wind. The second (8 species) and third (7 species) groups were similar to the first, with several few exceptions: mostly hemicryptophytes; producing very abundant (>1000 seed per shoot) or abundant (20-1000 seed per shoot) large seeds; and dispersal by epizoochory (transport on rather than in vertebrates) or entomochory. Less than 10% of species on the red-list are annuals, shade-intolerant, with graminoid foliage and limited lateral extension, which are traits generally shared by early successional species (REF). Several genera on the Finnish Red-List are also found in Canadian forests (*Viola, Gallium, Allium, Anemone, Asarum, Thalictrum, Geranium*, among others), together with some species that are common to both countries, including Dutchman's pipe (*Monotropa hypopitys*),rattlesnake fern (*Botrychium virginianum*), fairy slipper orchid (*Calypso bulbosa*), drooping woodreed (*Cinna latifolia*), wood anemone *(Anemone quinquefolia* L.), pink lady-slipper orchid (*Cypripedium acaule* Aiton), and Indian pipe (*Monotropa uniflora*) (Table 1.4). Emergent group analysis informed us that these species mainly shared persistence traits.

Tableau 1.4 Species on the red-list of the Ministry of the environment in Finland threatened by forest management

Emergente group 1		Emergente group 2	Emergente group 3
Agrostis *clavata*	***Cypripedium calceolus***	***Arctium*** *nemorosum*	*Aconitu mlycoctonum*
Allium *ursinum*	*Ophrys insectifera*	***Cardamine*** *impatiens*	***Bromus*** *benekenii*
Anemone trifolia	***Viola*** *collina*	*Crepis praemorsa*	***Carex*** *remota*
Asarum *europaeum*	***Viola*** *reichenbachiana*	***Geranium*** *bohemicum*	***Cinna latifolia***
Botrychium virginianum	*Epipogium aphyllum*	***Hypericum*** *montanum*	***Clematis*** *alpina*
Calypso bulbosa	*Lathraea squamaria*	*Melica picta*	***Galium*** *odoratum*
Cephalanthera longifolia	*Moehringia lateriflora*	***Thalictrum*** *aquilegiifolium*	*Melica uniflora*
Cephalanthera rubra	***Monotropa hypopitys***	***Vicia*** *cassubica*	

When genus or genus and species are in **bold** it mean that they are also found in Canadian forests. The three emergent groups created are the output of the Ward's hierarchical classification method, species with similar traits are found in the same emergent group.

1.4.4 Comparison between intensive plantations in Canada and Finland

We extended the gradient of forest management intensity further by comparing intensive plantations in Canada and Finland (Table 1.3). Hemicryptophytes and micro-phanerophytes were present to a lesser extent in Finnish plantations compared to Canadian ones. New insights into the effects of forest intensification are the lower occurrence of shade-tolerant species in intensively managed plantations in Finland (FI) along with the rarity of species having a stems bent in an arch-shape, decumbent stems or umbel stems. Species with erect leaf, rosette shape and phanerophyte with multi-stems were also less abundant in FI. In FI, the vegetation was characterized by fewer species with compact and intermediary lateral extension for phanerophytes. Also, a lower number of species produced abundant seeds compared to CI. Intensive plantations in Finland have a higher prevalence of species that has one or many of these traits: shade intolerant, epizoochorie, therophytes, graminoïd foliage structure and limited or compact lateral extension. FI trait assemblage also possesses higher prevalence of chamaephytes, species with erect leafy stem foliage structure, larger seeds and dispersion by endozoochorie. Table 1.2 showed no significant difference for many traits between CI and FI, suggesting that these traits are common to both. The common traits included fewer geophytes, perennials and semi-rosette or non-leafy foliage structure species and more summer flowering, tall species with limited vegetative reproduction capacity.

In Finland, a total of 109 species were found. Five were shared with CI. The two countries shared many genera and species in addition to long beech fern (*Phegopteris connectilis* (Michx.) Watt = *Thelypteris phegopteris*), European raspberry (*Rubus idaeus* L.), twinflower (*Linnaea borealis* L.), northern oakfern (*Gymnocarpium dryopteris* (L.) Newman), and northern buckler fern or spinulose wood fern (*Dryopteris carthusiana* (Vill.) H.P. Fuchs = *D. spinulosa* (O.F. Muell.) O. Kuntze). However, richness and diversity indices were significantly lower in FI compared to CI.

1.5 Discussion

Results showed trait filtering along the gradient of forest management intensity. Among other factors, reduction in forest retention elements, such as CWD (Table 1.2), homogenisation of canopy cover composition, and the formation of more frequent, regular openings in the canopy changed environmental conditions and created different trait filtering conditions in intensive plantations compared to extensively managed and naturally disturbed forests. Indeed, different syndromes were observed. Filtering effects on dispersion and persistence traits followed similar patterns in Canada and Finland with respect to intensively managed plantations, leading to the selection of species with colonisation traits. In Finland, the filter was even stronger, with greater number of colonisation traits and fewer persistence traits.

1.5.1 Syndrome of colonisation traits in intensively managed forest

As expected, we found an understorey vegetation syndrome of colonisation traits (i.e., great height) in intensively managed forests (CI and FI) (Wilson and Puettmann, 2007). Frequent canopy openings in plantations can greatly modify conditions of light, temperature and humidity (Gray and Spies, 1997), which filter persistence traits differently than conditions found in CE and CN. Natural tree mortality in mature forests (around 1% in temperates forests; (Runkle, 1981) did not create openings as frequently or as large as those incurred in intensive management where thinning (precommercial and commercial thinnings) remove about 20 to 30 % of the canopy every 20 years. The final cut is normally conducted after about 70-80 years, which implies that plantations are not left without interventions for longer than 30 years (Reinikainen *et al.*, 2000). Since many plantations in Finland have been managed over multiple rotations, the canopy has never had time to close completely (between 10 and 40 years to close; (Valverde and Silvertown, 1997) before a new removal of the canopy (thinning or cut) is initiated. Unlike FI, plantations in CI are recent and there still is a relatively large proportion of natural forest within the landscape (20 %). When compared to CI, the frequent regular openings in the canopy of FI permitted a greater number of traits that are related to a colonisation syndrome to persist, i.e., therophytes and graminoid foliage structure. Graminoid species are found more frequently in human-disturbed sites (Liira *et al.*, 2007). The Finnish Forest Research Institute (METLA), which has been following changes in vegetation in Finland since 1950, also noted that graminoid species are more abundant in Finnish forests today than have been historically present (Reinikainen *et al.*, 2000). Frequent canopy openings also allow shade-intolerant species to persist and compete for resources with shade-tolerant species (Bartemucci *et al.*, 2006 ; De Grandpré *et al.*, 2000).

In forests with greater canopy disturbance, a recalcitrant understorey layer (shrub) is often positively filtered due to the availability of light (Royo and Carlson, 2006). Our results did not support this observation, despite the extensive cover of *Rubus idaeus* that was found in CI. This species could potentially become part of a recalcitrant understorey layer, as has been found for salmonberry *(Rubus spectabilis* Pursh) in the forests of Oregon (Tappeiner *et al.*, 1991). Indeed, Reinikainen et al. (2000) found *Rubus idaeus* to be increasing in abundance in Finnish forest compared to previous records.

More disturbance at the end of the forest management gradient, including more trampling, can induce additional traits that are related to persistence and which require filtering by the environmental conditions (Keddy, 1992). During logging and thinning, the risk of stem damage is high and, thus, species with a rosette foliage structure that are adapted to resist trampling, are more abundant (Bernhardt-Römermann *et al.*, 2011 ; McIntyre *et al.*, 1995). In environments where light is less of a concern, such as in disturbed sites, species flower mainly in the summer (Lloret *et al.*, 2005). This response could be explained by the abundance of pollinators at that time of the year that increase their fitness (Allee effect).

It may seem surprising that dispersal traits in FI did not conform with previous studies in the scientific literature. In frequently disturbed environments, early successional species are expected as they reproduce mainly by small seeds, which can disperse over a long distances by wind (Sutherland *et al.*, 2000 ; Zaplata *et al.*, 2011). These characteristics are essential for colonising new areas (Weiher *et al.*, 1999); invasive alien species also share these traits (Lloret *et al.*, 2005). Other factors such as the ability to disperse seeds over a long distance also depend on the size of the plant, with tall species dispersing seeds further (Scheiner and Willig, 2007 ; Vittoz and Engler, 2007). The dominance of ***vaccinium*** in FI, which has big seeds, produced in limited quantity and dispersed by birds and animals probably explains why our observations were not congruent with the literature on colonisation traits.

Changes that were observed in Fl but not seen in Cl (i.e., epizoochorous, shade-intolerant, therophytes, and graminoid foliage structure) could be due to a lag in compositional shifts to the understorey vegetation in Canada (Bartemucci *et al.*, 2006). Indeed, the majority of understorey boreal species have the capacity to persist in disturbed sites through clonal growth, meaning that actual composition is a function of past establishment opportunities (De Grandpré *et al.*, 1993). We would further hypothesise that the relative resilience of Canadian plantations will be reduced following the cumulative impacts of multiple forest rotations. Short rotations, together with frequent thinning, as is done in Finland, could facilitate the maintenance of colonisation traits. It has been suggested that maintenance of abundant forest retention elements in time and space, especially in intensively managed landscapes, could help to maintain an environmental filter similar to untouched forest (Lindenmayer and Franklin, 2002). Indeed, we suppose that abundant forest retention around plantations could help to offset effects of frequent canopy opening on environmental conditions and, therefore, on trait filtering.

1.5.2 Syndrome of persistence traits in red-list species, natural and extensively managed forest

Important functional changes have likely started to occur in intensively managed forests of Canada. An examination of boreal forest species traits on the Finnish red-list could indicate which Canadian species are most likely at risk of being negatively affected by intensive forest management over the long-term. Further, trait analysis could help anticipate which species will be depleted first (Mouillot *et al.*, 2012) any genera and even species on Finland's red-list are frequently found in the Canadian boreal forest. In addition, most traits shared by red-list species were also negatively influenced in CI.

In contrast to frequently disturbed plantations, natural forest and extensively managed forest had more stable environmental conditions, with less patchy configurations. The need to disperse over long distance was reduced and, consequently, a syndrome of persistence traits was observed in red-list species (i.e., geophytes, non-leafy stems, and ant-dispersed) and in the natural and extensively managed forest (i.e. geophytes and perennial), instead of a syndrome of colonisation. Vulnerability of plants greatly depends on their capacity for dispersal and persistence and if these capacities are low, as in many late successional species, then they will be more vulnerable to disturbance (Schleicher *et al.*, 2011). For instance, geophytes are more sensitive to management because, among other things, soil disturbance can damage vegetative reproductive organs (rhizomes, bulbs, tubers, and corms) (Haeussler *et al.*, 2002) and reduce their capacity for persistence (Klimeš and Klimeš, 2000). Moreover, geophytes and chamaephytes have slow growth rates that limit their capacity to quickly colonise new areas (Ramovs and Roberts, 2005).

Many mycoheterotrophic species (e.g., *Corallorhiza maculata*) are known to be sensitive to forest management because of poor seed dispersal, their use of decaying dead wood for rooting, and their intolerance to full sunlight (Haeussler *et al.*, 2002).

They were found in CN and CE, but not in CI. Shade-tolerant species are often mentioned as being sensitive to forest management (De Graaf and Roberts, 2009) because they are physiologically and morphologically adapted to a low light levels (Neufeld and Young, 2003) and little competition (Hermy *et al.*, 1999).

With respect to FI, dispersal traits of red-list species were not perfectly congruent with the theoretical assumptions (Table 1.1). Predominance of orchids in the Finland red-list could partially explain the difference with theory. Orchids typically produce very small seeds that are wind-dispersed, rather than big seeds in fleshy fruits, although there are some exceptions, like vanilla (Kull and Arditti, 2002). Some orchids, such as *Calypso bulbosa* and *Cypripedium calceolus,* are on the red-list in Finland, where they are not strictly forest inhabitants, but are also found in groves (Rassi *et al.*, 2010), with dispersal traits that are adapted to open environments. Persistence traits that are related to germination (specific sets of mycorrhizal fungi) and slow growth probably better explain why they were included on the red-list (McCormick *et al.*, 2012).

In extensively managed forest, the maintenance of some forest retention elements presumably helps ecological functions to be maintained as ''lifeboats'' for slow-growing species (De Graaf and Roberts, 2009 ; Ramovs and Roberts, 2005), along with enhanced connectivity between forest patches (Gustafsson *et al.*, 2010). The absence of significant differences in environmental factors (retention elements such as dead wood) and trait occurrences between CN and CE illustrates the relative resilience of extensively managed boreal forests (Haeussler *et al.*, 2004 ; Wilson and Puettmann, 2007).

Our conclusions were limited given that no natural forests were sampled in Finland. The possibility that observed differences may be due solely to natural differences between the two regions cannot be excluded by this study. However, the predominance of persistence traits in the red-list species, together with the findings of

Reinikainen et al. (2000) concerning changes in vegetation cover in Finland since 1950, support our findings that a syndrome of persistence is maintained in natural and extensively managed forest and a syndrome of colonisation was created in plantations. The difference in soil fertility between sites may also have affected the results. Comparison of sites of the same soil fertility would have been optimal to exclude the effect of soil type preference of certain species.

1.6 Conclusion

Our results were mostly consistent with literature reports concerning the impacts of forest management on understorey vegetation. The global conclusion was supported by our study that a syndrome of persistence traits was filtered negatively and a syndrome of colonisation traits was filtered positively by intensification in forest management. This assertion was found to be even stronger at the end of the forest management intensity gradient, as was found in plantations of Finland. Conversely, where forest retention is high at the stand- and landscape-scale and no thinning occurred, as was the case in the extensively managed forests of Canada, no significant difference was observed in comparison with natural forest. However, the relative resilience of the understorey vegetation in Canada could be threatened if measures to maintain sufficient retention in time and space are not quickly implemented. Intensive plantations in Canada have started to experience important changes in the occurrence of functional traits. Traits that were lost in CI are the same as those reported in Finland red-list traits. Our results should be seen as an early warning of the long-term effects of increasing management intensity over a large proportion of the Canadian forest landscape. Many genera and species that are already on the red-list in Finland occur in the Canadian boreal forest. The cumulative effects of thinning and short forest rotations could be potentially harmful to late successional species over the long-term. To offset negative impacts of forest intensification, significant forest retention elements in time and space should be planned. Management of retention elements that is based on scientific knowledge of thresholds (ecological needs), and which are in accordance with human needs, could help to avoid species loss.

CHAPITRE II

How stakeholders perceive the value of forest retention as a way to improve the operationalization of ecosystem management?

Cynthia Patry,
Centre d'etude de la Foret, Departement des Sciences Biologiques, Universite du Quebec a Montreal, C.P. 8888, Succ. Centre-Ville, Montreal, Canada, H3C 3P8
patry.cynthia@courrier.uqam.ca

Daniel Kneeshaw
Centre d'etude de la Foret, Departement des Sciences Biologiques, Universite du Quebec a Montreal, C.P. 8888, Succ. Centre-Ville, Montreal, Canada, H3C 3P8.
kneeshaw.daniel@uqam.ca

Stephen Wyatt,
Faculté de foresterie, Université de Moncton Campus Edmundston, 165, boulevard Hébert, Edmundston (Nouveau-Brunswick), Canada, E3V 2S8
stephen.wyatt@umoncton.ca

Christian Messier
Centre d'etude de la Foret, Departement des Sciences Biologiques, Universite du Quebec a Montreal, C.P. 8888, Succ. Centre-Ville, Montreal, Canada, H3C 3P8.
messier.christian@uqam.ca

Nicolas Milot
Institut des sciences de l'environnement, Universite du Quebec a Montreal, C.P. 8888, Succ. Centre-Ville, Montreal, Canada, H3C 3P8.
milot.nicolas@uqam.ca

Abstract

The social-ecological system constituting the managed forest is in profound transition. Reduction of many retention elements (coarse woody debris, snags, large green trees, corridors, old forest, large forest patches, protected areas, and riparian buffers) has been identified as a key difference between natural and managed forests. We investigated how different groups of stakeholders who are involved in forest management decision-making processes theoretically and practically perceive forest retention. We conducted an internet-based survey of forest ecologists and various stakeholder groups (not industrial users, NGO in environment representative and researchers), who are involved in integrated management of natural resources in two regions of Quebec, Canada. Questions aimed to determine how they perceived the theoretical basis for forest retention, and what were their values and priorities. Also, what were the main obstacles to achieving their priorities concerning forest management, their level of trust in managers, and their satisfaction concerning the implementation of 8 retention elements? Our case study suggests that all stakeholder groups agreed with theory underlying forest retention, but differences in their preferences for implementation resulted in conflicting visions. Three of 4 groups (non-industrial users, ENGO representatives, and researchers) agreed that greater retention is required and asked for improved practices. Only industrial users preferred the status quo, despite agreeing with the other groups on the theoretical merits of maintained forest retention in time and space. Differences in values better explained this divergence in vision than did socio-demographic attributes. The main obstacle to implementing respondent priorities was identified as political will. Trust in forest managers needs to be built and two of the groups believed that more forest retention could help in that sense.

2.1 Introduction

To be successful, forest management must be based on more than just translating forest ecosystems functions into forest practices. Instilling and implementing an understanding of values (Bengston, 1994) and social preferences is also necessary (Elbakidze *et al.*, 2012 ; Holsman and Peyton, 2003). In recent decades, evidence for significant changes in forest values (Shindler and Cramer, 1999) has highlighted society's growing interest in forestry issues (Beckley and Korber, 1995). Environmental awareness of threats to forest resources is not new, given the belief that forest resources are inexhaustible has been questioned since 1870 (Chiasson and Leclerc, 2013 ; Frechette, 2013). Yet, it is only recently that society has requested greater involvement in forest management and has succeeded in forcing governments to introduce new participatory mechanisms (Ananda, 2007). Forest managers (industry and government) can no longer act alone (Howlett and Rayner, 2006), but instead must increasingly consider public values, preferences, beliefs and attitudes concerning forest management in their decisions (Beckley et al., 1999). This growing requirement for involvement underlies the emergence of concepts such as sustainable forest management (CCMF, 2003 ; Sheppard, 2005 ; Sturtevant *et al.*, 2007) and ecosystem-based management (Grumbine, 1994 ; Slocombe, 1998), as well as forest certification and management for resilience (Walker et al., 2002), all of which propose greater public involvement in decision-making.

Research has suggested that greater forest retention is required to achieve forest sustainability (Gustafsson *et al.*, 2011 ; Lindenmayer *et al.*, 2012). Indeed, worldwide exploitation of forests has led to major modifications in the structure and composition of forest ecosystems (Hanski, 2000). Comparisons between natural forests and managed forests have shown that some retention elements, such as old forest (Cyr *et al.*, 2009a), dead wood (Pedlar *et al.*, 2002 ; Perera *et al.*, 2007), and large forest patches (Wedeles and Sleep, 2008), have been reduced to unprecedented levels, with potentially important negative effects on biodiversity (McRae et al., 2001). As a consequence, forest processes are also negatively affected (Bengtsson *et al.*, 2000 ; Cardinale *et al.*, 2012). In this paper, “forest retention” is defined as any natural feature that is maintained at one or more spatial scales, and which will be maintained for a certain length of time in the forest matrix after harvesting or natural disturbance (i.e., dead wood). Continuity in biological legacies at various spatial and temporal scales is of great importance in the objective of maintaining forest integrity (Landres *et al.*, 1999 ; Lindenmayer and Franklin, 2002). Conservation should not be planed at only one spatial scale, because of scale dependency. For example, conservation of a specific specie will not only be dependent on large reserves, but also intermediate-scale reserves and corridors within wood production areas (Lindenmayer, 2000). Some species depend on very fine scale as dead wood (e.i. lichen) (Botting and DeLong, 2009). Consequently, it is important to document and plane maintenance of various forest retention element at the stand scale, as at the landscape scale and even at the regional scale. Even if the importance of retention has been scientifically demonstrated (Gustafsson *et al.*, 2011 ; Rosenvald and Lohmus, 2008) it has not been shown to be a social priority. Some authors have argued that forest retention can increase the social acceptability of forest practices (Brunson *et al.*, 1992). However, is the theory behind forest retention (maintenance of retention in time and space) understood and accepted by stakeholders?

In parallel, public and stakeholder participation in decision-making has the potential to greatly improve transparency and trust (Friedman and Miles, 2002 ; Wang and Wilson, 2007), together with increasing the sustainability of decisions (Glasmeier and Farrigan, 2005), the quality of decisions (Parkins and Mitchell, 2005), their social acceptability (Brunson *et al.*, 1992), and the resilience of the socio-ecosystem. The last point refers to "the capacity to cope and adapt, and the conservation of sources of innovation and renewal" (Lebel *et al.*, 2006). Inclusion of stakeholders in the decision-making process can enhance values and preference sharing among stakeholders and could lead to a more holistic view of forest management (Blumenthal and Jannink, 2000), which is needed for the implementation of ecosystem-based management (Yaffee, 1999). In the context of forest management, a balance is required between personal needs, the needs of others, and the needs of nature.

Some authors have highlighted the communication gap that exists between science and society (Bartonova, 2012). Integration of science into management plans faces many obstacles. The biggest challenge for scientists is to present scientific concepts in a manner that all stakeholders can understand and access (Chapple et al., 2011). On one hand, some authors would claim that ecology should be connected to stakeholders, and that scientists must escape their position of isolation by sharing their knowledge with other stakeholders (Schlesinger, 2010). On the other hand, even if scientific concepts are fully understood by stakeholders, they compete with many other elements in the decision-making process, given the diversity of values, interests and beliefs that will potentially conflict (Parkins and Mitchell, 2005). Indeed, the inclusion of stakeholders in the decision-making process of forest management may relegate scientific information to a peripheral role (Steel and Weber, 2001). Integration of scientific concepts into practice is not easy, but it is not impossible. On one hand, conflicting facts and views can make decisions more complex, given that science is not monolithic. On the other hand, acceptance and implementation of the ecosystem management concept in the United States is a good example of a theoretical concept being transferred into practice (Bengston et al., 2001), but not without important practical challenges (Brunner and Clark, 1997).

The objective of this research is to determine, using a study case approach, how different groups of stakeholders who are involved in the decision-making process regarding the implementation of forest management perceive the theory and practice of forest retention. We wonder if stakeholders agree upon the spatial and temporal theoretical issues of forest retention, as presented by Lindenmayer and Franklin (2002). Questions about forest retention practices have typically focused on 8 retention elements: downed woody debris (DWD), snags, individuals or patches of green trees, forested corridors, riparian buffers, old forest, large forest patches, and protected areas. These elements have been frequently discussed in the scientific literature and are seen as key elements for the maintenance of biodiversity (Andren, 1994 ; Botting and DeLong, 2009 ; Doyon *et al.*, 2008 ; Ecke *et al.*, 2002 ; Halpern *et al.*, 1999 ; Rosenvald and Lohmus, 2008).

We have attempted to understand both social and ecological needs that are related to forest retention and to determine what constrains to its implementation in North America. The necessity of understanding the social aspects of the concept and its implementation is of utmost importance and it was for this reason that we conducted this exploratory study in the Canadian province of Québec. Nowadays, forest managers could not only take into account ecologicals and economicals considerations, social considerations are also of importance. Our objective was to highlight relevant associations between acceptability of the theory (and conversely, its non-acceptance) and stakeholder preferences regarding forest retention to help move the concept from a theoretical standpoint to an operational one.

2.2 Methods

From 1988 to 2013, the forest management regime that was implemented in Quebec did not focus upon what should be left behind following harvest; rather, it considered what could be potentially removed (Coulombe et al., 2004). Less than 20 % of productive forests were harvested with any kind of provisions for retention at the stand-scale, leaving between 2 and 10% of standing trees in harvested stands (Gustafsson et al., 2011). The regime demanded that riparian buffers (20 m) and buffers between cut-blocks (60-100 m) be left standing, but some partial harvesting was allowed (Crête *et al.*, 2004). No specific legislation existed for the retention of dead wood (Crête *et al.*, 2004). Reducing timber wastage was an important concern, which forced the industry to collect the maximum amount of commercially usable wood (Crête *et al.*, 2004). No consideration for the maintenance of large forest patches and connectivity was addressed in the last forest regime (Coulombe et al., 2004). At a provincial scale, 8% of Quebec's land base has remained in protected areas (MDDEFP, 2010).

To help make retention operational, we conducted an internet-based survey of forest ecology scientists and various stakeholder groups (industrial users, non-industrial users, local environmental nongovernmental organisation (ENGO) representatives, and researchers), who are involved in integrated management of natural resources in Québec. Questions were aimed at determining what were their values and priorities. Furthermore, we determined what were the main obstacles to achieving these priorities for forest management, as well as their level of satisfaction concerning practices that were related to the 8 retention elements. Sampling was conducted in two forested regions of Quebec: the Mauricie (72°62"W, 47°60"N) and Temiscamingue (78°31"W, 48°09"N) administrative regions. In the Mauricie, 8 years of research have led to continued improvement of forest retention management practices.

A total of 133 stakeholders and 45 researchers were invited by email to complete the internet survey (Survey Monkey) between 17 December 2012 and 8 February 2013. Three reminder messages were sent to participants during that period. Surveys were returned in 34% of cases (61 respondents), but only 47 of them have been included in the analysis. The surveys that were not retained had been either partially completed or answered by stakeholders who were not part of our four groups (researchers, industrial users, not industrial users and ENGO). The survey was sent to all stakeholders who were actively engaged in one of the 6 local integrated land and resource management panels that were present in the two regions, regardless to their affiliation. Stakeholders groups were created post hoc based on who answered. These local integrated land and resource management panels (LILRPM) were created across Quebec and are part of the new approach that has been implemented under Quebec's most recent forest regime (MRNF, 2013). Scientists, for their part, were university professors or researchers in the federal public research department (CFS) or provincial service in Quebec (MNR). Stakeholders, but not the scientists, were living in one of the two regions.

The survey was created and conducted in French, based on the Total Design Method of Dilman (2007) for internet surveys. We integrated questions from McFarlane and Boxall (2010) on values (biocentric vs anthropocentric) and from Nadeau (2011) on forest priorities. We asked respondents to rate their level of satisfaction for each retention practice on a 5-point Likert scale, with response options of "very dissatisfied," "somewhat dissatisfied," "not dissatisfied/not satisfied," "somewhat satisfied," "very satisfied." or "I do not know." Respondents also rated a series of statements concerning retention elements on a 5-point scale ranging from "strongly disagree" to "strongly agree." The same scale was used to ask the 13 questions that were adapted from McFarlane and Boxall (2010) on values (anthropocentric vs biocentric). Also, respondents were asked to choose 5 priorities and obstacles among a range of possibilities and were asked further questions about their socio-economic situation (age, gender, type of employment, education, and level of income). Finally, we evaluated the sources (radio, scientific articles, etc.) that respondents used to be kept informed about forest management.

Respondents were classified afterward into 4 groups based on their affiliations. Groups with too few numbers of respondents were removed from the analysis, as was the case for the First Nations (Native peoples). Of the 47 respondents, 9 were members of a local ENGO, 12 were researchers, 7 were industrial users (professional managers in the forest industry), and 19 were not-industrial users (hunters, trappers, fishermen, outfitter employees or owners, and workers within a wildlife management zone). Responses to questions were compared among these four groups.

We did not have a probabilistic sample of the population for statistically analysing trends across the entire population. Nonparametric statistics Kruskall Wallis test and a discriminant function analyses were used only to characterise statements about values. In other cases, descriptive statistics were used. The discriminant analysis was performed in JMP 5.1 (SAS Institute, 2003).

2.3 Results

2.3.1 Characterisation of respondents

Most respondents were young (25- to 44-years-old) males, who worked full-time, held a university degree (ENGO = 78%, industrial users and researchers = 100%) and earned more than $40 000 CAD per year. Women represented 43% of industrial users, while a substantial number of non-industrial users were more than 55-years-old (53%). Also, 47% were retired. This last group was also less educated (47% had a university degree) compared to the other groups and 37% earned less than $40 000 CAD per year. In the larger population within the two regions, residents were not as well-educated as those in the sample groups (i.e., only 11% have a university degree) (Statistique Canada, 2006).

Stakeholders used many sources of information to remain current about forest management (Figure 2.1), which ranged from media and personal communication (e.g., radio and television), scientific communications (e.g., scientific journals and popular science magazines) to institutional communications (e.g., government reports). The most popular sources (> 50% of respondents in each group) were government websites, government reports and colleagues. Scientific articles were consulted by 100% of the industrial users who were surveyed and, obviously, by researchers. Yet, we note that scientific articles were also consulted by 56% and 47%

of environmental groups and non-industrial users, respectively. Scientific advisories were another source of information that was frequently used by all groups (> 56%), but more marginally so by non-industrial users (32%). Also, 71% of industrial users noted that they had participated in field visits with researchers. In general, respondents used scientific sources for information. Only five non-industrial users and one representative of an ENGO did not report using scientific sources.

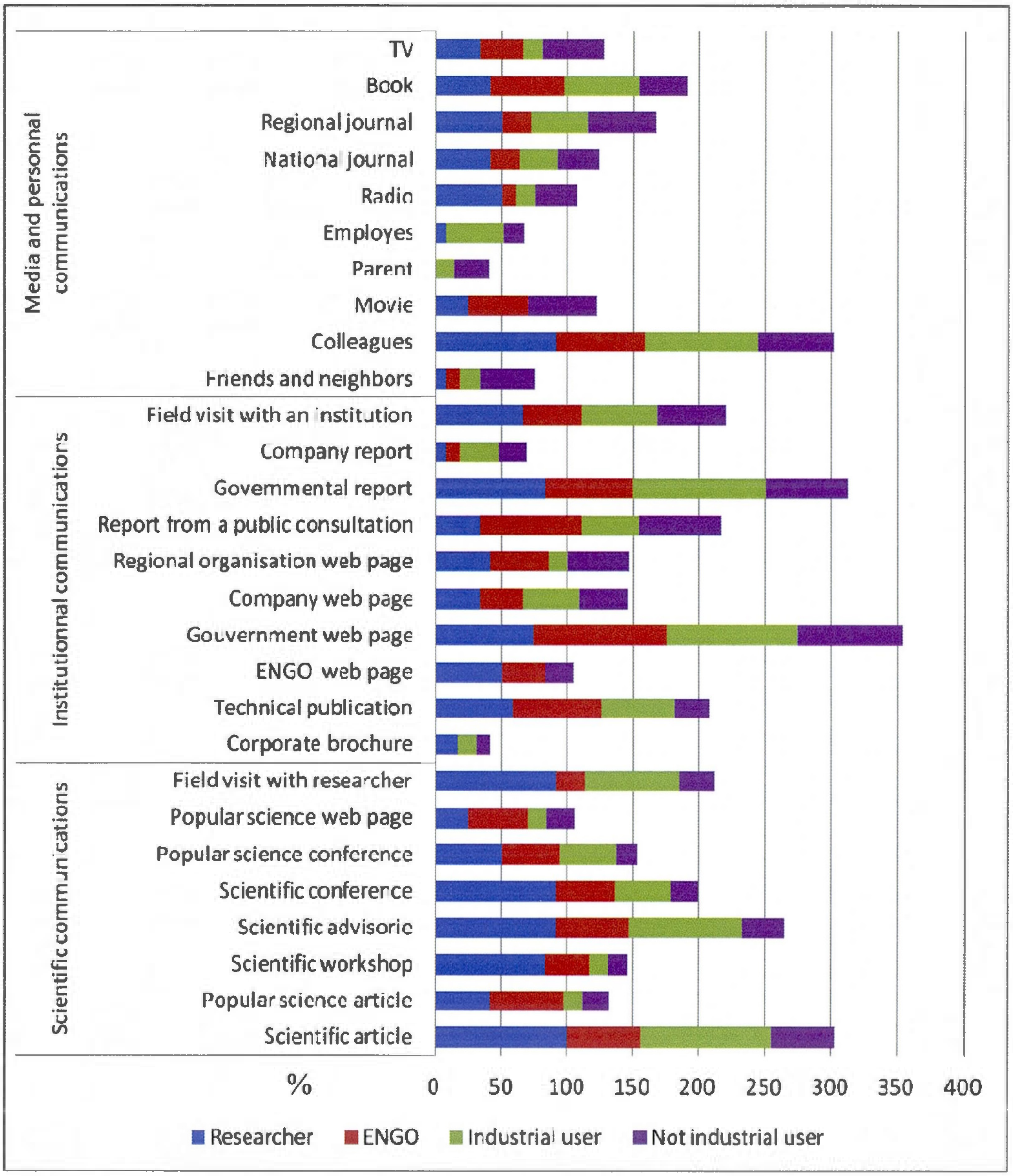

Figure 2.1 Source of information that stakeholders used to get informed about forest management. The x axis represents the percentage of positive responses for each group. A total of 400% means that all respondents in each of the four groups used that type of information.

2.3.2 Respondent values by groups

A set of 13 statements on values, which were drawn from McFarlane and Boxall (2010), were asked of all respondents. The scores of the respondents for each statement were compared among the four groups (researchers, industrial users, not industrial users and ENGO) using Kruskal-Wallis tests (i.e., nonparametric one-way ANOVA). These analyses were followed by discriminant function analysis (DFA) upon the ensemble of scores for the 13 statements (i.e., the variables), shown in Figure 2.2. The discriminate analysis allowed us to visually compare the four groups on their values. Confidence ellipses (95%) that touch or overlap are not significantly different (34.04% misclassified). The closer a circle is to a statement or a set of statements means that the respondents in that group had a higher score for that statement. The highest score mean agreement with the statement.

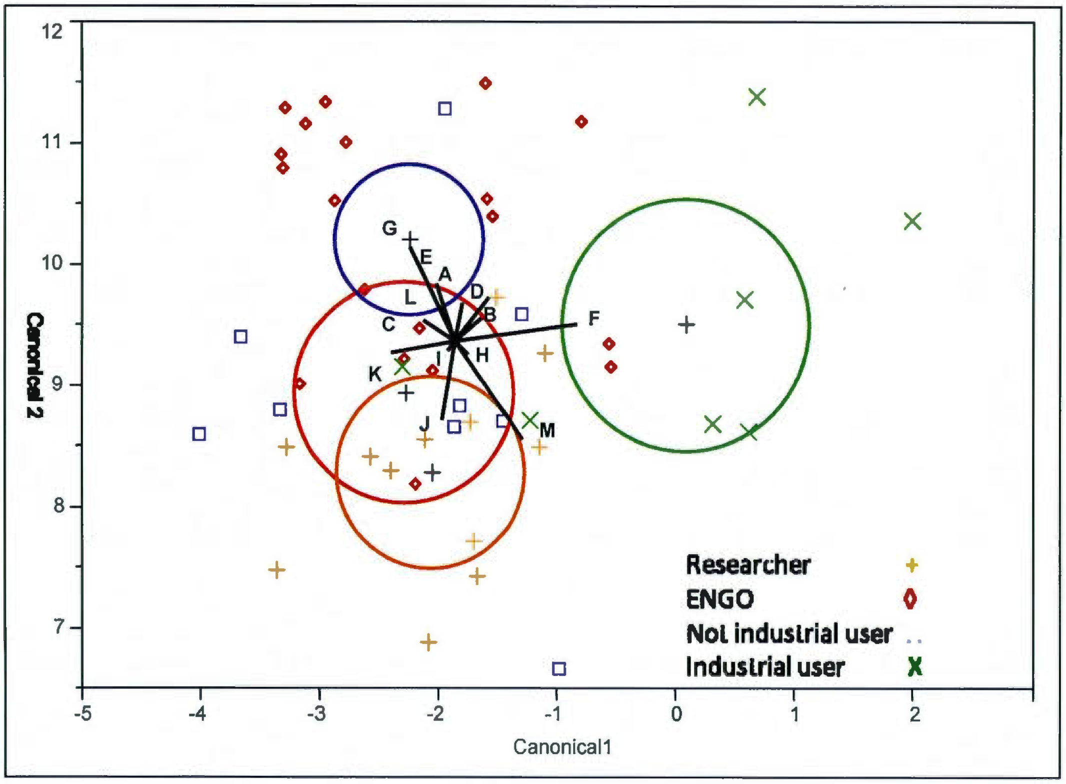

Figure 2.2 Discriminant analysis of values for each stakeholer group. To understand values of respondents we asked a set of 13 statements (letters A to M) derived from McFarlane and Boxall (2010). In figure 2.2, the arrows represent each statement. Scores of all respondents for each statement were plotted in figure 2.2 (cube, cross, x and diamond). A discriminate analysis (ellipse of confidence 95%) allows us to visually compare the values of each group. Ellipse of confidence that touch are not significantly different, showing no significant difference between ENGO representative and not industrial users and between not ENGO and researchers. Industrial users were significantly different in their values compared to other groups. The closer a ellipse was to a statement or a set of statements meant that respondents in that group agree with the statement and consequently had a higher score for that statement

Our analyses showed no significant differences among responses given by researchers, non-industrial users and ENGO representatives (Table 2.1). Each of these groups mostly agreed with statements affirming the existence of forests. Statements that emphasised the existence of forests for human needs, (Table 2.1: statements I, J and L) also received approval from these groups. For most statements (A, C, D, E F, I, J, K and L) industrial users responded in a manner similar to the other groups. Yet, for statements that expressed human needs, they always responded with higher scores. Even if they answered statement M (Table 2.1) very differently than others, scores of the industrial users and other groups only differed significantly with respect to the following question (B) : *The primary use of forests should be for products that are useful to humans* (Kruskal-Wallis test: *ChiSquare* = 830 df = 3, P =0.04). Industrial users agreed with this statement, thus setting them apart from other groups (Figure. 2.2). For two statements, G and H, no strong tendency emerged among groups, highlighting the variability in responses within groups.

In the survey we asked respondents how they view the forest: as a living environment for wildlife; as a place for protection of air, water and soil; as a source of wild game, berries, firewood and other non-timber products; as a place for recreation and relaxation; or as a source of economic wealth and job creation (Nadeau, 2011). Seventy-one percent of industrial users viewed the forest as a source of economic wealth and job creation, while 67% of people working for ENGOs viewed forests as a place for protection of air, water and soil as researchers and non-industrial did. These last two groups also viewed the forest as a living environment for wildlife.

Tableau 2.1 Agreement of stakeholders on statements about forest values (from (McFarlane and Boxall, 2010)

	Stakeholder groups	Disagree	Neutral	Agree	I do not know	Similar view between groups	Different view between groups	Not clear view within a group
A : Forests let us feel close to nature	Researcher			100		√		
	ENGO			100		√		
	Industrial user			100		√		
	Not industrial user			100		√		
B : The primary use of forests should be for products that are useful to humans*	Researcher	67	25	8		√		
	ENGO	33	33	33				√
	Industrial user		43	57			√	
	Not industrial user	53	16	32		√		
C : Whether or not I get to visit the forest as much as I like, it is important to know that forests exist in Queb	Researcher	8	8	83		√		
	ENGO			78	11	√		
	Industrial user		43	57		√		
	Not industrial user	5	5	84	5	√		
D : Forests that are not used by humans are a waste of our natural resources	Researcher	100				√		
	ENGO	89	11			√		
	Industrial user	57	14	29		√		
	Not industrial user	84		11	5	√		
E : Humans should have more respect and admiration for our forests	Researcher		17	83		√		
	ENGO			89		√		
	Industrial user		29	71		√		
	Not industrial user			95	5	√		
F : Forests rejuvenate the human spirit	Researcher		25	75		√		
	ENGO		11	89		√		
	Industrial user			100		√		
	Not industrial user	5	11	79		√		
G : As many uses (e.g., forestry, wildlife habitat, recreation, oil and gas) should be made of as much	Researcher	25	33	33				√
	ENGO	44	33	22				√

forested public land as possible	Industrial user	14	29	57		√		
	Not industrial user	21	11	58	11	√		
H : Forests are sacred places	Researcher	17	58	25				√
	ENGO	33	44	22				√
	Industrial user	43	29	29				√
	Not industrial user	42	26	26	5			√
I : It is important to maintain our forests so that future generations will enjoy the same benefit that we enjoy	Researcher			100		√		
	ENGO			100		√		
	Industrial user		14	86		√		
	Not industrial user	5		89	5	√		
J : Forests should be managed to meet the needs of as many people as possible	Researcher	8	25	67		√		
	ENGO			100		√		
	Industrial user			100		√		
	Not industrial user	11		84	5	√		
K : Forests give humans a sense of peace and well-being	Researcher			100		√		
	ENGO			89		√		
	Industrial user	14	14	71		√		
	Not industrial user	5	5	84	5	√		
L : If forests are not threatened, we should use them to add to the quality of human life	Researcher	8	25	67		√		
	ENGO	44		56		√		
	Industrial user		14	86		√		
	Not industrial user	21	5	68		√		
M : Setting aside forests from logging is not desirable if it means lower wages or fewer jobs	Researcher	67	25	8		√		
	ENGO	89	11			√		
	Industrial user	29	14	57			√	
	Not industrial user	84	11	5		√		

In Table 2.1 we merged the responses "strongly agree" with "agree" and "strongly disagree" with "disagree" to simplify interpretation.

Tableau 2.2 Agreement of stakeholders on statements regarding the theoretical bases of forest retention.

		Disagree	Neutral	Agree	I do not know	Similar view between groups	Different view between groups	Not clear view within a group
More forest retention is needed.	Researcher			100		√		
	ENGO			100		√		
	Industrial user	29	43	14	14			√
	Not industrial user	5		95		√		
More forest retention represents an obstacle to the economic profitability of forest natural resources exploitation.	Researcher	50	33	17		√		
	ENGO	56	11	22		√		
	Industrial user	14	29	57			√	
	Not industrial user	58		42		√		
Protected areas are sufficient to maintain biodiversity.	Researcher	58	8	33		√		
	ENGO	67		33		√		
	Industrial user	57	14	14	14	√		
	Not industrial user	84	5	11		√		
Only protected ares should be maintained over multiple rotations.	Researcher	75	8	17		√		
	ENGO	78		11	11	√		
	Industrial user	71	14	14		√		
	Not industrial user	68		21	11	√		
If the islets were mantained at a harvest, it is acceptable to cut back 20 years later	Researcher	67	17	17		√		
	ENGO	56	22	22		√		
	Industrial user	29		71			√	
	Not industrial user	42	11	42	5			√
It is essential to plan forest management over multiple harvest rotations to ensure that the retention elements maintained fulfill their ecological roles.	Researcher	8	17	75		√		
	ENGO	11		89		√		
	Industrial user	14		86		√		
	Not industrial user		11	89		√		
A spatial multi-scale approach is needed to maintain biodiversity and ecological	Researcher			100		√		
	ENGO	11		89		√		

processes.	Industrial user		14	86		√		
	Not industrial user		11	79	11	√		
Standards of forest regime are not sufficiently flexible and complete to maintain the natural variability	Researcher		17	83		√		
	ENGO	11		78	11	√		
	Industrial user	14		86		√		
	Not industrial user	5		89	5	√		

In Table 2.2 we merged the responses "strongly agree" with "agree" and "strongly disagree" with "disagree" to simplify interpretation.

2.3.3 Perception of forest retention

2.3.3.1 Perception of the basis for forest retention in time and space

All groups had similar responses regarding the maintenance of forest retention in space and time (Table 2.2). They agreed (> 75%) that planning forest management is essential, both over multiple rotations and at multiple spatial scales to ensure that retention elements are maintained to fulfill their ecological roles (maintain biodiversity and ecological processes). ENGO representatives, researchers and non-industrial users agreed (> 95%) that more forest retention is needed and does not represent a threat to profitability of the forests being exploited. Even if industrial users supported the theoretical basis for forest retention, only 14% believed that greater forest retention is necessary. It should be noted that 57% of their responses were apparently neutral or without opinion. Most industrial users agreed that greater forest retention could affect profitability. More than half of respondents in each groups disagreed (> 58%) that protected areas alone can maintain biodiversity, especially ENGO respondents (67%) and non-industrial users (84%). All groups also recognised that other retention elements should be maintained over multiple rotations, and that existing regulations were not sufficiently flexible to maintain natural variability. Even if they believed that maintaining retention in time is theoretically important, industrial users perceived (71%) that cutting patches after 20 years was acceptable, as did 42% of non-industrial users.

2.3.3.2 Perception of forest retention practices

Industrial users and non-industrial users were diametrically opposed with respect to their levels of satisfaction with forest retention practices. Industrial users were mostly satisfied (> 57%) or neutral (average 30%) regarding current practices, while most non-industrial users were dissatisfied (> 68%) (Figure 2.3). Researchers and ENGO representatives were also mostly dissatisfied with retention practices, but to a lesser extent with respect to downed dead wood and snags (< 45%). For these two groups, concerns were slightly greater (> 50%) about old forests, the size of the largest forest patches, and the abundance of green trees.

Figure 2.3 Level of dissatisfaction about the practices implemented in the last forest regime in Quebec of 8 retention elements

Lack of trust that was expressed by all groups can help explain low levels of satisfaction. Indeed, all groups agreed with the following statement: ``There is a problem of lack of confidence on the part of the regional population with the companies that manage the forest?``. However, industrial users did not respond as strongly, with only 57% supporting this statement, compared to more than 75% expressed by other groups. Greater forest retention was viewed by most of the non-industrial users (79%) and half of ENGO representatives (56%) as a way of improving public confidence in regional companies that manage the forest. Only 42% and 29% of researchers and industrial users, respectively, supported this statement.

2.3.3.3 Priorities of stakeholders for forest management and obstacles to the implementation of their priorities.

We asked respondents to choose their first 4 priorities among a list of elements that are affected by forest management (Figure 2.4). Multiple-resource management (> 71%) was the only priority that was shared by all groups. Researchers, non-industrial users and ENGO representatives had dissimilar priorities, except for prioritising conservation (83%, 79% and 67%, respectively). Only 30% of industrial users mentioned conservation as one of their top 4 priorities. They preferred job creation (71%), as did some researchers (58%), together with the development of new forest products in the region (100%). ENGO representatives also place high priority on the development of new forest products (78%). Integration of stakeholders into decisions was also viewed equivocally by researchers (50%) and ENGO representatives (56%), but was prioritised by non-industrial users (84%). Limiting road networks was mentioned as important by half of the ENGO representatives (56%). Finally, only 40% of industrial users selected profit-making as one of their four priorities.

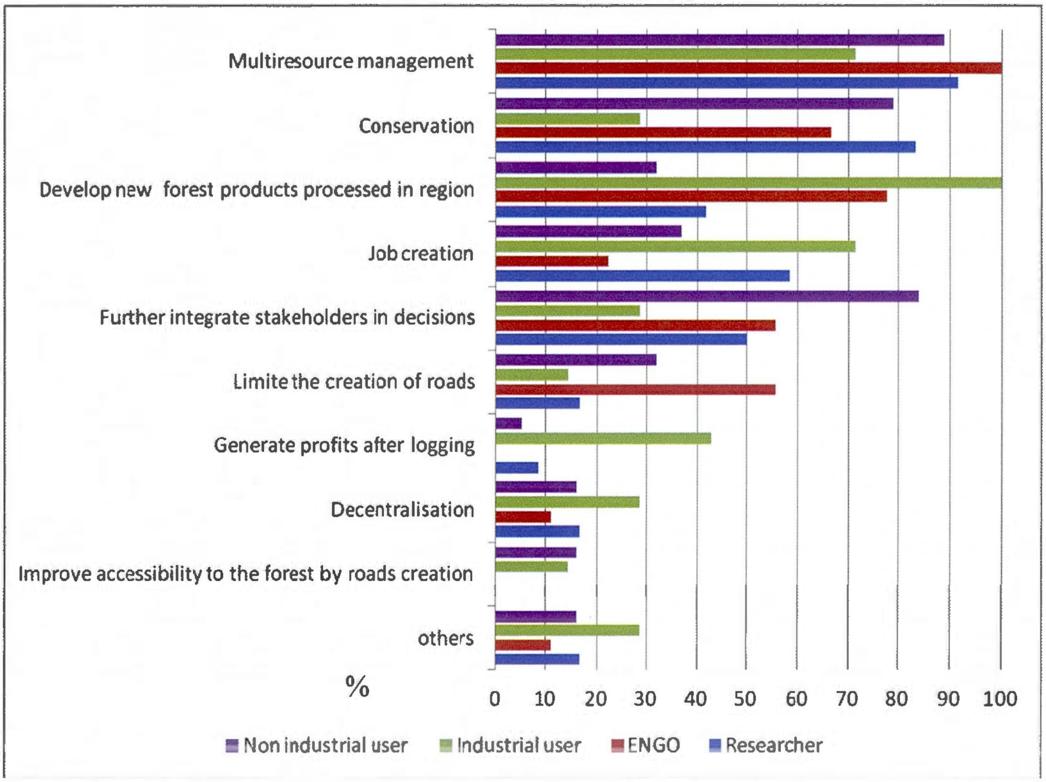

Figure 2.4 **Priorities of stakeholders about forest management**

We also asked respondents to identify the main obstacles to implementing their priorities from among eight choices: lack of political will; industrial will; financial resources; biophysical data; human resources in the region; scientific data;

socioeconomic data; and too-rigid laws. The most frequent responses were a lack of political and industrial will (> 67%). These last two obstacles were mentioned by less than half of industrial users (< 45%). A slight majority of industrial users mentioned the rigidity of laws (57%). Lack of financial resources was mentioned by about half of the respondents in all groups (> 53%) as an obstacle, but to a lesser extent by industrial users (43%) (Figure 2.5).

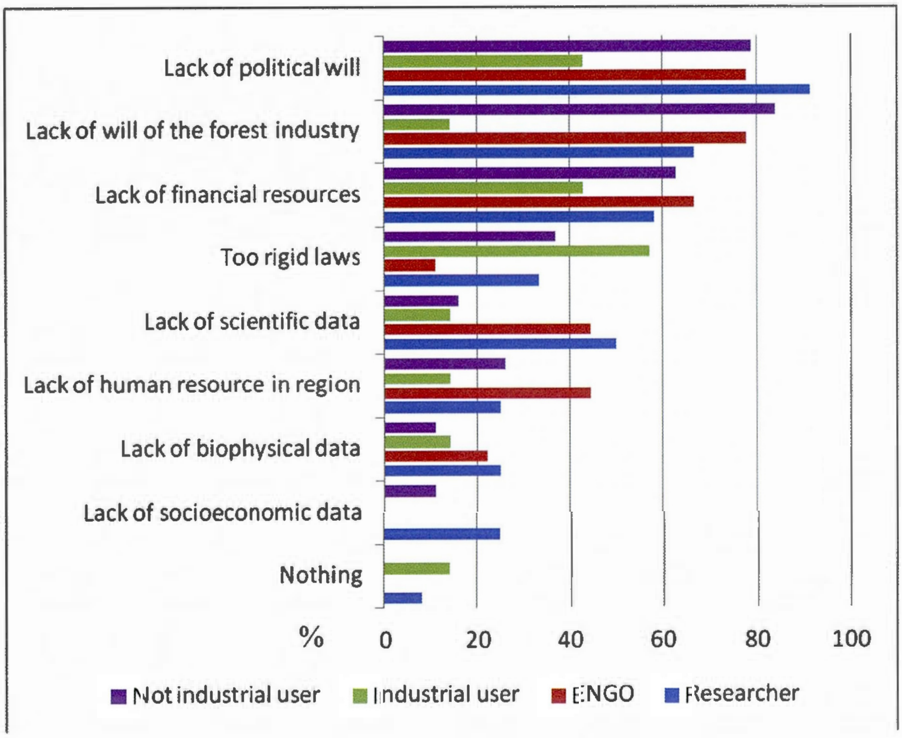

Figure 2.5 **Obstacles to stakeholder priorities implementation**

2.4 Discussion

2.4.1 From theory to practice

All groups agreed that forest retention is important, thus accepting the ecological arguments made by Lindenmayer and Franklin (2002) and others (see

Table 2.2). Indeed, most respondents agreed that it is essential to plan forest retention at multiple spatial and temporal scales to ensure retention elements that maintained and fulfill their ecological roles (maintain biodiversity and ecological processes). Respondents` answers showed that most viewed the forest as a complex system, just as scientists do. In fact, science went through a major paradigm shift from a reductionist to global approach in the early 21th century (Naveh, 2000). This holistic paradigm shift has influenced not only scientific views, but also the practice of resource management (Holling et al., 1998), Further, it seems to have influenced respondents` perceptions that we have observed in this case study.

As presented earlier, most respondents who are involved in the decision-making process were highly educated. Even the non-industrial users who were sampled had a high percentage of university-educated delegates (47%). Level of education can potentially explain our observation that practically all respondents used scientific sources of information to learn about forest management, which may have positively influenced perceptions regarding the role of forest retention in sustainable forest management (Gauthier *et al.*, 2008b). Education and information sources have the potential to greatly influence attitudes towards the forest and its management (Crona and Bodin, 2006). However, the larger population is not as well-educated and probably a good deal less informed about the scientific rationale for forest retention, which could potentially lead to very different preferences (Steel and Weber, 2001). However, knowledge is one factor among many others that can influence judgement. (Shindler *et al.*, 2004)

Support for the concept of spatio-temporality of retention was consistent with the strong recognition of forest existence value that was expressed by all respondents. Maintaining retention at various spatial and temporal scales involves recognising ecological processes in forests. As was the case in McFarlane and Boxall (2010)'s study, environmental issues seem to be of great importance for most respondents.

2.4.2 Two conflicting visions of forest retention

Even if all groups agreed on a theoretical basis for forest retention, two conflicting visions of forest retention practices emerged: the status quo versus increasing forest retention. Industrial users supported the status quo, while the remaining groups felt the need for greater retention and who were mainly dissatisfied with current forest retention practices.

2.4.2.1 Status quo

Most industrial users had a very different perception of operationalising forest retention compared to the other groups. They believed that current practices and levels of forest retention are sufficient. They were more concerned than were other groups about the impacts of maintaining greater forest retention on employment and profitability. This perception of forest retention accorded with their priorities (e.g., job creation) and their views of the forest (e.g., source of economic wealth and job creation). Attitudes toward forest management also could be influenced by socio-demographic attributes, values, knowledge, and social influences (McFarlane et al., 2011). Generally, young people and women living in the city have tended to emphasise recreational and environmental values (Lindkvist *et al.*, 2012 ; Steel and Weber, 2001). In our case study, the high percentage of women (43%) and young respondents within the industrial users group did not seem to influence desires to increase forest retention. Researchers were the only group in which respondents were not resident of one of the two region. The difference did not seems to influence the results. Values were probably a better predictor of preferences, as McFarlane and Boxall (2010) concluded in their study. Indeed, compared to other groups, industrial users had a stronger tendency to value the forest for human needs, even if they also supported at the same time the value of forest existence. The combination of biocentric and anthropocentric values is commonly found in the literature (Steel et al., 1994).

Knowledge was also likely a great determinant of stakeholder perceptions (Andrea and Vanclay, 2011). Industrial users likely possessed knowledge about forest retention that differed from the other groups. Indeed, they were probably better aware of the technical, legislative and financial constraints that are imposed on improving forest retention. For example, leaving more retention at the stand-scale as snags and green trees suggests safety issues for forestry workers (Crête *et al.*, 2004). It is also a challenge, because forest regulations against wasteful practices have required forest companies to remove all maintained trees from harvested sites (Bourgeois *et al.*, 2007). Contrary to general belief, but well-known among foresters, retention after harvesting is abundant at the scale of an entire harvest block. For example, a recent study showed that a greater area of residual forest was found in harvest blocks compared to burns (at the scale of hundreds to thousands of hectares), despite differences in shape and spatial arrangements (Dragotescu and Kneeshaw, 2012). However, after many short rotations the amount of retention will be probalbly less in cut blocks. Scientific knowledge about ecological thresholds (amount, configuration, disposition and quality of the retention) remain very elementary and not consensual (Rosenvald and Lohmus, 2008). Consequently, industrial users may be more aware of these issues than are non-industrial users. Planning and inventory exercises would also make them acutely aware of the forest that was being left behind.

This kind of information about technical, legislative and financial constraints of improving forest retention maybe not translate into sources of information that can be consulted by stakeholder groups other than industrial users. Yet, we expected that industrial users from the Mauricie region, where eight years of research on improving forest retention had been undertaken, had expressed a more positive preference for retention issues. Their preference for status quo is perhaps only a matter of delayed attitudes and behavioural changes (Chiasson and Leclerc, 2013 ; Reed *et al.*, 2010)

At a broader scale, government faces many challenges with respect to operationalising forest retention. For example, leaving large forest patches and creating new protected areas is very complex, given that the forest matrix has been already altered (Tittler et al., 2010) and that there are the multiple uses of forests (Coulombe et al., 2004). The creation of the new Opémican National Park in Temiscamingue is a good example. In fact, its establishment has raised serious conflicting discussions concerning the uses that are practiced in the territory, including aboriginal rights (Harvey, 2012).

2.4.2.2 Improving retention

Researchers, ENGO representatives and non-industrial users had a different vision of forest retention compared to industrial users. The former mainly believe that greater forest retention is needed and that current practices are not sufficient. They view the forest as a place for wildlife and protection of air, water and soil, beyond being considered simply as a source of non-timber products, recreation, and relaxation. This view of the forest and their preference for conservation was consistent with their support of existence value of forest as seen in other studies (Holsman and Peyton, 2003 ; Kaval, 2010). However, stakeholder values and priorities in other studies were not always within the scope of greater conservation (Glasmeier and Farrigan, 2005 ; Holsman and Peyton, 2003). Occasionally, stakeholders will focus on narrow preferences (e.g., wild game), given their utilisation of the forest (Holsman and Peyton, 2003). Even if this possibility cannot be excluded, most stakeholders who are not involved in the forest industry view the forest in a holistic manner, which is similar to McFarlane and Boxall's (2010) findings. These groups apparently understand that not only protected areas, but the entire ecosystem must be preserved if they are to maintain their use of the forest. Indeed, conservation no longer depends on protected areas alone (Pert et al., 2013).

Thus, forest retention seems to be viewed by these stakeholders as a way to operationalise that objective of conservation at multiple scales.

Respondents' concerns about forest retention transcended spatial scales. Indeed, they cared about retention elements at both the stand- (e.g., green tree) and landscape-scale (e.g., large forest patches), consistent with literature reports (Balmford et al., 2003). However, dead retention appears to be of less importance for researchers and ENGO representatives. This could be due to the fact that compared to other regions of the world (Scandinavian countries) (Siitonen, 2001), the lack of down dead wood is less of a concern in North America. All of this suggests that these two groups were able to think holistically and to rank different issues depending on their level of priority, compared to non-industrial users who reject strongly all practices. We suggest that non-industrial users, even if they also have used scientific sources of information, were influenced in their judgement by mistrust of forest managers.

2.4.2.3 Local institutions as a place for reconciliation between the two conflicting visions

Successful collaboration will come with a common understanding of forest processes, including human actions within the complex socio-ecosystem that constitutes the forest (Lebel et al., 2006). A holistic view of forest is needed to understand a variety of needs and constraints (Blumenthal and Jannink, 2000) and to achieve the main objective of local integrated land and resource management panels (LILRMP) (Chiasson and Leclerc, 2013), which is the harmonisation of different uses. Reaching a holistic view of the forest involves sharing knowledge, values, constraints, and interests among stakeholders (Dreyer and Renn, 2011) and, hence, the importance of social learning[5] (Reed et al., 2010). Unexpected answers about

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[5]Social learning is defined by Reed et al. (2010) as "a process of social change in which people learn from each other in ways that can benefit wider social-ecological

stakeholder priorities could be seen as signs of social learning in this study. For example, respondents in the ENGO group placed among their priorities the development of new forest products, while researchers included job creation. Surprisingly, industrial users did not place much emphasis on making profits. Non-industrial users, for their part, remained very close to their personal needs when stating their priorities (conservation, multiple-resource management, and integration of stakeholders in decisions).

Institutions such as LILRMP are very important in the success of natural resource management because they can promote opportunities for communication among stakeholder groups (Crona and Bodin, 2006). In fact, participants created ties among stakeholders groups by sharing their beliefs, values and knowledge about the resource to be managed and what is crucial (Schneider et al., 2003), while adapting their behaviour, opinions and values with persons in their network with whom they frequently exchange information (Prell et al., 2009). This transfer of information is invaluable in attaining mutual understanding and trust building (Lebel *et al.*, 2006 ; Ostrom, 2005). Outcomes of social learning, including mutual understanding, could enhance both trust and adaptive capacity, but they generally require time to be detected (Reed et al., 2010).

2.4.3 Trust and constraints.

Based on our survey results, most respondents believed that the level of trust between the public and managers is low. We expected that respondents would believe that greater forest retention can improve public confidence (trust) in forest managers.

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system." People are learning from their interactions with the environment and other participants (Muro and Jeffrey, 2008).

Surprisingly, only non-industrial users (79%), and to a lesser extent, ENGO respondents (56%) mainly expressed their support for that statement. Mistrust is probably deeply rooted in stakeholder perceptions and relies on a complex set of elements that are different from forest retention, such as as lack of power (Shahbaz et al., 2008). In this case study, stakeholder involvement in LILRMP was at the level of consultation (Conférence régionale des élus de la Mauricie, 2010 ; Desrosiers *et al.*, 2010). Power remains in the hands of government and industries, which probably explained why respondents mentioned that political will is a major obstacle to the implementation of their priorities, as has been noted in other studies (Koontz and Bodine, 2008 ; Shahbaz *et al.*, 2008).

2.5 Conclusion

All groups agreed upon the theoretical foundations of forest retention, but not on its implementation. Different stakeholder groups perceived retention issues differently, thereby creating two conflicting visions. On one hand, industrial users believed that the status quo concerning levels of forest retention and practices were sufficient. On the other hand, other groups agreed that greater forest retention and improvement in practices are needed. Forest values seem to have more influence on a respondent's vision of forest retention than do socio-demographic attributes, except perhaps for education level. Indeed, a high level of education likely affects the acquisition of scientific knowledge and, possibly, stakeholder preferences. Not all groups agreed that greater forest retention would increase the level of trust between the public and forest managers. Other preoccupations were probably of greater importance, such as the lack of power. The lack of political will was stated as the main obstacle to the implementation of priorities of the pro-forest retention respondents. Although we can speculate that stakeholder groups would force industries and government to improve retention practices and, consequently, defend ecological needs, the converse should also be tested, i.e., whether industrial users will be able to share their concerns about forest retention with other stakeholders. The successful operationalisation of ecosystem-based management implies that stakeholders hold a holistic view of the forest. We suggest that more research regarding the influence of local institutions on the adoption of holistic thinking should be encouraged.

CHAPITRE III

FOREST ECOSYSTEM MANAGEMENT IN NORTH AMERICA: FROM THEORY TO PRACTICE

Cynthia Patry,
Centre d'etude de la Foret, Departement des Sciences Biologiques, Universite du Quebec a Montreal, C.P. 8888, Succ. Centre-Ville, Montreal, Canada, H3C 3P8
patry.cynthia@courrier.uqam.ca

Daniel Kneeshaw
Centre d'etude de la Foret, Departement des Sciences Biologiques, Universite du Quebec a Montreal, C.P. 8888, Succ. Centre-Ville, Montreal, Canada, H3C 3P8.
kneeshaw.daniel@uqam.ca

Stephen Wyatt,
Faculté de foresterie, Université de Moncton Campus Edmundston, 165, boulevard Hébert, Edmundston (Nouveau-Brunswick), Canada, E3V 2S8
stephen.wyatt@umoncton.ca

Frank Grenon,
Centre d'enseignement et de recherche en foresterie de Sainte-Foy inc. (CERFO), 2424, chemin, Sainte-Foy, Québec (Québec), Canada, G1V 1T2
f.grenon@cerfo.qc.ca

Christian Messier
Centre d'etude de la Foret, Departement des Sciences Biologiques, Universite du Quebec a Montreal, C.P. 8888, Succ. Centre-Ville, Montreal, Canada, H3C 3P8.
messier.christian@uqam.ca

3.1 Abstract

Forest ecosystem management (EM) in North America has evolved from a theoretical concept to operational practice over the last two decades, but its implementation varies greatly among regions. This paper attempts to evaluate (1) if and how emulation of natural disturbances (END) is being used as a conceptual bases for implementing EM, and more particularly, what strategies are used to define the natural forest of reference, and (2) what temporal and spatial scale strategies are being considered for 7 important retention elements (downed woody debris, snags, green trees, corridors, riparian buffers, large patches and old forest)? To conduct this evaluation, 5 guides from 4 geographically well-distributed regions in North America are compared.

Although END is the central conceptual foundation underlying 4 of the 5 guides, a natural forest of reference is not always clearly identified and none of the guides consider future impacts due to global change. The major weakness common to all 5 guides is the lack of consideration of long-term forest dynamics, particularly the lack of clear strategies for retention elements at a temporal scale longer than a single rotation. Generally, the spatial scales chosen for retention elements are not well-justified ecologically and targets for each retention element are not identified at different spatial scales. We stress that strong efforts have been made to develop forest management that incorporates some elements of natural variability and which considers societal needs, but further improvements are required. We conclude by presenting some suggestions to improve the approach. For example, creating more realistic guidelines in integrating current and future forest dynamics with pre-settlement information and planning rotation lengths that are inspired by the dominant natural disturbance.

Key words: Forest ecosystem management, implementation, North America, retention strategies and emulation of natural disturbances, spatiotemporal scales.

3.2 Background information

In the early 1990s, the United States Department of Agriculture (USDA) Forest Service and the Department of the Interior Bureau of Land Management (BLM), were among the first in North America to officially adopt ecosystem management (EM) as the exclusive means of managing national forests (Butler and Koontz, 2005). Shortly afterward, Grumbine (1994) attempted to provide a working definition of EM. He described EM as the interface between scientific knowledge about ecosystems and the management of socio-political values, with the goal of protecting natural ecosystem integrity over the long-term. Since that time, many organizations throughout the world, ranging from local private owners to state governments, have begun endorsing and applying this approach to sustainable forest management. Many government organizations have developed sophisticated guidelines for EM (e.g., (Archibald *et al.*, 1997). Yet, the application of EM varies greatly from one region to another. We believe this is partly due to the vague theoretical foundations underpinning EM and its application to forestry, which leads to wide variation in its implementation (Rauscher *et al.*, 2000). This situation has created a growing interest in comparing the diversity of implementation strategies and their links with scientific ecological knowledge.

In parallel with the developing interest in EM, Hunter (1993) proposed an operational solution for maintaining ecosystem integrity. He suggested that forest management that "emulates natural disturbances" (END) could maintain or recreate the natural variability encountered in natural or semi-natural forest ecosystems. The main assumption of END is that the various organisms normally present in these ecosystems are adapted to the range of natural variation in time and space that is created by natural disturbances. The use of END can also be viewed as a coarse-filter approach to ecosystem management (Armstrong *et al.*, 2003). In North America, the idea of emulating natural disturbances was quickly integrated into EM (Dale *et al.*, 1998 ; Gauthier *et al.*, 2008b ; Work *et al.*, 2004).

Despite the scientific interest in using END for management purposes, its implementation presents many obstacles. First, forest management that is based on END requires knowledge of the natural range of variability (Landres *et al.*, 1999) under past disturbance regimes and the current state of the forest. Thus, information regarding variation in the size, intensity and frequency of past natural disturbances is required. Such information is often difficult to obtain, thereby limiting the application of the END approach in many cases, such as over much of Europe and Asia (Berry *et al.*, 1998). Second, a further challenge requires that the time period used to characterize the forest of reference be determined. Although the time period generally focuses on pre-settlement forest conditions (Hessburg *et al.*, 2005 ; Wallin *et al.*, 1996), no consensus has emerged to date regarding what period should be used. Third, given that the effects of global change are expected to alter forest ecosystems, a debate is growing regarding the usefulness of emulating past conditions as guiding principles for establishing and maintaining future forests (Klenk *et al.*, 2009). An additional argument against the strict implementation of END revolves around the difficulty in attaining social acceptability when emulating the extremes of the natural range of variability. For example, the creation of large aggregate cut-blocks incorporating various forms of retention that emulate large fires in boreal forests may not be acceptable to some groups within the wider population (**Kimmins, 2004**).

Retention[6] is an important aspect of END since most natural disturbances rarely can ever completely reinitiate large areas and never remove as much biomass as conventional harvesting. For example, fire leaves a mosaic of patches that have been burnt to a greater or lesser degree (Bergeron *et al.*, 2002). In addition, under most disturbance regimes, retention is maintained for a much longer period of time than under classic cutting rotations of less than 100 years. This induces a variety of

[6] We have defined retention in this paper as any *natural feature that is maintained at one or different spatial scales and which will be maintained for a certain time in the forest matrix after harvesting or natural disturbances.*

spatiotemporal patterns for different retention elements. For this review, we focus on the spatiotemporal characteristics of seven key elements of retention: downed woody debris (DWD), snags, individual or patches of green trees, forested corridors, riparian buffers, old forest, and large forest patches. These are the elements that appear most frequently in the scientific literature, with a variety of strategies being proposed. Establishing protected areas[7] is, of course, also an important strategy for retention and we treat this separately.

The natural variability of many retention elements was reduced following the arrival of industrial forestry. Forest management homogenizes many structural elements in the forest and has driven some elements beyond their natural range of variability (Cissel *et al.*, 1999 ; Cyr *et al.*, 2009a). A review of the literature regarding the impacts of forest management on biodiversity reveals that the loss of old forest attributes (Gauthier *et al.*, 2008b ; Hanski, 2000 ; Noss, 1999) and increased forest fragmentation (Andren, 1994 ; Etheridge *et al.*, 2006) are among the most critical factors. The lack of large coarse woody debris following harvest also threatens the persistence of many saproxylic insects (Jonsson *et al.*, 2005), cavity-nesting birds (Darveau and Desrochers, 2001 ; Drapeau and Imbeau, 2006), cryptogams, and fungi (Crites and Dale, 1998).

The creation of large and numerous protected areas has been proposed as a solution to these issues. However, it is now recognized that the amount of forest that would be protected is likely to be insufficient for maintaining forest biodiversity (Heller and Zavaleta, 2009 ; Wiersma and Nudds, 2009). Nowadays, 92% of the world's forests are outside of protected areas (Commonwealth of Australia 1999, cited

7 The designation of protected areas in guides matched the definition that was provided by Wiersma *et al.* 2010: "Geographic space clearly defined, recognized, dedicated and managed, through effective means, legal or otherwise, to ensure long-term conservation of nature and ecosystem services and cultural values associated with it".

by Lindenmayer *et al.* 2006). As a consequence, particular attention must be focused on the managed forest matrix and on the connectivity between protected areas and other retention elements (Lindenmayer and Franklin, 2002). Connectivity is critical for many animal and plant species which are adapted to continuous forest cover (Bennett, 2003 ; Franklin, 1993 ; Lindenmayer, 2000 ; Rosenvald and Lohmus, 2008). Forests have been historically less fragmented in many regions than they are today (Wedeles and Sleep, 2008).

Another important element to consider for successful implementation of EM is the maintenance of forest resilience. This is particularly important today due to rapid socio-ecological changes that are occurring worldwide. We define resilience as the capacity of a system to absorb and/or adapt to disturbance so as to persist in time (adapted from (Holling, 1973). A resilient forest ecosystem greatly depends on the maintenance of functional diversity and important ecological processes across scales (Gunderson, 2000). Because biodiversity and many ecological processes are affected by management that homogenizes forest structure, causes fragmentation, and reduces DWD and areas of old forests, we urgently need new management strategies that will maintain resilience. Although many key elements are needed to ensure a resilient forest, the retention of structural elements at both stand- and landscape-levels is crucial (Lindenmayer *et al.*, 2012). These retention elements may also act as "temporal lifeboats" for biodiversity (Vanha-Majamaa and Jalonen, 2001), meaning that these elements need to be planned over the long-term (Landres *et al.*, 1999). Figure 3.1 illustrates the management suggested by literature regarding the seven retention elements and protected areas across temporal and spatial scales.

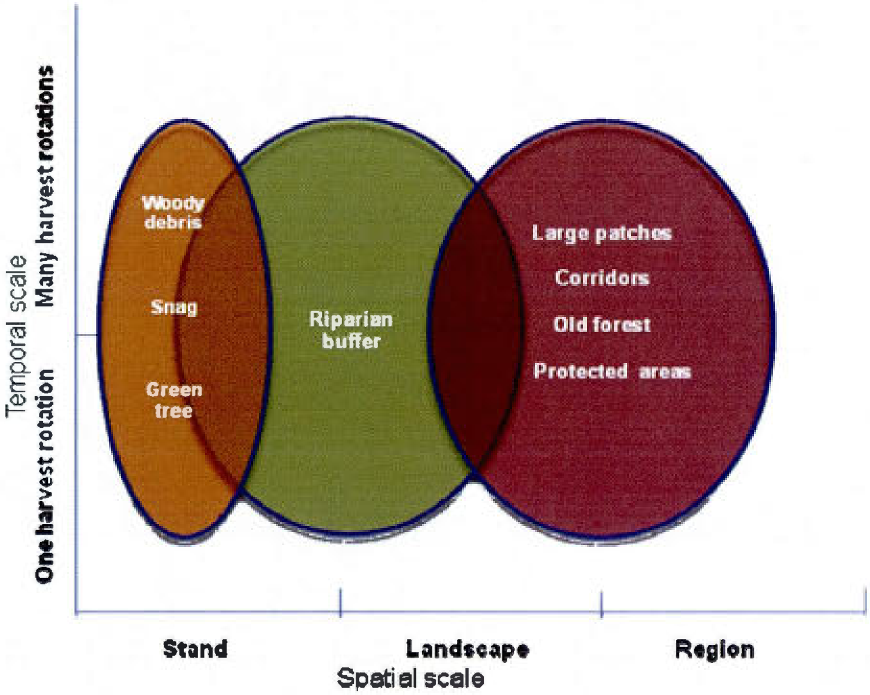

Figure 3.1 Theorical spatio-temporal objectives for retention elements. Visual representation of the main spatiotemporal theoretical objectives with respect to the seven retention elements of concern and protected areas. The X-axis shows the three spatial scales and the Y-axis shows the two temporal scales that were considered. The order of elements within a sphere is irrelevant; it is the delimitation of a sphere that is important.

Since EM is proposed as a way of ensuring long-term forest functioning and maintenance of biodiversity, the main objective of this paper is to critically review how EM is being implemented in four different regions of North America. Social and economic issues are important in EM (Bengston, 1994 ; Grumbine, 1994), but our analysis focuses on END and the spatiotemporal requirements for the aforementioned retention elements. We examined implementation guidelines in each of four regions, asking the following questions:

1) Is END used as one of the conceptual bases to implement EM, and if so, what strategies are used to define the natural forest of reference?

2) Since legacy elements are important for ecological processes and biodiversity, are the temporal and spatial scales proposed for retention elements appropriate to achieve EM objectives?

3.3 Methods

For the comparison, we selected four regions that are widely distributed across North America to get a representative sample of different approaches being used in different forested ecosystems. These four regions represent different types of forests, disturbance regimes, and administrative organizations, but they all contain publicly owned forests. The regions are the Pacific Coast of the United States, the Pacific Coast of Canada, central Canada, and Atlantic Canada. Our choice was also based on the chronological date of EM adoption, from the earliest region being the US Pacific Coast in 1994 to the most recent being the Bay of Fundy (New Brunswick) in 2005. Each region defined its EM strategy in various guides, plans, or handbooks. We analyzed five different guides: two distinctive approaches for the Pacific Canadian Coast (governmental and non-governmental) and one for each of the other regions. In Table 1.1, the title and acronym, authors, reference, location, land tenure and complementary documents are presented for each guide. With some exceptions, guides are not stand-alone documents and are complemented by other guides (1.1) or legislation (data not shown).

Tableau 3.1 Document title authors, location, land tenure and additional documents of the five chosen guides relevant to the four regions.

NDPE[8]	Document title	*Forest Management Guide for Natural Disturbance Pattern Emulation* (NDPE)
	Authors and reference	Ontario Ministry of Natural Resources (OMNR, 2001)
	Location	Ontario: Boreal and the Great Lakes-St. Lawrence Forest
	Land tenure	Provincial public forest
	Additional documents	*Ontario's Living Legacy*, among others A new version of the guide now exists.
GFE	Document title	*Forest management guidelines to protect native biodiversity in the Greater Fundy Ecosystem, 2nd edition* (GFE)
	Authors and reference	Greater Fundy Ecosystem Research Group (Betts and Forbes, 2005)
	Location	New Brunswick: Fundy Model Forest watershed
	Land tenure	Federal public forest and private forest
	Additional documents	*Best Management Practices: A Practical Guide for New Brunswick's Private Woodlots*
BG	Document title	*Biodiversity Guidebook - Forest Practices Code of British Columbia* (BG)
	Authors and reference	Ministry of Forests and Range of British Columbia (Province of British Columbia, 1995)
	Location	British Columbia
	Land tenure	Provincial public forest
	Additional documents	*Riparian Management Area Guidebook and the Managing Identified Wildlife Guidebook*, among others
CIT guide	Document title	*Ecosystem-based management planning handbook* (CIT)
	Authors and reference	Coast Information Team (Coast Information Team, 2004)
	Location	British Columbia: Central and North Coast and Haida Gwaii
	Land tenure	First Nations territories and public provincial forest
	Additional documents	*Hydroriparian Planning Guide, The Scientific Basis of Ecosystem-based Management, BC Protected Areas Strategy*, among others.
NWFP	Document title	*Northwest Forest Plan: Standards and Guidelines for Management of Habitat for Late-Successional and Old-Growth Forest Related Species Within the Range of the Northern Spotted Owl* (NWFP)

[8] Acronym used in the text

	Authors and reference	USDA Forest Service and the USDI Bureau of Land Management (USDA and USDI, 1994)
	Location	Range of the northern spotted owl in Washington, Oregon, and northern California
	Land tenure	Federal forest
	Additional documents	*Record of decision for Amendments to Forest Service and Bureau of Land Management Planning Documents Within the Range of the Northern Spotted Owl*

Acronym used in the text

As a first step to answering our two questions, we reviewed the literature for key concepts of END and retention elements in forests, and prepared sets of keywords to be used for each of our questions. The first keyword list contained terms referring to the emulation of natural disturbances and included terms such as "mimic," "emulate," "recreate," and "forest of reference," among others. The second list consisted of the seven retention elements and their synonyms (examples of synonyms in parentheses) that are most commonly discussed in the literature: downed coarse woody debris, snags (e.g., cavity trees), green trees (e.g., variable retention), corridors (e.g., leave strips), riparian buffers (e.g., riparian reserve), large forest patches and old forest (e.g., over-mature forest).

In the second step, we searched electronic copies of the five guides, identifying text dealing with each keyword or synonym from the two keyword lists. The presence of the keywords in sub-titles or in the text led to the associated paragraphs or section being identified with a code based on the keyword. In some cases, a single section included two (or more) keywords and, therefore, was coded for both elements. Sections of the text lacking keywords were not coded.

In the third step, we used two different sets of criteria to analyze the text coded for END and the text coded for the seven retention elements. The four criteria used for analyzing each portion of the text that was coded for END were the following: emulation of natural disturbance or not, the temporal period of reference (e.g.: past, present, future) for the forest of reference, the inclusion of global changes in forest of reference or not, and when information about the forest of reference was gathered (before or after creation of the guides). The two criteria used to analyze the text dealing with the seven retention elements were the following: the temporal scale (level of permanence: not permanent, not all permanent, thereby ensuring recruitment, and permanent) and the spatial scale (stand, landscape, watershed, region, territory) used in each retention element strategy.

From this analysis two tables were created for the second question. We created Table 3.2 to show at which spatial and temporal scale each guide chose to implement each retention element, given that a retention element can be implemented at more than one spatial or temporal scale. The strategies that were proposed for each retention element are summarized in Table 3.3 from the coded text created in step 2.

3.4 Results

3.4.1 Is END used as one of the conceptual bases to implement EM?

All guides, except for the oldest example of the North West Forest Plan (NWFP)[9], clearly refer to END as one of their conceptual bases for implementing EM. In these guides, the term “natural disturbance” was always linked to "emulate," "mimic," "approximating," "resemble," and "simulate." This is exemplified by a statement from the Biodiversity Guidebook (BG): "The more the managed forests will look like the forests established after natural disturbances, the greater is the probability that all native species and ecological processes are maintained (Province of British Columbia, 1995)." In the case of the NWFP, "natural disturbance" was instead linked to the concepts "maintaining disturbance regimes" and "management

[9] We do not cite the reference each time a guide is mentioned in the results and discussion section. Please see references to guides in Table 1.

of disturbance risk." In this guide, it is only in late-successional reserves that the term "recreate" is linked to pre-settlement conditions.

For the four guides that endorsed END, identification of a dominant natural disturbance per territory is central to the choice of retention strategies that should be implemented. For example, in British Columbia, the amount of mature and over-mature forest to be maintained in a landscape that is dominated by rare stand-initiating disturbances will be much higher than in landscapes that are dominated by frequent stand-initiating disturbances.

Forest of reference

In all guides, forests of reference refer to the pre-settlement period without any further specification, despite the fact that recommendations for retention elements mostly depend on the historic disturbance type. The strategy that is often used to define the natural forests of reference and to implement END is the creation of a historical portrait. This historical portrait details the natural disturbance history and historical forest inventory data for the pre-industrial vegetation conditions. In fact, for the two most recent guides (*Ecosystem-based management planning handbook* (CIT) and *Forest management guidelines to protect native biodiversity in the Greater Fundy Ecosystem* (GFE)), the historical portrait of the whole territory was done before the actual creation of the guides. That method clearly influenced the way in which these guides were compiled. For the NDPE, the historical portrait is done whenever a new unit is planned and so the overall guidelines tend to be more general to accommodate various types of disturbances. For BG, the natural disturbance type is already determined in the guide for each existing biogeoclimatic zone in British Columbia. New information about the forest of reference is needed only to plan connectivity. Indeed, it is recommended that a connected landscape should be maintained in the same manner as in pre-industrial times. None of the guides discussed the possible changes in forest dynamics due to global change (e.g., modification of disturbance regimes, deer browsing, etc.). Only the NDPE briefly recommends combining long-term simulations with pre-settlement information.

> 3.4.2 Since legacy elements are important for ecological processes and biodiversity, are the temporal and spatial scales proposed for retention elements appropriate to achieve EM objectives?

Following the evaluation of the five guides, we noted that several important points concerning the spatial and temporal scales that had been proposed were not totally congruent with what is found in the scientific literature (Figure 3.1). These included the temporal maintenance of retention, the ecological justification of the spatial scale that was used, and the integration of multiple spatial scales.

Before presenting our evaluation of each guide, we need to specify that the different strategies present in Table 3.3 are dependent on a certain land classification. For example, in GFE and BG, the land is subdivided according to the dominant disturbance type[10]. The land can also be subdivided according to the risk level[11] (CIT), the biodiversity emphasis[12] (BG), or an ecological land classification[13] (GFE). Depending on the land classification, the strategy for a given retention element will

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[10] Dominant disturbance type: GFE= Gap-replacing disturbance, Patch-replacing disturbance and Stand-replacing disturbance. BG = Rare stand-initiating disturbance, infrequent stand-initiating disturbance, frequent stand-initiating disturbance, frequent stand-maintaining disturbance, alpine tundra, and sub-alpine. One disturbance type is given per biogeoclimatic zone.

[11] Risk level: There are four possible designations, from very low to high. Low = meaning a 30% difference from what is found naturally. High = meaning a 70% difference from what is found naturally.

[12] Biodiversity emphasis: There are three designations that may have a landscape unit in connection with the risk to biodiversity loss: Low = Priority given to social and economic objectives (30-55% of the region and not all in the same area). Intermediate = Trade-off between conservation and timber production (35-60% of the region). High = Higher priority to conservation (10% of the region).

[13] Ecological Land Classification is a hierarchical classification of ecological units at multiple scales.

be different. For example, in lands chosen for high biodiversity emphasis, large patches will be bigger and more abundant (BG). For its part, the NWFP conducted a watershed analysis[14] during management planning. This analysis also modulates some retention element strategies.

3.4.2.1 Temporal maintenance of retention

Despite certain exceptions, the guides are generally ambiguous with respect to the long-term maintenance of retention elements. Globally, only protected areas and recruitment of DWD and snags have clear long-term strategies that are common to all guides. Only the CIT guide had no clear strategies for woody debris. For many retention elements no mention is made of the period of time that the elements should be maintained. When duration is mentioned, it is often to state when the elements can be partially or totally removed before the next rotation (Table 3.2 and 3.3). For example, it is possible in the NDPE to cut retention patches when the surrounding forest reaches a height of 3 m. In the BG, it is proposed that structural diversity[15] equivalent to that found in natural forests must be recreated in the surrounding forest before a final cut in the retention area can be allowed (Table 3.3). This also means that retention is not permanent, although it could be maintained for a certain length of time. The same observation can be applied to riparian buffers; in some circumstances,

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[14] Watershed analysis: Procedures for conducting an analysis that evaluates geomorphic and ecologic processes operating in specific watersheds. Prior to resource management, it delineated riparian reserves.

[15] Structural diversity: "A variety of canopy layers (vertical structure) and spatial patchiness (horizontal structure). This variety of layers includes the naturally occurring forest understory of shrubs and forbs, which provide food and cover for numerous species. To maintain understory vegetation, a partially open or patchy forest canopy is required Province of British Columbia, *Biodiversity guidebook: Forest practices code of British Columbia* ."

partial cuts are allowed within these areas, e.g., in the GFE and CIT guides (Table 3.3). Even old forests are not clearly identified as permanent features (Table 3.2). Only the two west coast guides (BG and NWFP) recommend maintaining retention features for more than one rotation. The BG recommends a long-term landscape management approach in creating the Forest Ecosystem Network (see definition in the following section: *Spatial multi-scale approach*), in which some components should be permanent reserves. The NWFP guide mentioned that 15% of the stand must be maintained as permanent green tree retention (over multiple rotations) and that no subsequent cuts are allowed in riparian buffers (Table 3.3) .

Tableau 3.2 Temporal and spatial requirements for each retention element in each guide

Retention element	Scale	NDPE	GFE	BG	CIT guide	NWFP
DWD	Temporal	Ensuring recruitment	Ensuring recruitment	Not all permanent	No detailed strategy	Ensuring recruitment
	Spatial	Stand	Stand	Stand	Stand	Landscape
Snag	Temporal	Not mentioned	Ensuring recruitment	Ensuring recruitment	No detailed strategy	Ensuring recruitment
	Spatial	Stand	Stand	Stand	Stand	Stand
Green tree	Temporal	Not all permanent	Not mentioned	Not permanent	Not mentioned	Permanent
	Spatial	Stand	Stand	Biogeoclimatic zone and landscape	Watershed and stand	Stand
Riparian buffer	Temporal	No detailed strategy	Not all permanent	Not mentioned	Not all permanent	Permanent
	Spatial	No detailed strategy	Stand	Stand	Subregional and watershed	Watershed
Corridor	Temporal	No detailed strategy	Not mentioned	Not mentioned	Not permanent	No detailed strategy
	Spatial	No detailed strategy	Ecodistrict	Landscape	Subregional, landscape, watershed	No detailed strategy
Large forest patch	Temporal	No detailed strategy	Not permanent	Permanent	Not all permanent	Not all permanent
	Spatial	No detailed strategy	Ecodistrict	Landscape	Subregional, watershed, landscape	Federal land
Old forest	Temporal	Not mentioned	Not mentioned	Not all permanent	Not mentioned	Not mentioned
	Spatial	Landscape	Landscape	Biogeoclimatic zone and landscape	Subregional	Watershed

No detailed strategy = the element is mentioned but no strategy is explained.
Not mentioned = a strategy is mentioned for the element, but there is no mention of the permanence of the retention element.
Not permanent = the strategy permits an eventual removal of the element.
Not all permanent = the strategy permits eventual removals of part of the element.
Ensuring recruitment = green trees are maintained to ensure DWD and snag recruitment.
Permanent = the element is maintained for multiple rotations
NDPE = Natural disturbance pattern emulation, GFE = Great Fundy Ecosystem, BG = Biodiversity guidebook, CIT = Coast information team, NWFP =

North West Forest Plan

Tableau 3.3 Summary of strategies used by each guide for each retention element.

	Downed woody debris
NDPE	Avoid full tree harvesting, leave non-merchantable logs on site and redistribute roadside chipping waste.
GFE	Maintain minimum 50% of pre-treatment coarse woody debris in the same diversity of size and species. Allow 10 to 20 green trees/ha with a DBH $\geq$ 30cm to ensure snag and DWD recruitment and also leave tree limbs and tops.
BG	Maintain minimum 50% of pre-treatment coarse woody debris.
CIT	Maintain biological legacy, including coarse woody debris. Where necessary restore biological legacies. No detailed strategy.
NWFP	In the matrix, a prescription for each geographical region should be developed. Maintain bigger downed logs (>40 cm diameter) between 15 m and 30 m of logs/ha. Downed woody debris must be appropriate in quantity, quality (such as species, decay stage and size) and distribution. DWD already on the ground should be retained. DWD quantity and quality must reflect rare and locally endemic species needs.
	Snag
NDPE	Maintain 25 individual trees or snags per hectare (ha) or create them mechanically.
GFE	Maintain 8 potential cavity trees/ha and 8 snags/ha. Allow 10 to 20 green trees/ha with a DBH $\geq$ 30cm to ensure snag and DWD recruitment
BG	Some existing snags should be retained, but equally important is ensuring that new snags will be recruited into the stand in the future. Retain some live trees during harvesting as a source of large-diameter snags in the subsequent rotation. Also create snags.
CIT	Maintain biological legacy, including snags. Where necessary restore biological legacies. No detailed strategy.
NWFP	Maintain enough cavity trees to preserve 40% of the cavity-nesting bird population. Ensure future snag recruitment by living large trees.
	Green tree
NDPE	Percent residual area must vary between 10% and 50%, including a range of 2% to 10% for internal (inside the cutting area) and 8% to 40% for peninsular patches (at the margin of the cutting area). Harvesting allowed in 50% of retained patches when surrounding vegetation has reached >3 m height. Maintain individual trees (25 trees/ha). No harvest and restricted harvest buffers exist for areas of concern, like nesting sites of bald eagles, great blue herons and ospreys.
GFE	In clear cuts, maintain patches of minimum 1.0 ha in each 20 ha instead of individual trees. Tree islands should have tree species composition that is representative of the harvested stand.
BG	The % of trees left depends on the % landscape already harvested and on the % allowed cuts in the biogeoclimatic sub-zone. Patches must be well-distributed in the cutting area and separated by a maximum of 500 m. No harvesting is permitted in patches until the surrounding forest has reached a structural diversity equivalent to natural habitat for wildlife. A diversity of species must be maintained.

CIT	Maintain 15 to 70% of retention on site, depending on watershed risk targets and site objectives. Distribute the retention (aggregated (>1 ha) or dispersed retention) to represent rare and at risk ecosystems.
NWFP	In the matrix, retain at least 15% of the area in individual or patches of living trees. Patches (70% of green tree retention must be in patches of 0.2 ha to more than 1.0 ha and a minimum of patches > 1 ha) should be retained **indefinitely**. Relative proportion of patches vs single trees retained must reflect local knowledge of individual species needs, especially rare and locally endemic species.
	Corridors
NDPE	No mention of corridors, but clear cuts must be separated by strips of 200 m to 600 m and more (peninsular patches, see green trees).
GFE	Maintain corridors 200 m in width and maximum 3 km in length in ecodistricts characterized primarily by gap-driven disturbance. Corridors should reflect pre-settlement composition (stand type and age class) and structure (closed-canopy). Protected areas are connected by corridors
BG	Not mentioned clearly, but seems to be part of Forest Ecosystem Network.
CIT	Maintain connectivity for red- and blue-listed and focal wildlife species with the creation of reserve corridors, where no or very little extractive resource use takes place.
NWFP	See the Connectivity/Diversity Block standards and guidelines, not in the NWFP. In NWFP riparian reserve = corridors.
	Riparian buffer
NDPE	Riparian buffer mentioned but no clear strategy presented.
GFE	Maintain a riparian buffer of 30 to 60 m in which a partial cut can be applied, except within 5 m of the shoreline.
BG	Riparian buffers are part of the Forest Ecosystem Network (FEN). See the *Riparian Management Area guidebook*
CIT	Maintain 30 to 97% of riparian buffer, depending on the risk level and spatial scale. Targets are developed at various spatial scales. Targets at lower scale depend on average targets at higher scale.
NWFP	Maintain riparian reserve. Width of riparian reserve is established based on ecological and geomorphic factors during the watershed analysis. The percent of area in riparian reserves varies among administrative units. **No harvesting, grazing, mining or recreational activities are permitted in riparian reserves (buffer)**.
	Large forest patch different than protected areas
NDPE	No clear strategy presented to leave patches greater than 1 ha. Protected areas are only large patches and are defined in Ontario's Living Legacy.
GFE	Keep habitats of different sizes with at least one of 1000 ha by cover type in ecodistrict characterized by gap-replacing disturbance. In ecodistricts characterized by stand-replacing disturbance, maintain patches of 375-500 ha. Also, maintain ecologically significant areas and apply a variable-width buffer. Harvesting can be allowed. These strategies complement protected areas.
BG	Maintain patches in a variety of sizes. Size and number depend on the biodiversity emphasis and the natural disturbance type. Larger ones are

	called reserves and they may be areas requiring special management or **even total protection from harvesting,** to complement protected areas (see the provincial biodiversity strategy).
CIT	Make reserves, where no, or very little, extractive resource use takes place, to complement protected areas (see *BC Protected Areas Strategy*) for rare ecological features, red- and blue-listed communities and focal species. Analyze wildlife requirements at each spatial scale.
NWFP	Maintain Managed Late-Successional Areas, Late-Successional Reserves, Administrative Withdrawals, Riparian Reserves and Congressionally Reserved areas for a total of 72% of federal lands. Buffers around spotted owl (100 acres), marbled murrelet and late-successional forest associated species habitats are also needed if they are in the matrix. Protected areas are included in these designations.
	Old forest
NDPE	Vary treatment to keep a proportion of uneven-aged forest and an age-class structure similar to pre-industrial landscape see the *"Old Growth Policy for Ontario's Crown Forest*" (OMNR, 2003)
GFE	In ecodistricts dominated by gap-replacing disturbance, maintain 40 to 85% of the forest landscape in mature or over-mature forest and 10-12% of this landscape should have old-growth characteristics. In ecodistricts that are dominated by stand-replacing disturbance, maintain 35 to 40% of the forest landscape in mature or over-mature forest.
BG	Determine the approximate natural seral stage distribution, based on estimates of the long-term average interval between stand-destroying events for each landscape by biogeoclimatic zones. Maintain from 50 to 70% of natural seral distribution in each ecosystem type. This means that, depending on the natural disturbance type, from 8 to 54% of the forest landscape must be mature or over-mature forest. When those objectives of representation and old forests are not met with FEN, it is suggested that an *Old growth management area* be created to fill the gap. *Old growth management areas* can be harvested when equivalent old-seral stage areas are available.
CIT	Maintain 50 to 70% of the natural old-seral distribution in each ecosystem type, depending on the risk level and spatial scale. Targets are developed at various spatial scales. Targets at lower scales depend on average targets at higher scales. Where necessary estimate old forest restoration requirements. Prevent excessive mid-seral representation.
NWFP	In the matrix, maintain at least 15% of the watershed in old-growth stage. Late-Successional Reserves and Managed Late-Successional Areas (prohibit or limit activities) are used to recreate and maintain pre-settlement distributions of age class and composition.

The wording from the guides is retained when possible

NDPE = Natural disturbance pattern emulation, GFE = Great Fundy Ecosystem, BG = Biodiversity guidebook, CIT = Coast information team, NWFP = North West Forest Plan

3.4.2.2 Determination of spatial scale based on ecological considerations

All guides subdivide their respective territories into a minimum of three spatial scales: from the stand to the region or greater (Table 3.2). The spatial scales were rarely defined by guides. We assumed that they are quite similar in each guide, but it remains a possible source of bias in the comparison. In general, recommendations are made explicit for the stand and landscape scales, but the proposed standards are not necessarily based on ecological knowledge. Rather, they are the result of practical decisions (e.g., management unit dimensions and respect of administrative borders). Large patches, old forest and corridors are mainly considered at the landscape scale, while DWD, snags and riparian reserves are planned at the stand scale (Table 3.2). Some guides made exceptions and have proposed targets at broader scales, such as the ecodistrict (GFE) or biogeoclimatic zone (BG). These scales are more ecologically significant because it is at these scales that the natural disturbance type is delineated. For example, in the GFE, corridors and large patches are planned at the ecodistrict scale. Similarly in the BG, green tree retention and old seral class distributions are determined by biogeoclimatic zone. The NWFP and CIT guides are innovative in recommending watershed-scale planning for many retention elements, such as old-growth forest and riparian buffers. Indeed, in the NWFP, 15% of the watershed should be in the old-growth stage (Table 3.2 and 3.3).

3.4.2.3 Spatial multi-scale approach

As previously stated, most recommendations are made for stand and landscape scales, but also were frequently implemented at only one of these scales. The lack of integration between scales can lead to concerns about connectivity. For example, in the NDPE guide, connectivity is represented solely by the remaining riparian reserves and peninsular patches at the stand scale and no analyses that would ensure connectivity are conducted at larger scales (Table 3.2). Only two guides make a notable effort to integrate spatial scales. The BG integrates biogeoclimatic and landscape scales in its requirements for the creation of a "Forest Ecosystem Network" in which the links among all components are viewed as essential. It includes a variety of protected areas, inaccessible forests, riparian buffers, high visual quality areas, wetlands, old forests, and corridors. In FEN, the degree of connectivity depends on the biodiversity emphasis (importance put on biodiversity) and the dominant disturbance type (Table 3.3). In the CIT guide, an example of integration across scales is that corridors and large patches are planned at the subregional-, landscape- and watershed-scales. For these two guides, strategies that are implemented at smaller scales depend on strategies developed at coarser scales (Table 3.2 and 3.3).

3.5 Discussion

3.5.1 Is END used as one of the conceptual bases to implement EM, and if so, what strategies are used to define the natural forest of reference?

END is an important theoretical component in each of the approaches that were listed for implementing EM, except in the region in which EM was first implemented (USDA and USDI, 1994). The NWFP is the oldest guide and was created only one year after Hunter's (1993) proposal for END, which may explain why END is not explicitly described in this guide. The creation of a guide is a long and laborious process that often starts many years before publication. Despite END being central to most of the guides, the temporal reference period for which the natural disturbance regime is to be emulated has not been clearly stated in any of them. Yet, general references are mentioned that provide some idea as to the targeted time period, such as pre-industrial, pre-European, and pre-settlement periods. This being said, several researchers have shown evidence that disturbance regimes are constantly changing (Bergeron *et al.*, 2006 ; Bergeron and Flannigan, 1995 ; Logan *et al.*, 2003) and that this temporal variability should be considered when the emulation of a certain pre-settlement period is planned. Landres *et al.* (1999) proposed that no *a priori* time period or spatial extent should be used in defining the natural range of variability. According to these authors, specific goals, site-specific field data, inferences that were derived from data collected elsewhere, simulation models, and explicitly stated value judgements must all contribute to the selection of the relevant time period and the spatial extent that is used in defining natural variability. Only one guide (NDPE), however, partially integrates simulations into its strategy to define forest conditions by combining long-term simulations with pre-settlement information.

The determination of a historical portrait each time that a new management unit is planned, as some guides suggest, is necessary to maintain the natural variability that occurs among units within the same region. Past conditions are a good starting point for understanding the processes and functions that are associated with forest resilience to natural conditions. However, this strategy does not consider that current and future conditions under which forests will develop are likely to be different from those of the past. Many global conditions are changing. Climate, atmospheric concentrations of CO_2, acid precipitation, nitrogen deposition levels, and invasive species and pests, together with permanent fragmentation of the landscape (Ruckstuhl *et al.*, 2008 ; Thompson *et al.*, 2009), are all factors that should be considered in our planning. These considerations could be at least partially considered through long-term modelling of future conditions and monitoring of the forest of reference. This is a compromise between what Landres *et al.* (1999) have suggested and the analysis of the pre-settlement forest alone. We believe that EM should still use information on pre-settlement natural variability, but this information must also be evaluated in light of changing global environmental, social and economic conditions to create a forest that will be as resilient as possible to unknown future conditions (Puettmann, 2011 ; Puettmann *et al.*, 2009). Basing the management of our future forests on conserving the complexity of systems could help achieve the long-term objective of preserving the multitude of ecosystem services that forests provide (Puettmann *et al.*, 2009 ; Witté, 2012).

3.5.2 Since legacy elements are important for ecological processes and biodiversity, are the temporal and spatial scales proposed for retention elements appropriate to achieve EM objectives?

3.5.2.1 Temporal scale

The greatest weakness that was identified in all guides was the lack of temporal consideration for most of the retention elements that were being proposed. In contrast to spatial scales, temporal scales are nearly absent from any discussion in the guides that we surveyed. It is obvious that some elements, other than protected areas, need to be maintained over many rotations to better emulate natural disturbances and to fulfill ecological roles (Drapeau and Imbeau, 2006). In this sense, it is a positive step that some guides have planned for the recruitment of snags and DWD in the next rotation, because the maintenance of these key forest attributes is essential for many species (Crête *et al.*, 2004 ; Deans *et al.*, 2003 ; Drapeau and Imbeau, 2006). A minimum degree of permanent retention is needed, even if the amount and the duration of these elements vary considerably with the dominant disturbance regime. All natural disturbances generate retention elements at diverse spatial scales that are maintained for much longer than the conventional harvest rotation, which tends to vary from 60 to 100 years or longer (Hopwood, 1991 ; McRae *et al.*, 2001 ; Perron *et al.*, 2008). Without some specifications regarding the temporal scale over which retention elements are to be retained, there is a great risk that many crucial structural elements will not be maintained for a period of time sufficient to fulfill their ecological functions. For example, if riparian buffers and corridors are not maintained over multiple rotations, some species that require old forests, such as woodpecker (*Rangifer tarandus caribou*), could be affected, (Crête *et al.*, 2004).

The lack of clear long-term temporal considerations regarding retention elements in all guides is clearly symptomatic of the static viewpoint of western society regarding natural ecosystems. The uncertainty and complexity of managing for the long-term clearly exceeds the capacity (financial and technical) of most stakeholders to address these issues (Brunner and Clark, 1997). Yet, the lack of knowledge regarding the long-term dynamics and ecological effects of the retention elements that are retained (Rosenvald and Lohmus, 2008) is probably the main explanation for the lack of a temporal consideration in many of the guides. To develop adequate recommendations, more long-term research is needed with respect to the temporal role of a given retention element for the maintenance of ecological processes and biodiversity. More research on monitoring, modelling and analyses of ecosystem functions is needed (Handcock and Csillag, 2004 ; Rosenvald and Lohmus, 2008), especially in the context of global change (Heller and Zavaleta, 2009). Adaptive management through monitoring and readjustment of management approaches will be critical in ensuring the long-term success of EM approaches that are being attempted in all of these regions. Fortunately, most guides have monitoring plans.

Forest ecosystem values (economic and social, among others) are also diverse (Nadeau *et al.*, 2007 ; Roy, 2008 ; Tarrant *et al.*, 2003), which increases the complexity of managing all retention elements through time and space without being in conflict with multiple human activities in forested landscapes (DeFries *et al.*, 2007). In that sense, all guides made an effort to involve a wide variety of stakeholders in their creation. In turn, many targets (e.g., percentage of old forest and size of patches) appear to be more the result of a consensus among stakeholders than based on strong scientific knowledge. For example, there is no justification for maintaining 15% of the watershed in the old-growth stage considering that, in the United States, "the historical extent of old-growth forest in the Pacific Northwest was roughly two-thirds of the total land area (Strittholt *et al.*, 2006)." Lower levels could be justified if some threshold values for the maintenance of biodiversity or ecological function had been determined previously, but such information is often lacking and difficult to obtain. There is no doubt that involvement of various stakeholders is an important step forward in the democratization of forest management, but basic scientific information regarding ecological thresholds is also needed to reach EM objectives. We suggest applying the precautionary principle by emphasizing the importance of planning more permanent retention, such as large patches, corridors, and riparian buffers where no future harvest is permitted. Τηισ ρεχομμενδατιον ισ εϖεν μορε ιμπορταντ ιν αρεασ τηατ αρε δομινατεδ β ψ ινφρεθυεντ νατυραλ διστυρβανχεσ. Ωε αλσο μυστ ηιγηλιγητ τηε φαχτ τηατ ιτ χαν βε χηαλλενγινγ το ηαϖε α δεμοχρατιχ δεχισιον–μακινγ προχεσσ and at the same time make sound scientific decisions (Holmgren, 2012).

3.5.2.2 Spatial scale

Proposals that address management at various spatial scales are a significant advancement over past practices, which focused on the stand scale. However, the ecological significance of scales needs to be clearly addressed. For example, the use of the watershed to create management units, as implemented in the two western guides (CIT guide and NWFP), is better linked to natural processes. It is at the watershed-level that hydrological and geomorphological processes occur, such as the generation of sediment loads, erosion, and flooding (Hopwood, 1991). For other guides, in contrast, the determination of stand and landscape scales is based on traditional management scales which may have little ecological relevance. Indeed, the determination of scales is often not focused on when meeting ecological objectives, but it is based instead on logistical considerations. To follow the precepts of END, the management scale must be congruent with the dimensions of the natural disturbances being emulated (Perera *et al.*, 2004). Following this logic, the largest scale (region) that is used in the boreal forest should be large enough to cover the largest fire events, whereas in forest landscapes dominated by small-scale perturbations, such as coastal forests (Gavin *et al.*, 2003 ; Pearson, 2010), much smaller units could be used. Using appropriate scales that are based on ecological justifications (Christensen *et al.*, 1996) will help us to establish retention targets that are appropriate to the prevalent natural disturbances of the region. In that sense, the BG uses biogeoclimatic zones and the GFE, the ecodistrict zone, to determine the dominant natural disturbance. Subsequently, recommendations regarding retention elements should be modulated depending on the dominant disturbance in the biogeoclimatic or ecodistrict zone being evaluated.

Another weakness of the guides is that most of the targets are developed at only one spatial scale. Targeting various scales, as was proposed in the CIT and BG guides, is more likely to recreate the natural range of variability (Landres *et al.*, 1999). Indeed, all retention elements must be analyzed and planned at different scales to adequately represent all possible ranges of variability that are found in the landscape being managed (Lindenmayer, 2000). The lack of multi-scale approaches can lead to several problems concerning proposed strategies for these retention elements. Many phenomena such as connectivity are visible at different scales. Moreover, the interdependence of scales makes understanding of a phenomenon at one scale difficult (Levin, 1992).

For forest biota, connectivity is of the utmost importance in maintaining biodiversity across the territory (Bennett, 2003) and, thus, should not be managed at only one spatial scale. Management exclusively at the stand scale is not particularly useful, as scaling up can lead to homogenization at larger scales. The use of a riparian buffer that ensures connectivity within a territory is a good first step, but this approach needs to be complemented by strategies at larger scales. Furthermore, it cannot always be assumed that riparian reserves that are managed at the stand scale will be sufficiently numerous and dispersed across the landscape to fully link retention elements. Three guides have suggested, in addition to riparian reserves, the use of corridors to ensure landscape connectivity. Probably the most highly developed proposition concerning connectivity is the Forest Ecosystem Network that is described in the BG guide. It is the only strategy that places emphasis on connectivity among all retention elements at both the scale of the landscape and that of the biogeoclimatic zone.

3.5.2.3 Recommendations

Following the comparison of the five guides, we have made a number of proposals (Table 3.4). First, a better effort should be made to clearly define the forest of reference. Also consideration of the effects of global change should be included in this determination. Second, the temporal and spatial scales that are used to develop strategies for retention elements should be made more explicit. More generally, there was variation in the guides in their coverage of END, and in temporal and spatial scales of retention. Some guides have more complete strategies than others concerning these issues (Table 3.3). Finally, we highlight (Table 3.4) the strategies that have been already proposed in some guides, and which address many of our concerns. In doing so, we hope to facilitate their use in future versions of guides or in guides that are currently being developed in other jurisdictions.

Tableau 3.4 Principal weaknesses identified in five EM guides from North America, together with proposals and existing strategies for addressing them

Weaknesses	Existing strategies (see Tables 3.2 and 3.3)	Proposals
Lack of details on the natural disturbance regime to recreate/emulate.	Only NDPE briefly discusses modelling.	An integration of pre-settlement, actual and future information (modelling) about the forest dynamic should be analyzed with the objective of basing our strategies on a more realistic forest of reference.The analysis of the forest of reference must be performed at various spatial and temporal scales. Global changes should be part of the modelling exercise.
Lack of emphasis on the temporal maintenance of retention	NDPE, GFE and NWFP proposed to ensure the recruitment of CWD and snags over multiple rotations. NWFP suggests avoiding management in green tree patches and riparian buffer. BG suggests creating reserves to complement protected areas.	Better planning for retention in time. Some components, other than protected area, need to stay longer than the first pass. The duration and choice of retention elements should be based on ecological considerations, (e.g., the needs of wildlife) and be based on the dominant natural disturbance. Rotation length should be inspired by natural disturbances when possible.
The determination of spatial scale is not always based on ecological considerations	GFE used the ecodistrict, BG the biogeoclimatic zone and the watershed is used by CIT and NWFP. These scales are more ecologically appropriate.	The determination of spatial scales should be based on ecological processes, like natural disturbance. For example, use of an ecological classification, the watershed, and the disturbance type to define the scales should be encouraged.
The analysis of each retention element is conducted at only one spatial scale	The BG and CIT proposed well integrated multi-scale approaches, including the Forest Ecosystem Network strategy by BG.	Set targets for each retention element at various spatial scales in order to help recreate the natural range of variability and avoid connectivity problems.

3.6 Conclusion

The implementation of EM strategies and guidelines in North America, as we have compared here among the five guides, is an important first step towards a more holistic approach to management. We are now far from past management strategies at the stand scale that dealt only with the production of timber. This review has highlighted many weaknesses where further improvements are required for the implementation of EM:

- The pre-settlement forest is usually chosen as the forest of reference, but the use of the pre-settlement forest does not take into account possible alterations in forest ecosystems due to global change. To address this problem, we suggest integrating notions of resilience and complexity with the historical portrait, together with modelling potential future conditions, for the creation of new guidelines. In doing so, we think that the forest will be more adaptable to the most likely outcomes of global change (Messier *et al.*, 2013).

- The lack of consideration of the temporal scale of retention is probably the single greatest weakness that is shared by most guides. It is essential to plan for much longer periods of time to ensure that retention elements fulfil their diverse ecological roles. This means that some retention elements need to be maintained over many rotations.

- No multi-scale approach that was proposed by any guide is sufficiently complete. A multi-scale management approach is critical in EM to maintain biodiversity and ecological processes within a given territory. Some good strategies are presented at different spatial scales, but improvements can still be made. For example, the scales chosen should be justified ecologically (e.g., use of watersheds) and targets for each retention element should be presented at various spatial scales (to avoid connectivity problems).

This review has focused on the ecological issues of EM, particularly retention elements, without addressing other concerns such as social or economic aspects. Clearly, these issues also affect the way in which EM is implemented and, thus, the role of socio-economic concerns should be treated in future evaluations.

CONCLUSION

4.1 Découvertes

La présente thèse apporte un éclairage nouveau sur les implications de la rétention forestière, en terme de besoins écologiques et sociaux, dans la mise en œuvre de l'aménagement écosystémique. À la lumière des résultats, il semble que la rétention forestière soit bel et bien un élément clé dans la mise en œuvre d'un mode de gestion plus durable des forêts. En effet, tel que démontré dans cette thèse, la rétention forestière rejoint à la fois des enjeux écologiques et sociaux. Le chapitre 1 démontre qu'une modification de la quantité de la rétention forestière à différentes échelles spatiales et sur une longue période de temps, comme en Finlande, influence le maintien de la biodiversité par une modification présumée des processus de dispersion et de persistance des espèces. Malgré qu'au Canada la situation soit moins préoccupante, des signes de changement dans la strate herbacée commencent à poindre. En effet, les mêmes traits de persistance que les traits des espèces sur la liste rouge en Finlande sont affectés ici même au Canada dans les plantations intensives. De plus, plusieurs genres, voire plusieurs espèces en danger en Finlande, se retrouvent dans nos forêts canadiennes (ex : *Botrychium virginianum, Calypso bulbosa, Cypripedium acaule, Monotropa hypopitys* et *Monotropa uniflora*).

Il est donc primordial que cette influence soit comprise de la société civile et particulièrement des gens impliqués plus étroitement dans les prises de décision concernant la forêt. À ce titre, les résultats du chapitre 2 suggèrent que la majorité des répondants à l'étude sont insatisfaits des pratiques de rétention et demandent plus de rétention forestière. Seule une partie des industriels considèrent qu'il y a suffisamment de rétention et que les pratiques sont satisfaisantes. Il est également encourageant de constater, grâce au chapitre 3, que les préoccupations pour la rétention forestière sont opérationnalisées par la mise en place de stratégies d'aménagement dans les guides analysés pour cette thèse.

À la lumière des résultats, il semble que les préoccupations pour la rétention forestière ont dépassé les limites du milieu scientifique et sont intégrées dans les priorités des parties prenantes impliquées dans le processus de décision relatif à la gestion forestière. Cependant, il est difficile de juger à partir des résultats de ce projet de recherche si cette prise en compte des enjeux liés à la rétention forestière est due à un transfert de connaissance du milieu scientifique vers le milieu civique ou à une réflexion découlant de leur propre expérience de la forêt. Le niveau d'éducation des parties prenantes et leurs habitudes à consulter des sources d'information scientifiques (articles scientifiques, avis scientifiques, etc.) laissent suggérer qu'ils intègrent dans leurs réflexions et leurs perceptions de la rétention des assises scientifiques. Les guides en aménagement écosystémique sont aussi bien supportés scientifiquement. D'ailleurs, autant les répondants à l'étude de cas que les guides en aménagement écosystémique supportent les fondements théoriques de la rétention forestière à plusieurs échelles de temps et d'espace, tel que présenté dans les travaux de Lindernmayer et Franklin (2002). Le choix d'opter pour l'émulation des perturbations naturelles pour planifier la rétention forestière est également signe que la science a percolé dans les milieux pratiques. C'est donc dire que certains concepts théoriques en écologie et en foresterie peuvent être intégrés dans la réflexion des parties prenantes concernant l'éménagement forestier. Toutefois, il faut interpréter ce résultat en tenant compte que les répondants à cette étude de cas étaient très éduqués.

Toutefois, l'opérationnalisation du maintien de la rétention à différentes échelles spatiales et temporelles semble poser des problèmes. Entre autres, les industriels qui ont répondu au sondage semblent réticents à laisser plus de rétention à diverses échelles spatiales et sur le long terme. Ils sont plutôt d'avis de venir récupérer cette rétention. L'aspect temporel de la rétention est également l'élément qui est le plus ignoré dans l'ensemble des guides en aménagement écosystémique. Il semble difficile d'opérationnaliser le maintien de la rétention forestière, autre que les aires protégées sur une période de temps supérieure à une révolution forestière. La forêt est encore de nos jours gérée sur des échelles de temps restreintes qui ne sont pas toujours compatibles avec les cycles naturels de perturbation. Cette lacune est symptomatique de la perception que nous avons de la nature. Il est à souhaiter que notre perception de la nature et du lien que nous entretenons avec cette dernière va continuer à évoluer. En tant que société nous avons déjà fait un bon bout de chemin en s'éloignant peu à peu de la vision essentiellement utilitariste de la nature qui était dominante au tout début de la foresterie. Comme le démontre cette étude, nous tendons vers une prise en compte de plus en plus grande de la valeur d'existence des forêts, tout en demeurant des utilisateurs de la ressource forestière.

Les résultats du chapitre 1 démontrent également que l'aspect temporel est très important pour la flore. Si, comme en Finlande par exemple, des considérations pour l'effet à long terme de l'accumulation des conséquences (ex. : ouverture fréquente de la canopée) des aménagements intensifs ne sont pas pris en compte dans la planification à de grandes échelles spatiales, cela risque de venir affecter le maintien de la biodiversité. L'enjeu de la conservation des espèces est parmi les priorités de la grande majorité des parties prenantes et occupe une place importante dans les guides en aménagement écosystémique. Il est donc essentiel d'opérationnaliser des stratégies pour maintenir dans le temps et l'espace la rétention forestière, et ce, à des échelles spatiales pertinentes écologiquement. Pour ce faire, l'émulation des perturbations naturelles et la modélisation des changements globaux sont probablement à l'heure actuelle le meilleur gage de référence.

Les trois chapitres qui présentent chacune des trois étapes menant à la mise en œuvre d'un concept théorique proposent que l'aménagement écosystémique et plus particulièrement la rétention forestière est un concept avec des bases scientifiques pertinentes (chapitre 1), qui sont comprises et acceptées par une majorité des parties prenantes sondées (chapitre 2) et qui est opérationnalisable (chapitre 3). Il faut toutefois préciser que l'opérationnalisation du concept pose plusieurs défis. Entre autres, les industriels ne veulent pas tous nécessairement augmenter la quantité de rétention en raison des contraintes financières, techniques et législatives que cela implique. En parallèle, les groupes de parties prenantes ont exprimé leur manque de confiance dans la volonté de l'industrie et du gouvernement de changer leurs pratiques. De plus, les stratégies proposées pour opérationnaliser le concept de rétention ne sont pas encore optimales (voir propositions du chapitre 3), particulièrement en ce qui concerne l'aspect temporel et la prise en compte des changements globaux dans les orientations concernant la forêt de référence.

Plusieurs théories en écologie et en sociologie sont sous-jacentes à ce projet de recherche et sont venues agrémenter la réflexion issue de l'analyse des résultats. Notamment, la théorie du filtre brute (Armstrong *et al.*, 2003) mise en œuvre par l'émulation des perturbations naturelles, la base théorique de Lindenmayer et Franklin selon laquelle l'aménagement forestier doit être réalisé à des échelles spatio-temporelles variées afin de maintenir la biodiversité (Lindenmayer et Franklin, 2002) . En sociologie la théorie des parties prenantes (Friedman et Miles, 2002) et la théorie de l'apprentissage social (Reed *et al.*, 2010) ont beaucoup alimenté les réflexions concernant le rôle des parties prenantes dans l'aménagement forestier. Mais sans contredit la théorie de la complexité est la seule qui couvre l'ensemble des facettes de l'aménagement forestier (Puettmann, 2011). La théorie de la complexité n'a pas été discutée explicitement dans les trois chapitres, mais est sous-jacente à la réflexion entreprise concernant la recherche de solutions concernant les problématiques soulevées par cette thèse. Par exemple, la théorie de la complexité suggère de maintenir des écosystèmes complexes (ici diverses formes de rétention à diverses échelles de temps et d'espace) pour en assurer la résilience (Puettmann *et al.*, 2009). De plus, elle suggère de faire intervenir une variété d'acteurs pour trouver des solutions innovantes aux problèmes de l'aménagement forestier (Lebel *et al.*, 2006). Certains auteurs étudiant la théorie de la complexité suggèrent également que les aménagements actuels doivent tenir compte non seulement des perturbations du passé, mais également des perturbations actuelles et futures (Messier *et al.*, 2013). Tous des aspects qui ont été abordés dans la thèse.

4.2 Limites

Les résultats obtenus dans le cadre de cette thèse présentent certaines limites. Tout d'abord, afin de renforcer la légitimité de la comparaison entre la Finlande et le Canada, il aurait été optimal de retrouver dans toutes les régions échantillonnées l'ensemble des différents niveaux d'intensification des forêts. Par exemple, en Finlande il aurait été optimal de pouvoir échantillonner des forêts régénérées naturellement, ce qui n'a pas été possible. Pour contrer ce problème des forêts régénérées naturellement à proximité, en Russie, auraient pu être utilisées. Dans le chapitre 1, la comparaison des deux régions repose sur la prémisse que des écosystèmes qui ont les mêmes processus peuvent être comparés, malgré qu'ils ne possèdent pas les mêmes espèces. Une validation de cette prémisse par des données terrain aurait bonifié l'étude. De plus, de grandes différences dans la fertilité des sols ont possiblement influencé les résultats. En effet, les plantations au Canada étaient très fertiles comparativement aux autres sites. En Finlande également, les sites n'étaient pas tous issus de la même classe de fertilité. Il aurait été bien de mieux contrôler cette variable.

Le chapitre 2 est une étude de cas avec un nombre restreint de répondants, ce qui limite la portée des conclusions à l'aire d'étude couverte par le questionnaire. Il n'est pas possible de généraliser les résultats car l'échantillon n'est pas probabiliste. Il aurait été intéressant de pouvoir comparer les préférences des parties prenantes dans les diverses régions du Québec, voire dans d'autres provinces canadiennes. Pour ce faire, le questionnaire aurait pu être envoyé à l'ensemble des tables de concertation du Québec. Il se peut que des tendances régionales aient émergé d'une étude plus étendue. Toutefois, il est difficile de convaincre des bénévoles qui consacrent déjà beaucoup de temps à préparer et assister aux tables de concertation de passer 20 à 30 minutes à remplir un questionnaire. Le questionnaire aurait pu être davantage ciblé et ne pas dépasser plus de 15 minutes, ce qui aurait grandement diminué les abandons. Le taux de réponse est sous les valeurs généralement rencontrées pour des questionnaires internet, de l'ordre de plus de 50% (Dillman, 2007). Les questions concernant la proximité des parties prenantes avec les projets de recherche dans leur région auraient pu être enlevées, puisqu'elles n'ont pas été traitées. Elles avaient été créées pour voir des différences régionales, mais le faible effectif de répondants au Témiscamingue n'a pas permis cette comparaison régionale. Des questions sur la manière selon eux d'améliorer les pratiques de rétention auraient été plus intéressantes. Ou encore des questions qui auraient permis de mieux comprendre l'importance de la rétention forestière comme priorité versus les autres enjeux, tel que le manque de pouvoir. Il est possible d'affirmer avec une certaine assurance à la lumière des résultats de cette étude que la rétention forestière est un enjeu important pour la majorité des répondants. Toutefois, l'étude ne permet pas de comprendre si la rétention forestière joue un rôle important au non comparativement aux autres enjeux. Les enjeux sont nombreux, car les besoins sont diversifiés, mais quelles parties prenantes et dans quelle mesure les différents groupes de parties prenantes influencent réellement la priorisation des enjeux?

Le dernier chapitre met en lumière certaines stratégies de rétention fortes intéressantes. Toutefois, l'analyse des guides ne permet pas de juger de leur réelle utilisation. La plupart des guides en aménagement écosystémique comprennent des lignes directrices pour aider les aménagistes. Ils n'ont pas force de loi. Il serait intéressant d'étudier leur réelle utilisation et de voir à quel point ils ont influencé les pratiques forestières des dernières années. Suite à leur création, les stratégies de rétention doivent passer une dernière étape avant d'être mises en œuvre sur le terrain, soit les décisions prises par les aménagistes forestiers qui sont les responsables des plans d'aménagement. Certaines études ont tenté d'évaluer le succès de la mise en œuvre du North West Forest Plan (Rapp, 2008). Il serait maintenant intéressant de faire de même pour les autres guides et de comparer l'efficacité des stratégies et les facteurs qui influencent positivement ou négativement leur mise en œuvre. De plus, la présente étude se limite à l'étude des guides. Par contre, plusieurs informations importantes concernant la rétention se retrouvent dans les lois, guides complémentaires et autres documents officiels qui n'ont pas été analysés pour cette thèse. Le questionnaire du chapitre 2 est basé en partie sur les grands constats du chapitre 3 (manque de considération pour la temporalité de la rétention, manque d'intégration des échelles, etc.). Toutefois, le lien aurait pu être encore plus fort en posant des questions sur l'opérationnalisation de l'émulation des perturbations naturelles et le maintien de la rétention forestière.

4.3 Propositions

L'étude sur l'impact du gradient d'aménagement sur les traits fonctionnels est intéressante, mais permet seulement d'observer les différences sans pouvoir les expliquer par des processus. Un portrait général des éléments de rétention entre les régions est décrit. Il aurait été intéressant de pousser plus loin la description des éléments de rétention (vieille forêt, massif, connectivité et aires protégées), surtout à l'échelle du paysage. Une description plus fine du lien entre la variation dans la quantité, la répartition et la qualité de la rétention dans le temps et l'espace et les variations dans les facteurs environnementaux (lumière, température, humidité, etc.) permettrait de mieux comprendre les processus qui sont à l'origine des changements observés. Une telle étude demanderait des dispositifs expérimentaux suivis sur une longue période de temps, où les huit éléments de rétention seraient contrôlés en terme de qualité, de répartition et de quantité et où les facteurs environnementaux seraient mesurés fréquemment.

Certaines questions posées dans le questionnaire ont ouvert une porte à la réflexion. Il est dommage que dans le questionnaire la question du rôle des institutions locales ou de la confiance par exemple n'ait pas été davantage abordée, afin de faire le lien avec leur appui apparent aux questions de rétention forestière. En d'autres mots, ils peuvent bien promouvoir plus de rétention forestière, mais ont-ils le pouvoir d'agir? Vu les règles de gouvernance des tables GIRT, qui ne donnent pas de pouvoir décisionnel aux participants, il est possible de penser que la volonté politique soit centrale dans l'atteinte de l'acceptabilité des parties prenantes. Si le lien de confiance est mince entre les parties prenantes et les aménagistes, il est fort à penser que la confiance des parties prenantes est fonction de la reconnaissance de leurs recommendations (entre autres plus de rétention) dans les plans d'aménagement. Donc, dans ce cas il serait très important que les instances gouvernementales soient conscientes de cela dans l'élaboration des plans d'aménagement. Une perte de confiance des parties prenantes envers le processus décisionnel peut être néfaste pour la résilience du socio-écosystème car elle peut conduire à une diminution de la diversité des acteurs dans le processus. Une diversité des acteurs, des idées et des intérêts défendus contribue à s'adapter et/ou résister à des perturbations car elle influence positivement la capacité d'innovation et de renouvellement du système (Lebel *et al.*, 2006). Un des objectifs de l'aménagement durable des forêts est de favoriser la participation du plus grand nombre d'acteurs. Les résultats de la présente étude démontrent qu'une grande variété d'acteurs sont actuellement impliqués dans la gestion intégrée des forêts, mais tout porte à croire que leur engagement peut être fragilisé si le lien de confiance est miné. Il est donc recommandé pour une saine gestion des forêts de se préoccuper du maintien et de l'amélioration de ce lien de confiance. Cette recommandation est universelle et peut s'appliquer au processus de gestion intégrée en général.

Le second chapitre soulève une question intéressante : est-ce qu'une grande diversité d'acteurs impliqués dans le processus de décision concernant l'élaboration de stratégies forestières favorisera une priorisation des besoins écologiques? La présente thèse met la table pour répondre à cette question sans le faire. Pour tester cette hypothèse, un gradient allant d'une planification forestière très centralisée (gouvernement) à une planification forestière locale impliquant de multiples parties prenantes (ex. : "community forest") pourrait être comparé sur la base des trois étapes expliquées dans cette thèse : sur le désir des participants à prioriser les besoins écologiques; sur l'analyse des stratégies d'aménagement concrètes décidées par ces derniers et finalement par un suivi sur le long terme de l'implication des décisions prises concernant la rétention forestière sur le maintien de la biodiversité (intégrité écologique). Pour ce faire, un questionnaire semblable à celui utilisé pour cette thèse pourrait être envoyé aux personnes qui ont été impliquées dans l'élaboration de guides en aménagement écosystémique et/ou encore impliquées dans une "community forest", ainsi qu'aux parties prenantes (gouvernement et industries) impliquées dans un mode de gestion traditionnel plus centralisateur. Un tel projet pourrait être novateur et potentiellement renforcer l'argument selon lequel une diversité d'acteurs stabilise le socio-écosystème.

Le passage de la foresterie conventionnelle à l'aménagement écosystémique pose la question du suivi. L'objectif poursuivi par la nouvelle foresterie n'étant plus uniquement la production du bois, mais étant maintenant multiple (objectifs écologiques et sociaux), il faut dorénavant élaborer des méthodes de suivi qui seront en mesure de rendre compte des changements, non pas seulement de la production de matière ligneuse mais également des changements de biodiversité et dans les communautés humaines (Blumenthal et Jannink, 2000). Les suivis sont primordiaux et une emphase importante est mise sur les suivis dans les guides en aménagement écosystémique analysés pour cette thèse. Sans planification de suivis rigoureux et systématiques, comment savoir si les objectifs fixés par l'aménagement écosystémique seront rencontrés (ex : maintenir des populations viables in situ de l'ensemble des espèces indigènes et accommoder les besoins humains et leur occupation du territoire à l'intérieur de ces contraintes), entre autres, l'effet de plus de rétention. Malheureusement, le nouveau régime forestier au Québec ne semble pas mettre beaucoup d'importance, pour l'instant, sur les suivis humain et écologique.

Le défi soulevé par cette thèse, à savoir : analyser les aspects écologiques et sociaux de la mise en œuvre d'un concept théorique, soit la rétention forestière dans un contexte d'aménagement écosystémique, contribue à une vision plus complète des dynamiques forestières. Trois grands messages issus de chacune des étapes menant à la mise en œuvre du concept théorique de la rétention forestière sont à retenir pour améliorer la gestion des forêts.

- Tout d'abord, attention à l'intensification, car il y a un risque de perdre des espèces plus sensibles qui ont des traits de persistance. Ces espèces évoluent dans des milieux stables et apparaissent vers la fin de la succession forestière. Avec l'intensification, la forêt est modifiée tous les 30 ans environ en forêt boréale ce qui change les conditions environnementales et filtre négativement les espèces de fin de succession.

- De plus, malgré que la majorité des parties prenantes interrogée supportent les principes théoriques concernant la rétention forestière, il y a encore présence de visions opposées quant à sa mise en œuvre, soit le statut quo et un désir d'améliorer les pratiques de rétention.

- Et finalement, malgré la présentation de plusieurs stratégies novatrices, les guides en aménagement écosystémique discutent trop peu de temporalité de la rétention forestière. Il y a également une réticence de la part de certains répondants de modifier les pratiques forestières, afin de laisser des éléments de rétention forestière sur plus d'une rotation de coupe.

Peu importe où une gestion forestière est pratiquée, il serait important de valider ces trois éléments. Le concept de rétention forestière est un concept qui fait le lien entre les considérations économiques, écologiques et sociales et qui peut s'appliquer dans tous les types de forêt. Il est illusoire de penser comprendre la complexité de l'écosystème forestier sans y inclure la dimension humaine. Comme il a été démontré dans cette thèse, au final ce sont des considérations humaines qui dictent grandement l'avenir de la forêt.

APPENDICE A

gLOSAIRE DES CONCEPTS

Aménagement écosystémique: Définie comme l'interface entre les connaissances scientifiques à propos de l'écosystème et l'aménagement des valeurs socio-politiques avec comme but la protection de l'intégrité naturelle des écosystèmes sur le long terme (modifié de (Grumbine, 1994)).

Rétention forestière: Dans ce document est considéré comme de la rétention forestière, tout élément naturel retrouvé à une ou plusieurs échelles spatiales qui sera maintenu pour un certain temps dans la matrice forestière, après une coupe ou une perturbation naturelle. Cela inclut : Bois mort au sol, chicots, arbres vivants, corridors, bandes riveraines, larges ilots, vieilles forêts et aires protégées.

Résilience: Définie comme la capacité d'un système à absorber et/ou s'adapter aux perturbations et persister dans le temps (même structures, fonctions et capacité d'innovation et renouvellement) (modifié de (Holling, 1973 ; Lebel *et al.*, 2006)).

Traits fonctionnels: Définis comme "des traits morpho-physio-phénologiques mesurables qui ont un impact indirect sur le "fitness" via leurs effets sur la croissance, la reproduction et la survie d'un individu" (Violle *et al.*, 2007).

Partie prenante ("stakeholder"): "Tout groupe ou individu qui est affecté ou qui peut affecter l'achèvement des objectifs d'une organisation" (Freedman et McVea, 2001). Dans ce cas-ci, toute personne impliquée dans le processus décisionnel concernant la gestion des ressources forestières.

Apprentissage social ("Social learning"): Défini comme "un processus de changement social dans lequel les gens apprennent les uns des autres par des moyens qui peuvent bénéficier au système socio-écologique" (Reed *et al.*, 2010). Les gens apprennent de leurs interactions avec l'environnement et avec les autres participants (Muro et Jeffrey, 2008).

Système socio-écologique ("social-ecological system" (SES)) : "Consiste en une unité bio-géo-physique et ses acteurs et institutions associés. Les systèmes socio-écologique sont complexes et adaptatifs délimités par des limites géographiques ou fonctionnelles entourant des écosystèmes particuliers et leurs problématiques " (Glaser *et al.*, 2012).

APPENDICE B

Questionnaire du chapitre 3

Ce questionnaire porte sur les priorités et valeurs associées à la forêt, et plus particulièrement à la rétention forestière, ce qui signifie, tout ce qui n'est pas prélevé suite à l'aménagement forestier. Cela inclus: le bois mort au sol, les chicots, les îlots, les massifs, les aires protégées, les bandes riveraines, les corridors et les vieilles forêts. Nous voulons mieux comprendre quelles sont les divergences entre les priorités et valeurs des parties prenantes et celles des scientifiques, afin de mieux intégrer de part et d'autres les priorités et valeurs de chacun.

De plus, le manque de transfert des connaissances issue de la science est souvent décrié par les utilisateurs de la forêt. Par cette recherche nous tentons de mieux comprendre comment s'effectue ce transfert des connaissances et quelles sont les lacunes. Votre participation est cruciale dans l'atteinte de l'objectif premier de ce questionnaire qui est de favoriser les interactions entre le développement des connaissances scientifiques et leur utilisation lors de la mise en œuvre de stratégies d'aménagement.

Ce questionnaire comporte 5 parties:

Partie 1: Priorités et valeurs associées à la forêt
Partie 2: Priorités et valeurs associées à la rétention forestière
Partie 3: Familiarité avec la recherche
Partie 4: Utilisation de la forêt
Partie 5: Données socio-économiques

Le questionnaire prend environ 20 min à compléter et vous avez jusqu'au 25 janvier 2013 pour le remplir. Une fois le questionnaire terminé, il nous sera acheminé automatiquement par voie électronique.

N'oubliez pas qu'il n'y a pas de bonnes ou de mauvaises réponses; choisissez les réponses qui résument bien votre situation ou votre opinion.

Page de consentement

AVANTAGES, RISQUES ET DÉSAVANTAGES: D'un point de vue individuel, participer à cette recherche vous permettra d'exprimer vos priorités et valeurs en termes d'aménagement forestier et de participer à un dialogue entre scientifiques et acteurs du milieu. Plus généralement, votre participation nous permettra de mieux comprendre les différences et points communs entre les priorités et valeurs des scientifiques et ceux des parties prenantes. Elle permettra également de proposer des pistes de solutions pour améliorer les transferts de connaissances d'un milieu à l'autre. Aucune rémunération ou compensation d'aucune sorte n'est associée à votre participation. Participer à cette recherche ne présente pas de risque ou de désavantage.

DROIT DE RETRAIT: Votre participation reste complètement volontaire. Vous pouvez vous retirer à n'importe quel moment par une annonce verbale, sans préjudice et sans avoir à justifier votre décision. Si vous décidez de vous retirer, vous pouvez communiquer avec la représentante par téléphone au numéro mentionné ci-bas. Si vous en décidez ainsi, les données récoltées lors de votre entretien seront détruites.

CONFIDENTIALITÉ ET DIVULGATION DES RÉSULTATS: Le questionnaire est anonyme. Votre identité ne pourra en aucun cas être relié aux résultats de ce questionnaire. Seuls les chercheurs mentionnés plus bas auront accès aux informations. Les données récoltées seront gardées sous format électronique seulement dans les ordinateurs de ces mêmes chercheurs. Ces résultats constitueront essentiellement une base pour des articles et présentations scientifiques. De plus, à la demande des utilisateurs des tables de concertation, une rencontre de diffusion des résultats pourra être organisée. Le CRSNG a participé au financement de ce projet de recherche.

APPROBATION ÉTHIQUE: Le Comité institutionnel d'éthique de la recherche avec des êtres humains de l'UQAM a approuvé le projet de recherche auquel vous allez participer (no 701551). Pour des informations concernant les responsabilités de l'équipe de recherche au plan de l'éthique de la recherche avec des êtres humains ou pour formuler une plainte, vous pouvez contacter la présidence du Comité, par l'intermédiaire de son secrétariat au numéro (514) 987-3000 # 7753 ou par courriel à CIEREH@UQAM.CA

Pour de plus amples renseignements vous pouvez contacter Cynthia Patry (Candidate au doctorat), Tel: 514-987-3000 poste 6936, patry.cynthia@courrier.uqam.ca.

Chercheurs également impliqués dans le projet:
Daniel kneeshaw, professeur à l'Université du Québec à Montréal, Tel: 514-987-3000 poste 4480, kneeshaw.daniel@uqam.ca,
Stephen Wyatt, professeur adjoint à l'Université de Moncton, campus d'Edmundston, Tel : 506-737-5373, stephen.wyatt@umoncton.ca.
Christian Messier, à l'Université du Québec à Montréal, Tel: 514-987-3000 poste 4009, messier.christian@uqam.ca

***1. En cliquant sur le bouton "ACCEPTER" au bas de la page vous déclarez; 1) avoir lu les informations ci-haut, 2) obtenu des réponses à vos questions sur votre participation y compris l'objectif, la nature, les risques, les avantages et désavantages de participer à cette recherche. Vous consentez librement à participer à cette recherche. Vous êtes conscient que vous pouvez vous retirer à n'importe quel moment sans préjudice et sans avoir à justifier votre décision.**

Pour débuter le questionnaire veuillez, S.V.P., cocher la case "ACCEPTER".

- ACCEPTER
- REFUSER

2. À quel(s) groupe(s) suivant(s) appartenez-vous? Cochez LA ou LES bonne(s) catégorie (s).

- Chercheur
- Membre d'une association de villégiateurs
- Villégiateurs sans être membre d'une association
- Membre d'une association de pêche, chasse ou plein-air
- Pratique la pêche, chasse ou plein-air sans être membre d'une association
- Membre d'une association ou organisme à but non lucratif en environnement
- Travailleur de l'industrie forestière en terre publique
- Travailleur de l'industrie forestière en terre privée
- Travailleur au sein d'une ZEC
- Membre d'une ZEC
- Membre d'une communauté autochtone
- Travailleur gouvernemental au sein du MRNF ou MDDEFP
- Travailleur gouvernemental au sein d'un autre ministère
- Travailleur d'une municipalité ou d'une MRC
- Pourvoyeur
- Travailleur du domaine récréotouristique
- Aucun de ces groupes

Autre (veuillez préciser)

3. Siégez-vous sur une table de concertation?

- Oui
- Non

4. Dans quelle région siégez-vous sur une table de concertation?

- Mauricie
- Témiscamingue

Autre (veuillez préciser)

Partie 1 : Priorités et valeurs associées à la forêt

5. En considérant la forêt au Québec, classez les utilisations suivantes par ordre d'importance. Cochez «1» à côté de l'utilisation que vous considérez comme la plus importante, «2» à côté de celle que vous classez au second rang, et ainsi de suite, jusqu'à ce que tous les énoncés aient été classés (de 1 à 5).

	1	2	3	4	5
Comme source d'emplois et de richesse économique					
Comme milieu de loisirs et de détente					
Comme milieu de protection pour l'eau, l'air et le sol					
Comme milieu de vie animale et végétale					
Comme source de gibier, de bois de chauffage, de petits fruits et autres produits forestiers non ligneux					

Partie 1 : Priorités et valeurs associées à la forêt

6. Selon vous, quelles sont les priorités concernant la gestion de la forêt. Veuillez cocher 4 des options suivantes que vous jugez les plus prioritaires.

- [ ] Création d'emplois
- [ ] Conservation
- [ ] Décentralisation (Gestion régionale)
- [ ] Gestion multi-ressources (pas seulement basé sur l'exploitation du bois)
- [ ] Générer des profits issue de l'exploitation de la forêt
- [ ] Développer de nouveaux produits forestiers transformés en région
- [ ] Améliorer l'accessibilité à la forêt, par plus de chemins forestiers carrossables
- [ ] Limiter la création de chemins en forêt
- [ ] Intégrer davantage les parties prenantes dans les décisions concernant la forêt

Autre (veuillez préciser)

7. Selon vous, qu'est-ce qui freine la mise en œuvre de vos priorités énoncées à la question précédente concernant la gestion des forêts ? Veuillez cochez (√) TOUS les éléments que vous jugez être un frein.

- [ ] Manque de données socio-économiques (Ex: emplois)
- [ ] Manque de données bio-physiques (Ex: volume de bois)
- [ ] Manque de données scientifiques (Ex: impacts des changements climatiques)
- [ ] Législations trop rigides
- [ ] Manque de moyens financiers
- [ ] Manque de volonté gouvernementale
- [ ] Manque de volonté de la part de l'industrie
- [ ] Manque de ressources en région (Ex: personnel qualifié)
- [ ] Rien ne freine la mise en œuvre

Autre (veuillez préciser)

Partie 1 : Priorités et valeurs associées à la forêt

8. Comment voyez-vous la forêt? Veuillez indiquer dans quelle mesure vous êtes en accord ou en désaccord avec CHACUNE des affirmations suivantes.

	Tout à fait en désaccord	En désaccord	Neutre	En accord	Tout à fait en accord	Ne sais pas
Les forêts nous permettent de nous sentir près de la nature.						
L'utilisation première des forêts devrait être la production de produits qui sont utiles à l'homme.						
Malgré que je ne visite pas les forêts aussi souvent que je l'aimerais, il est important de savoir que les forêts existent au Québec.						
Les forêts qui ne sont pas utilisées par l'homme sont un gaspillage de nos ressources naturelles.						
Les humains devraient avoir plus de respect et d'admiration pour nos forêts.						
Les forêts ressourcent l'esprit humain.						
Les nombreux usages de la forêt (foresterie, chasse, récréation, etc) devraient être réalisés sur le plus de forêts publics possible.						
Les forêts sont des endroits sacrées.						
Il est important de préserver nos forêts afin que les générations futures puissent jouir des mêmes bénéfices dont nous jouissons.						
Les forêts doivent être gérées pour répondre aux besoins du plus grand nombre de personnes possible.						
Les forêts donnent aux humains un sentiment de paix et de bien-être.						
Si les forêts ne sont pas menacées, nous devons les utiliser pour améliorer la qualité de vie des humains.						
Soustraire de l'exploitation forestière certaines forêts n'est pas souhaitable si cela implique une baisse dans les salaires ou une baisse dans le nombre d'emplois.						

Partie 2 : Priorités et valeurs associées à la rétentio...

Les questions relatives à la section 2 se réfèrent aux pratiques actuelles (avant 2013) d'aménagement de la sapinière et la pessière. Répondez selon vos impressions.

Partie 2 : Priorités et valeurs associées à la rétentio...

9. Veuillez indiquer dans quelle mesure vous trouvez que le pourcentage de territoires en aires protégées est satisfaisant ou non.

Dans le cadre de ce questionnaire une AIRE PROTÉGÉE est définis comme une zone géographiquement délimitée où l'exploitation minière et forestière est interdite et où l'objectif premier est la conservation. Par exemple, les ZEC ainsi que les réserves fauniques ne sont pas des aires protégées suivant cette définition.

- Très insatisfaisant
- Assez insatisfaisant
- Ni satisfaisant, ni insatisfaisant
- Assez satisfaisant
- Très satisfaisant
- Je ne sais pas

Partie 2 :Priorités et valeurs associées à la rétention...

10. Veuillez indiquer à quel point il est prioritaire pour vous d'augmenter le pourcentage de territoires en aires protégées.

- Non prioritaire
- Peu prioritaire
- Prioritaire
- Très prioritaire
- Je ne sais pas

Partie 2 : Priorités et valeurs associées à la rétentio...

11. Selon vous, qu'est-ce qui freine la mise en œuvre de l'augmentation du pourcentage de territoires en aires protégées? Veuillez cochez (√) TOUS les éléments que vous jugez être un frein.

- ☐ Manque de données socio-économiques (Ex: emplois)
- ☐ Manque de données bio-physiques (Ex: volume de bois)
- ☐ Manque de données scientifiques (Ex: impacts des changements climatiques)
- ☐ Législations trop rigides
- ☐ Manque de moyens financiers
- ☐ Manque de volonté gouvernementale
- ☐ Manque de volonté de la part de l'industrie
- ☐ Manque de ressources en région (Ex: personnel qualifié)
- ☐ Rien ne freine la mise en œuvre

Autre (veuillez préciser)

Partie 2 : Priorités et valeurs associées à la rétentio...

12. Veuillez indiquer dans quelle mesure vous trouvez que suite à une coupe, le pourcentage d'arbres vivants laissé sur le parterre de coupe est satisfaisant ou non.

- ○ Très insatisfaisant
- ○ Assez insatisfaisant
- ○ Ni satisfaisant, ni insatisfaisant
- ○ Assez satisfaisant
- ○ Très satisfaisant
- ○ Je ne sais pas

Îlot d'arbres vivants sur un parterre de coupe

Partie 2 : Priorités et valeurs associées à la rétentio...

13. Veuillez indiquer à quel point il est prioritaire pour vous d'augmenter le pourcentage d'arbres vivants laissés après coupe.

- Non prioritaire
- Peu prioritaire
- Prioritaire
- Très prioritaire
- Je ne sais pas

Partie 2 : Priorités et valeurs associées à la rétentio...

14. Selon vous, qu'est-ce qui freine la mise en œuvre de l'augmentation du pourcentage d'arbres vivants laissés après coupe? Veuillez cochez (√) TOUS les éléments que vous jugez être un frein.

- Manque de données socio-économiques (Ex: emplois)
- Manque de données bio-physiques (Ex: volume de bois)
- Manque de données scientifiques (Ex: impacts des changements climatiques)
- Législations trop rigides
- Manque de moyens financiers
- Manque de volonté gouvernementale
- Manque de volonté de la part de l'industrie
- Manque de ressources en région (Ex: personnel qualifié)
- Rien ne freine la mise en œuvre

Autre (veuillez préciser)

Partie 2 :Priorités et valeurs associées à la rétention...

15. Veuillez indiquer dans quelle mesure vous trouvez que les pratiques concernant le maintient des vieilles forêts est satisfaisant ou non.

Comme vous pouvez le voir sur la photo plus bas, une VIEILLE FORÊT est une forêt suffisamment âgée pour qu'une partie des arbres commencent à mourir et que des jeunes arbres commencent à pousser en sous-étage.

- Très insatisfaisant
- Assez insatisfaisant
- Ni satisfaisant, ni insatisfaisant
- Assez satisfaisant
- Très satisfaisant
- Je ne sais pas

Vieille forêt
Photo de Philippe Cadieux

Partie 2 :Priorités et valeurs associées à la rétention...

16. Veuillez indiquer à quel point il est prioritaire pour vous d'augmenter le pourcentage de vieilles forêts maintenues sur le territoire.

- Non prioritaire
- Peu prioritaire
- Prioritaire
- Très prioritaire
- Je ne sais pas

Partie 2 : Priorités et valeurs associées à la rétentio...

17. Selon vous, qu'est-ce qui freine la mise en œuvre du maintien d'un plus grand pourcentage de vieilles forêts sur le territoire? Veuillez cochez (√) TOUS les éléments que vous jugez être un frein.

- Manque de données socio-économiques (Ex: emplois)
- Manque de données bio-physiques (Ex: volume de bois)
- Manque de données scientifiques (Ex: impacts des changements climatiques)
- Législations trop rigides
- Manque de moyens financiers
- Manque de volonté gouvernementale
- Manque de volonté de la part de l'industrie
- Manque de ressources en région (Ex: personnel qualifié)
- Rien ne freine la mise en œuvre

Autre (veuillez préciser)

Partie 2 : Priorités et valeurs associées à la rétentio...

18. Veuillez indiquer dans quelle mesure vous trouvez que les pratiques actuelles concernant la connectivité du territoire sont satisfaisantes ou non.

Comme vous pouvez le voir sur la photo plus bas, la CONNECTIVITÉ représente le degré de liaison entre plusieurs îlots de forêt dans un paysage fragmenté.

- Très insatisfaisantes
- Assez insatisfaisantes
- Ni satisfaisantes, ni insatisfaisantes
- Assez satisfaisantes
- Très satisfaisantes
- Je ne sais pas

Paysage forestier fragmenté
Photo de JF Côté Bowater Produits Forestiers du Canada

Partie 2 : Priorités et valeurs associées à la rétentio...

19. Veuillez indiquer à quel point il est prioritaire pour vous d'améliorer les pratiques concernant la connectivité du territoire.

- Non prioritaire
- Peu prioritaire
- Prioritaire
- Très prioritaire
- Je ne sais pas

Partie 2 : Priorités et valeurs associées à la rétentio...

20. Selon vous, qu'est-ce qui freine l'amélioration des pratiques concernant la connectivité du territoire? Veuillez cochez (√) TOUS les éléments que vous jugez être un frein.

- Manque de données socio-économiques (Ex: emplois)
- Manque de données bio-physiques (Ex: volume de bois)
- Manque de données scientifiques (Ex: impacts des changements climatiques)
- Législations trop rigides
- Manque de moyens financiers
- Manque de volonté gouvernementale
- Manque de volonté de la part de l'industrie
- Manque de ressources en région (Ex: personnel qualifié)
- Rien ne freine la mise en œuvre

Autre (veuillez préciser)

Partie 2 : Priorités et valeurs associées à la rétentio...

21. Veuillez indiquer dans quelle mesure vous trouvez que les pratiques actuelles concernant les grands massifs forestiers sont satisfaisantes ou non.

Un MASSIF FORESTIER est définis par le MRN comme un territoire de plus de 30 km2, de forme compacte, qui contient plus de 70% de peuplements forestiers matures.

- Très insatisfaisantes
- Assez insatisfaisantes
- Ni satisfaisantes, ni insatisfaisantes
- Assez satisfaisantes
- Très satisfaisantes
- Je ne sais pas

Partie 2 : Priorités et valeurs associées à la rétentio...

22. Veuillez indiquer à quel point il est prioritaire pour vous d'améliorer les pratiques concernant les grands massifs forestiers.

- Non prioritaire
- Peu prioritaire
- Prioritaire
- Très prioritaire
- Je ne sais pas

Partie 2 : Priorités et valeurs associées à la rétentio...

23. Selon vous, qu'est-ce qui freine l'amélioration des pratiques concernant les grands massifs forestiers? Veuillez cochez (√) TOUS les éléments que vous jugez être un frein.

- Manque de données socio-économiques (Ex: emplois)
- Manque de données bio-physiques (Ex: volume de bois)
- Manque de données scientifiques (Ex: impacts des changements climatiques)
- Législations trop rigides
- Manque de moyens financiers
- Manque de volonté gouvernementale
- Manque de volonté de la part de l'industrie
- Manque de ressources en région (Ex; personnel qualifié)
- Rien ne freine la mise en œuvre

Autre (veuillez préciser)

Partie 2 : Priorités et valeurs associées à la rétentio...

24. Veuillez indiquer dans quelle mesure vous trouvez que les pratiques actuelles concernant les bandes riveraines sont satisfaisantes ou non.

Dans le cadre de ce questionnaire une BANDE RIVERAINE, telle que montrée sur la photo ci-dessous, est définis comme une zone de végétation qui est maintenue après coupe, d'une largeur variable (généralement 20 m) entre le milieu aquatique et le milieu terrestre.

- Très insatisfaisantes
- Assez insatisfaisantes
- Ni satisfaisantes, ni insatisfaisantes
- Assez satisfaisantes
- Très satisfaisantes
- Je ne sais pas

Bande riveraine

Partie 2 : Priorités et valeurs associées à la rétentio...

25. Veuillez indiquer à quel point il est prioritaire pour vous d'améliorer les pratiques concernant les bandes riveraines.

- Non prioritaire
- Peu prioritaire
- Prioritaire
- Très prioritaire
- Je ne sais pas

Partie 2 : Priorités et valeurs associées à la rétentio...

26. Selon vous, qu'est-ce qui freine l'amélioration des pratiques concernant les bande riveraines? Veuillez cochez (√) TOUS les éléments que vous jugez être un frein.

- Manque de données socio-économiques (Ex: emplois)
- Manque de données bio-physiques (Ex: volume de bois)
- Manque de données scientifiques (Ex: impacts des changements climatiques)
- Législations trop rigides
- Manque de moyens financiers
- Manque de volonté gouvernementale
- Manque de volonté de la part de l'industrie
- Manque de ressources en région (Ex: personnel qualifié)
- Rien ne freine la mise en œuvre

Autre (veuillez préciser)

Partie 2 : Priorités et valeurs associées à la rétentio...

27. Veuillez indiquer dans quelle mesure vous trouvez que les pratiques actuelles concernant le bois mort au sol sont satisfaisantes ou non.

Le BOIS MORT AU SOL est définis par le MRN comme tout arbre, branche ou déchet de coupe qui jonche le sol, en tout ou en partie, ainsi que les rameaux et les ramilles encore attachés à ces branches. On inclus aussi dans les débris ligneux, les arbres chablis, les souches de moins de 1.3 m de hauteur, les troncs ou billots décomposés ou non, et toute autre portion de tige arrachée lors d'une perturbation quelconque.

- Très insatisfaisantes
- Assez insatisfaisantes
- Ni satisfaisantes, ni insatisfaisantes
- Assez satisfaisantes
- Très satisfaisantes
- Je ne sais pas

Bois mort

Partie 2 : Priorités et valeurs associées à la rétentio...

28. Veuillez indiquer à quel point il est prioritaire pour vous d'améliorer les pratiques concernant le bois mort au sol.

- Non prioritaire
- Peu prioritaire
- Prioritaire
- Très prioritaire
- Je ne sais pas

Partie 2 : Priorités et valeurs associées à la rétentio...

29. Selon vous, qu'est-ce qui freine l'amélioration des pratiques concernant le bois mort au sol? Veuillez cochez (√) TOUS les éléments que vous jugez être un frein.

- Manque de données socio-économiques (Ex: emplois)
- Manque de données bio-physiques (Ex: volume de bois)
- Manque de données scientifiques (Ex: impacts des changements climatiques)
- Législations trop rigides
- Manque de moyens financiers
- Manque de volonté gouvernementale
- Manque de volonté de la part de l'industrie
- Manque de ressources en région (Ex: personnel qualifié)
- Rien ne freine la mise en œuvre

Autre (veuillez préciser)

Partie 2 : Priorités et valeurs associées à la rétentio...

30. Veuillez indiquer dans quelle mesure vous trouvez que les pratiques actuelles concernant les chicots sont satisfaisantes ou non.

Les CHICOTS sont définis par le MRN comme toute tige morte, sur pied, entière ou non, dont la plupart des racines restent attachées au sol.

- Très insatisfaisantes
- Assez insatisfaisantes
- Ni satisfaisantes, ni insatisfaisantes
- Assez satisfaisantes
- Très satisfaisantes
- Je ne sais pas

Chicot

Partie 2 : Priorités et valeurs associées à la rétentio...

31. Veuillez indiquer à quel point il est prioritaire pour vous d'améliorer les pratiques concernant les chicots.

- Non prioritaire
- Peu prioritaire
- Prioritaire
- Très prioritaire
- Je ne sais pas

Partie 2 : Priorités et valeurs associées à la rétentio...

32. Selon vous, qu'est-ce qui freine l'amélioration des pratiques concernant les chicots? Veuillez cochez (√) TOUS les éléments que vous jugez être un frein.

- Manque de données socio-économiques (Ex: emplois)
- Manque de données bio-physiques (Ex: volume de bois)
- Manque de données scientifiques (Ex: impacts des changements climatiques)
- Législations trop rigides
- Manque de moyens financiers
- Manque de volonté gouvernementale
- Manque de volonté de la part de l'industrie
- Manque de ressources en région (Ex: personnel qualifié)
- Rien ne freine la mise en œuvre

Autre (veuillez préciser)

Partie 2 : Priorités et valeurs associées à la rétentio...

33. Nous utilisons le terme « rétention forestière » pour englober plusieurs façons de maintenir les aires non-coupées lors d'une opération de récolte forestière, telles que les bandes riveraines, les aires protégées, les veilles forêts, etc. Veuillez indiquez dans quelle mesure vous êtes en accord ou en désaccord avec CHACUNE des affirmations suivantes.

	Tout à fait en désaccord	En désaccord	Neutre	En accord	Tout à fait en accord	Ne sais pas
Plus de rétention forestière est nécessaire.						
Plus de rétention forestière représente un frein à l'exploitation rentable des ressources de la forêt.						
Les aires protégées sont suffisantes pour maintenir la biodiversité.						
Seules les aires protégées devraient être conservées sur plusieurs rotations de coupe.						
Si les îlots ont été maintenus lors d'une récolte, il est acceptable de retourner pour les couper 20 ans plus tard						
Il est essentiel de planifier l'aménagement sur plus qu'une rotation de coupe afin de s'assurer que les éléments de rétention maintenus remplissent leur rôle écologiques.						
Une approche d'aménagement multi-échelle (temporelle et spatiale) est nécessaire pour maintenir la biodiversité et les processus écologiques.						
Les normes du régime forestier ne sont pas suffisamment flexibles et complètes pour maintenir la variabilité naturelle						
Il est préférable de diviser les unités d'aménagement selon les bassins versants.						

Partie 2 : Priorités et valeurs associées à la rétentio...

34. Veuillez indiquer dans quelle mesure vous êtes en accord ou en désaccord avec l'affirmation suivante:

"Il y a un problème de manque de confiance de la part de la population régionale envers les compagnies qui aménagent la forêt."

- Tour à fait en désaccord
- En désaccord
- Neutre
- En accord
- Tout à fait en accord
- Ne sais pas

Partie 2 : Priorités et valeurs associées à la rétentio...

35. Veuillez indiquer dans quelle mesure vous êtes en accord ou en désaccord avec l'affirmation suivante:

"Davantage de rétention forestière (i.e., plus d'aires protégées, conservation de vieilles forêts, laisser plus d'arbres vivants après coupe, etc) peut améliorer la confiance de la population régionale envers les compagnies qui aménagent la forêt."

- Tout à fait en désaccord
- En désaccord
- Neutre
- En accord
- Tout à fait en accord
- Ne sais pas

Partie 3: Familiarité avec recherche

36. Êtes-vous au courant si un projet collaboratif entre scientifiques et intervenants régionaux concernant la gestion forestière a eu cours dans votre région? Ou si vous êtes un chercheur, avez-vous déjà participé à un tel projet?

- Oui
- Non

Partie 3: Familiarité avec recherche

37. Quel est le nom de ce projet?

38. Quel est son objectif?

39. Avez-vous participé à des activités en lien avec ce projet (visites de terrain, conférences, colloques etc)?

- Oui
- Non

Partie 3: Familiarité avec recherche

40. Lors de ces activités avez-vous acquis de nouvelles connaissances?

- Oui
- Non

Partie 3: Familiarité avec recherche

41. Sur quels thèmes avez-vous acquis ces connaissances?

Partie 3: Familiarité avec recherche

42. Vos priorités en terme d'aménagement des forêts ont-elles été influencées par la participation à un tel projet collaboratif?

- Grandement influencées
- Légèrement influencées
- Pas vraiment influencées
- Pas du tout influencées
- Je ne sais pas

Partie 3: Familiarité avec recherche

43. Si vous avez besoin d'informations particulières, connaissez-vous un chercheur universitaire ou gouvernemental assez bien pour pouvoir lui téléphoner?

- Oui
- Non

Partie 3: Familiarité avec recherche

44. Quels types de sources tirez-vous vos informations par rapport à l'aménagement des forêts? Veuillez sélectionner TOUS les types de sources que vous consultez dans une année.

Communications institutionnelles................................Communications médiatiques et personnelles ....Communications scientifiques

- Site internet d'ONG environnemental (Greenpeace, etc.)
- Site internet gouvernemental (MRNF, MDDEP, etc.)
- Site internet d'industrie (Resolut, Tembec etc.)
- Site internet d'organismes régionaux
- Brochure corporative (Tembec, Resolut, etc.)
- Fiche technique
- Mémoire d'une consultation publique
- Rapport d'entreprise (Tembec, Resolut, etc.)
- Rapport gouvernemental (MRNF, MDDEP, etc.)
- Visite sur le terrain avec une institution

- Films documentaires (Erreur boréale, etc.)
- Livre
- Radio
- Télévision
- Journal régional
- Journal national (La Press, Le Soleil etc.)
- Collègues
- Patrons
- Amis/voisins
- Parenté

- Article scientifique
- Avis scientifique (rapport)
- Article de vulgarisation scientifique (Québec Science etc.)
- Site internet de vulgarisation scientifique
- Conférence scientifique
- Conférence de vulgarisation scientifique
- Visite sur le terrain avec un chercheur
- Ateliers scientifiques

Partie 3: Familiarité avec recherche

45. Veuillez indiquer dans quelle mesure vous êtes en accord ou en désaccord avec l'affirmation suivante.

"À chaque année, plusieurs millions de dollars sont dépensés en recherche dans le milieu forestier. Par contre, les résultats de ces recherches sont trop souvent méconnus par les utilisateurs potentiels de ces résultats"

- Tout à fait en désaccord
- En désaccord
- Neutre
- En accord
- Tout à fait en accord
- Ne sais pas

Partie 4 : Utilisation de la forêt

46. Veuillez cochez (√) TOUS les types de forêts que vous fréquentez habituellement au cours d'une année.

- ☐ Parcs provinciaux ou aires protégées
- ☐ Parcs fédéraux
- ☐ Forêts privées
- ☐ Terres publiques aménagées par les compagnies forestières
- ☐ Forêts situées à l'intérieur des limites municipales
- ☐ ZEC
- ☐ Je visite des forêts, mais je ne sais pas à qui elles appartiennent
- ☐ Aucune des options précédentes, je ne visite aucune forêt

Autres types de forêts (précisez s.v.p.)

Partie 4 : Utilisation de la forêt

47. Veuillez indiquer les activités que vous pratiquez habituellement en forêt au cours d'une année. Cochez (√) TOUTES les activités qui s'appliquent.

- ☐ Pique-nique
- ☐ Quatre roues ou VTT
- ☐ Ornithologie
- ☐ Canoë, kayak ou canotage de plaisance
- ☐ Camping
- ☐ Chasse
- ☐ Marche, randonnée pédestre
- ☐ Motoneige
- ☐ Ski
- ☐ Séjour dans un camp ou un chalet
- ☐ Pêche
- ☐ Je ne participe à aucune de ces activités

Autre(s) (précisez)

Parie 5 : Données socio-économiques

48. Quel est votre sexe ?

- Homme
- Femme

49. Quel est votre âge ?

- Moins de 25 ans
- 25–34 ans
- 35–44 ans
- 45–54 ans
- 55–64 ans
- 65–74 ans
- 75 ans ou plus

Parie 5 : Données socio-économiques

50. Êtes-vous :

- Travailleur à plein temps, à l'année longue
- Travailleur saisonnier à temps plein
- Travailleur à temps partiel, à l'année longue
- Travailleur saisonnier à temps partiel
- À la retraite

Autre (veuillez préciser)

Partie 5 : Données socio-économiques

51. Quel niveau d'études avez-vous atteint :

- Secondaire 5 non complété
- Secondaire 5 complété
- DEC au CEGEP
- Baccalauréat
- Diplôme d'études supérieures

52. Quel est votre revenu annuel avant impôt ?

- Moins de 20 000 $
- 20 000–$39 999 $
- 40 000–$59 999 $
- 60 000–$99 999 $
- 100 000 $ ou plus

53. Avez-vous des commentaires supplémentaires ou des préoccupations que vous aimeriez inscrire au sujet de la gestion des forêts ou plus particulièrement sur la rétention forestière (i.e., aires protégées, massifs, bois mort, etc)?

Fin du questionnaire

Merci d'avoir participé à ce sondage!

Si vous voulez connaître les résultats de ce sondage quand ils seront publiés, veuillez communiquer avec :

Cynthia Patry,
Candidate au doctorat en sciences de l'environnement,
Centre d'étude de la forêt
Université du Québec à Montréal
Case postale 8888, succ. Centre-ville,
Montréal (Qc)
Canada (H3C 3P8)
Téléphone: (506) 987-3000 poste 6936
Fax : 1-514-987-4647

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RÉFÉRENCES

Ahti, T., L. Hämet-Ahti et J. Jalas. 1968. «Vegetation Zones and Their Sections in Northwestern Europe». *Annales Botanici Fennnici.* vol. 5, p. 169-211.

Alexander, J.D., N.E. Seavy et P.E. Hosten. 2007. «Using conservation plans and bird monitoring to evaluate ecological effects of management: An example with fuels reduction activities in southwest Oregon». *Forest Ecology and Management.* vol. 238, no 1-3, p. 375-383.

Alvarez, E., L. Bélanger, L. Archambault et F. Raulier. 2011. «Portrait préindustriel dans un contexte de grande variabilité naturelle: une étude de cas dans le centre du Québec (Canada)». *Forestry Chronicle.* vol. 87, no 5, p. 612-624.

Ananda, J. 2007. «Implementing Participatory Decision Making in Forest Planning». *Environmental Management.* vol. 39, no 4, p. 534-544.

Andrea, J.L., et J.K. Vanclay. 2011. «Stakeholder engagement in social learning to resolve controversies over land-use change to plantation forestry». *Regional environmental change.* vol. 1, no 1, p. 175-190.

Andren, H. 1994. «Effects of habitat fragmentation on birds and mammals in landscapes with different proportions of suitable habitat: a review.». *Oikos.* vol. 71, p. 355-366.

Angers, V.A., C. Messier, M. Beaudet et A. Leduc. 2005. «Comparing composition and structure in old-growth and harvested (selection and diameter-limit cuts) northern hardwood stands in Quebec». *Forest Ecology and Management.* vol. 217, no 2-3, p. 275-293.

Archibald, D.J., W.B. Wiltshire, D.M. Morris et B.D. Batchelor. 1997. *Forest management guidelines for the protection of the physical environment,* version 1.0. Toronto, Ontario: Queen's Printer for Ontario, , Ontario Ministry of Natural Resources,42 p.

Armstrong, G.W., W.L. Adamowicz, J.A. Beck, S.G. Cumming et F.K.A. Schmiegelow. 2003. «Coarse filter ecosystem management in a nonequilibrating forest». *Forest Science.* vol. 49, no 2, p. 209-223.

Aubin, I., W. Bell, J. Dacosta, L. DeGrandpré, S. Gachet, F. Hébert, C. Messier, A. Munson, A. Paquette, M. Poulin, J.-P. Ricard, B. Shipley, L. Sirois, N. Thiffault et M. Vellend. 2012. «Traits of Plants in Canada (TOPIC)». Natural Resources Canada. En ligne. <http://topic.nrcan.gc.ca/>. Consulté le 2010.

Aubin, I., S. Gachet, C. Messier et A. Bouchard. 2007. «How resilient are northern hardwood forests to human disturbance? An evaluation using a plant functional group approach». *Ecoscience*. vol. 14, no 2, p. 259-271.

Aubin, I., C. Messier et A. Bouchard. 2008. «Can plantation develop understory biological and physical attributes of naturally regenerated forests». *Biological Conservation*. vol. 141, p. 2461-2476.

Aubin, I., M.-H. Ouellette, P. Legendre, C. Messier et A. Bouchard. 2009. «Comparison Q2 of two plant functional approaches to evaluate natural restoration along an old-field – deciduous forest chronosequence». *International Association for Vegetation Science*, p. 1-14.

Balmford, A., K.J. Gaston, S. Blyth, A. James et V. Kapos. 2003. «Global variation in terrestrial conservation costs, conservation benefits, and unmet conservation needs». *Proceedings of the National Academy of Sciences of the United States of America*. vol. 100, no 3, p. 1046-1050.

Bartemucci, P., C. Messier et C.D. Canham. 2006. «Overstory influences on light attenuation patterns and understory plant community diversity and composition in southern boreal forests of Quebec». *Canadian Journal of Forest Research*. vol. 36, no 9, p. 2065-2079.

Bartonova, A. 2012. «How can scientists bring research to use: The HENVINET experience». *Environmental Health: A Global Access Science Source*. vol. 11, no SUPPL.1.

Beckley, T., et D. Korber. 1995. «Sociology's potential to improve forest management and inform forest policy». *The Forestry Chronicle*. vol. 71, no 6, p. 712-719.

Beckley, T.M., P.C. Boxall, L.K. Just et A.M. Wellstead (1999). Forest stakeholder attitudes and values: selected social-science contributions. Can. For. Serv. Nat. Resour. Can., North. For. Cent.,. Edmonton, Alberta, Canadian Forest Service, Northern Forestry Centre. Information Report NOR-X-362.

Beese, W.J., et A.A. Bryant. 1999. «Effect of alternative silvicultural systems on vegetation and bird communities in coastal montane forests of British Columbia, Canada». *Forest Ecology and Management*. vol. 115, no 2-3, p. 231-242.

Beese, W.J., B.G. Dunsworth, K. Zielke et B. Bancroft. 2003. «Maintaining attributes of old-growth forests in coastal BC through variable retention». *Forestry Chronicle*. vol. 79, no 3, p. 570-578.

Bengston, D.N. 1994. «Changing forest values and ecosystem management». *Society and Natural Resources*. vol. 7, p. 515-533.

Bengston, D.N., G. Xu et D.P. Fan. 2001. «Attitudes Toward Ecosystem Management in the United States, 1992-1998». *Society & Natural Resources*. vol. 14, no 6, p. 471 - 487.

Bengtsson, J., S.G. Nilsson, A. Franc et P. Menozzi. 2000. «Biodiversity, disturbances, ecosystem function and management of European forests». *Forest Ecology and Management*. vol. 132, p. 39-50.

Bennett, A.F. 2003. *Linkages in the landscape the role of corridors and connectivity in wildlife conservation*: IUCN, Gland, Switzerland and Cambridge, UK, 254 p.

Bergeron, Y., D. Cyr, C.R. Drever, M. Flannigan, S. Gauthier, D. Kneeshaw, E. Lauzon, A. Leduc, O. Le Goff, D. Lesieur et K. Logan. 2006. «Past, current, and future fire frequencies in Quebec's commercial forests: implications for the cumulative effects of harvesting and fire on age-class structure and natural disturbance-based management». *Canadian Journal of Forest Research*. vol. 36, no 11, p. 2737-2744.

Bergeron, Y., et M.D. Flannigan. 1995. «Predicting the effects of climate change on fire frequency in the southeastern Canadian boreal forest». *Water, Air, & Soil Pollution*. vol. 82, no 1, p. 437-444.

Bergeron, Y., A. Leduc, B.D. Harvey et S. Gauthier. 2002. «Natural fire regime: A guide for sustainable management of the Canadian boreal forest». *Silva Fennica*. vol. 36, no 1, p. 81-95.

Bernhardt-Römermann, M., A. Gray, A.J. Vanbergen, L. Berges, A. Bohner, R.W. Brooker, L.D. Bruyn, B.D. Cinti8, T. Dirnbock, U. Grandin, A.J. Hester, R. Kanka, S. Klotz, G. Loucougaray, L. Lundin, G. Matteucci, I. Meszaros, V. Olah, E. Preda, B. Prevosto, J. Pykälä, W. Schmidt, M.E. Taylor, A. Vadineanu, T. Waldmann et J. Stadler. 2011. «Functional traits and local environment predict vegetation responses to disturbance: a pan-European multi-site experiment». *Jounal of ecology*. vol. 99, p. 777-787.

Berry, J., G.D. Brewer, J.C. Gordon et D.R. Patton. 1998. «Closing the gap between ecosystem management and ecosystem research». *Policy Sciences* vol. 31, no 1, p. 55-80.

Betts, M., et G. Forbes. 2005. *Forest Management Guidelines to Protect Native Biodiersity in the Greater Fundy Ecosystem*, 2e. Fredericton, NB: New Brunswick Co-operative Fish and Wildlife Research Unit, University of New Brunswick.

Blanchet, P. 2010. «Les conflits d'usage du domaine public et les débuts de la foresterie scientifique au Québec: 1867-1936». *Le Naturaliste Canadien*. vol. 134, no 1, p. 62-69.

Blumenthal, D., et J.L. Jannink. 2000. «A classification of collaborative management methods». *Conservation Ecology*. vol. 4, no 2, p. 13.

Bock, M.D., et K.C.J. Van Rees. 2002. «Forest harvesting impacts on soil properties and vegetation communities in the Northwest Territories». *Canadian Journal of Forest Research*. vol. 32, no 4, p. 713-724.

Botting, R.S., et C. DeLong. 2009. «Macrolichen and bryophyte responses to coarse woody debris characteristics in sub-boreal spruce forest». *Forest Ecology and Management*. vol. 258, no SUPPL.

Boucher, Y., D. Arseneault, L. Sirois et L. Blais. 2009. «Logging pattern and landscape changes over the last century at the boreal and deciduous forest transition in Eastern Canada». *Landscape Ecology*. vol. 24, no 2, p. 171-184.

Bourgeois, L., D. Kneeshaw, L. Imbeau, N. BÃ©langer, S. Yamasaki et S. Brais. 2007. «How do Alberta's, Ontario's and Quebec's forest operation laws respect ecological sustainable forest management criteria in the boreal forest?». *The Forestry Chronicle*. vol. 83, no 1, p. 61-71.

Bouthillier, L. 2011. «Histoire et évolution de la foresterie au Québec : la gestion forestière au Québec, une histoire à raconter». Institut hydro-Québec en environnement, développement et société (EDS). En ligne. <http://www.ihqeds.ulaval.ca/14501.html?&no_cache=1&tx_ttnews[tt_news]=722&tx_ttnews[cat]=130>. Consulté le 19 janvier 2013.

Bradbury, S. 2004. «Understorey plant communities in boreal cutblocks with different sizes and numbers of residual tree patches». *Canadian Journal of Forest Research*. vol. 34, no 6, p. 1220-1227.

Brandt, J.P. 2009. «The extent of the North American boreal zone». *Environ. Rev*. vol. 17, p. 101-161.

Brumelis, G., et T.J. Carleton. 1989. «The vegetation of post-logged black spruce lowlands in central Canada. II. Understorey vegetation». *Journal of Applied Ecology*. vol. 26, no 1, p. 321-339.

Brunner, R.D., et T.W. Clark. 1997. «A practice-based approach to ecosystem management». *Conservation Biology*. vol. 11, no 1, p. 48-58.

Brunson, M.W. 1996. «A definition of "Social Acceptability" in ecosystem management». In *Defining social acceptability in ecosystem management: a workshop proceedings,* Linda E. Kruger Brunson Mark W., Catherine B. Tyler, Susan A. Schroeder. Departement of Agriculture, Forest Service, Pacific Northwest Research Station, p. 7-17. Portland: Diane Publishing Co.

Brunson, M.W., L.E. Kruger, T.C. B. et J.A. Schaefer. 1992. *Defining social acceptability in ecosystem management: a workshop proceedings*. Portland: Departement of Agriculture, Forest Service, Pacific Northwest Research Station, 142 p.

Butler, K.F., et T.M. Koontz. 2005. «Theory into practice: Implementing ecosystem management objectives in the USDA Forest Service». *Environmental Management*. vol. 35, no 2, p. 138-150.

Byron, C., D. Bengtson, B. Costa-Pierce et J. Calanni. 2011. «Integrating science into management: Ecological carrying capacity of bivalve shellfish aquaculture». *Marine Policy*. vol. 35, no 3, p. 363-370.

Cajander, A.K. 1926. «The theory of forest types». *Acta Forestalia Fennica*. vol. 29, p. 1-108.

Cardinal, L., et C. Andrew. 2000. *La démocratie à l'épreuve de la gouvernance*, Les presses de l'Université d'Ottawa. Ottawa: Les presses de l'Université d'Ottawa 240 p.

Cardinale, B.J., J.E. Duffy, A. Gonzalez, D.U. Hooper, C. Perrings, P. Venail, A. Narwani, G.M. Mace, D. Tilman, D.A. Wardle, A.P. Kinzig, G.C. Daily, M. Loreau, J.B. Grace, A. Larigauderie, D.S. Srivastava et S. Naeem. 2012. «Biodiversity loss and its impact on humanity». *Nature*. vol. 486, no 7401, p. 59-67.

Carleton, T.J., et P. Maclellan. 1994. «Woody vegetation responses to fire versus clear-cutting logging: a comparative survey in the central Canadian Boreal forest». *Ecoscience*. vol. 1, no 2, p. 141-152.

CCMF. 2003. «Définir l'aménagement forestier durable au Canada: Critères et indicateurs». En ligne. <www.ccmf.org/ci/CI_Booklet_f.pdf>. Consulté le 27 novembre.

Chapple, R., D. Ramp, R. Bradstock, R. Kingsford, J. Merson, T. Auld, P.S. Fleming et R. Mulley. 2011. «Integrating Science into Management of Ecosystems in the Greater Blue Mountains». *Environmental Management*. vol. 48, no 4, p. 659-674.

Chiasson, G., et É. Leclerc. 2013. *La gouvernance locale des forêts publiques québécoise: Une avenue de développement des régions périphériques?* Québec: Presses de l'Université du Québec, 252 p.

Christensen, N.L., A.M. Bartuska, J.H. Brown, S. Carpenter, C. Dantonio, R. Francis, J.F. Franklin, J.A. MacMahon, R.F. Noss, D.J. Parsons, C.H. Peterson, M.G. Turner et R.G. Woodmansee. 1996. «The report of the Ecological Society of America committee on the scientific basis for ecosystem management». *Ecological Applications*. vol. 6, no 3, p. 665-691.

Cissel, J.H., F.J. Swanson et P.J. Weisberg. 1999. «Landscape management using historical fire regimes: Blue River, Oregon». *Ecological Applications*. vol. 9, no 4, p. 1217-1231.

Coast Information Team (2004). Ecosystem-based management planning handbook. Victoria, Coast Information Team: 88 p

Commonwealth Forestry Association (2010). Commonwealth Forests 2010: An overview of the forests and forestry sectors of the countries of the Commonwealth. Craven Arms, Commonwealth Forestry Association: 183 p

Conférence régionale des élus de la Mauricie (2010). Règles et modalités de fonctionnement des tables de gestion intégrée des ressources et du territoire (TGIRT): Région de la Mauricie, Conférence régional des élus: 24 p

Cools, N., et B. DeVos (2010). Sampling and Analysis of Soil. Manual Part X. In: Manual on methods and criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on forests. ICP Forests UNECE. Hamburg: 208 p

Coulombe, G., J.A. J. Huot, E. Beauce, J.-T. Bernard, A. Bouchard, M.A. Liboiron et G. Szaraz. 2004. *Rapport de la Commission d'étude sur la gestion de la forêt publique québécoise*: Bibliothèque nationale du Québec p.

Craig, A., et S.E. Macdonald. 2009. «Threshold effects of variable retention harvesting on understory plant communities in the boreal mixedwood forest». *Forest Ecology and Management*. vol. 258, no 12, p. 2619-2627.

Crête, M., S. Brais, M. Campagna, M. Darveau, M. Desponts, S. Déry, P. Drapeau, B. Drolet, J.-P. Jetté, C. Maisonneuve, A. Nappi et P. Petitclerc. 2004. *Pourquoi et comment maintenir du bois mort dans les forêts aménagées du Québec. Avis scientifique.* : gouvernement du Québec, Société de la faune et des parcs du Québec: Direction du développement de la faune et Ministère des Ressources naturelles du Québec: Direction de l'environnement forestier,35 p.

Crites, S., et M.R.T. Dale. 1998. «Diversity and abundance of bryophytes, lichens, and fungi in relation to woody substrate and successional stage in aspen mixedwood boreal forests». *Canadian Journal of Botany*. vol. 76, no 4, p. 641-651.

Crona, B., et Ö. Bodin. 2006. « What you know is who you know? Communication patterns among resource users as a prerequisite for co-management». *Ecology and Society*. vol. 11, no 2, p. 7.

Cyr, D., S. Gauthier, Y. Bergeron et C. Carcaillet. 2009a. «Forest management is driving the eastern North American boreal forest outside its natural range of variability». *Frontiers in Ecology and the Environment*. vol. 7, no 10, p. 519-524.

Cyr, D., S. Gauthier, Y. Bergeron et C. Carcaillet. 2009b. «Forest management is driving the eastern North American boreal forest outside its natural range of variability». *Frontiers in Ecology and the Environment; Research communications.*

Daily, B.F., et S. Huang. 2001. «Achieving sustainability through attention to human resource factors in environmental management». *International Journal of Operations & Production Management.* vol. 21, no 12, p. 1539-1552.

Dale, V.H., A.E. Lugo, J.A. MacMahon et S.T.A. Pickett. 1998. «Ecosystem management in the context of large, infrequent disturbances». *Ecosystems.* vol. 1, no 6, p. 546-557.

Darveau, M., et A. Desrochers. 2001. «Le bois mort et la faune vertébrée: état des connaissances au Québec». Ministère des Ressources Naturelles. Québec: Gouvernement du Québec.

De Graaf, M., et M.R. Roberts. 2009. «Short-term response of the herbaceous layer within leave patches after harvest». *Forest Ecology and Management.* vol. 257, p. 1014-1025.

De Grandpré, L., L. Archambault et J. Morissette. 2000. «Early understory successional changes following clearcutting in the balsam fir-yellow birch forest». *Ecoscience.* vol. 7, no 1, p. 92-100.

De Grandpré, L., D. Gagnon et Y. Bergeron (1993). Changes in the understory of Canadian southern boreal forest after fire, Blackwell Publishing Ltd. 4: 803-810 p

Deal, R.L. 2001. «The effects of partial cutting on forest plant communities of western hemlock - Sitka spruce stands in southeast Alaska». *Canadian Journal of Forest Research.* vol. 31, no 12, p. 2067-2079.

Deans, A.M., J.R. Malcolm, S.M. Smith et T.J. Carleton. 2003. «A comparison of forest structure among old-growth, variable retention harvested, and clearcut peatland black spruce (Picea mariana) forests in boreal northeastern Ontario». *Forestry Chronicle.* vol. 79, no 3, p. 579-589.

DeFries, R., A. Hansen, B.L. Turner, R. Reid et J.G. Liu. 2007. «Land use change around protected areas: Management to balance human needs and ecological function». *Ecological Applications.* vol. 17, no 4, p. 1031-1038.

Dekker, M., E. Turnhout, B.M.S.D.L. Bauwens et G.M.J. Mohren. 2007. «Interpretation and implementation of Ecosystem Management in international and national forest policy». *Forest Policy and Economics.* vol. 9, no 5, p. 546-557.

Desrosiers, R., S. Lefebvre, P. Munoz et J. Pâque (2010). Guide sur la gestion intégrée des ressources et du territoire: son application dans l'élaboration des plans d'aménagement forestier intégré. Québec, Ministère des Ressources naturelles et de la Faune: 18 p

Díaz, S., et M. Cabido. 2001. «Vive la différence: plant functional diversity matters to ecosystem processes». *Trends in Ecology & Evolution*. vol. 16, no 11, p. 646-655.

Dillman, D.A. 2007. *Mail and internet surveys: The tailored design method*: Hoboken, N.J. : Wiley.

Dovciak, M., C.B. Halpern, J.F. Saracco, S.A. Evans et D.A. Liguori. 2006. «Persistence of ground-layer bryophytes in a structural retention experiment: Initial effects of level and pattern of overstory retention». *Canadian Journal of Forest Research*. vol. 36, no 11, p. 3039-3052.

Doyon, F., S. Yamasaki et R. Duchesneau. 2008. «The use of the natural range of variability for identifying biodiversity values at risk when implementing a forest management strategy». *Forestry Chronicle*. vol. 84, no 3, p. 316-329.

Dragotescu, I., et D.D. Kneeshaw. 2012. «A comparison of residual forest following fires and harvesting in boreal forests in Quebec, Canada». *Silva Fennica*. vol. 46, no 3, p. 365-376.

Drapeau, P., et L. Imbeau. 2006. «Conséquences et risques potentiels inhérents à la récolte des forêts résiduelles laissées depuis 1988 au sein de grands parterres de coupe pour la faune associée aux forêts matures». Chaire industrielle CRSNG UQAT-UQAM en aménagement forestier durable. En ligne. <http://www.greenpeace.org/canada/Global/canada/report/2009/7/un-avis-scientifique-sur-les-f.pdf>. Consulté le 2 March 2012.

Dray, S., et P. Legendre. 2008. «Testing the species traits environment relationships: the fourth-corner problem revisited». *Ecology*. vol. 89, no 12, p. 3400-3412.

Drever, C.R., et K.P. Lertzman. 2003. «Effects of a wide gradient of retained tree structure on understory light in coastal Douglas-fir forests». *Canadian Journal of Forest Research*. vol. 33, no 1, p. 137-146.

Dreyer, M., et O. Renn. 2011. «Participatory Approaches to Modelling for Improved Learning and Decision-making in Natural Resource Governance: an Editorial». *Environmental Policy and Governance*. vol. 21, no 6, p. 379-385.

Ecke, F., O. Lofgren et D. Sorlin. 2002. «Population dynamics of small mammals in relation to forest age and structural habitat factors in northern Sweden». *Journal of Applied Ecology*. vol. 39, no 5, p. 781-792.

Ehnstrom, B. 2001. «Leaving dead wood for insects in boreal forests - Suggestions for the future». *Scandinavian Journal of Forest Research*, p. 91-98.

Elbakidze, M., P. Angelstam et R. Axelsson. 2012. «Stakeholder identification and analysis for adaptive governance in the kovdozersky model forest, Russian federation». *Forestry Chronicle*. vol. 88, no 3, p. 298-305.

Environment Canada. 2012. « National Climate Data and Information Archive: Canadian Climate Normals 1971-2000». En ligne. <http://www.climate.weatheroffice.gc.ca/climate_normals/results_e.html?stnID=5957&prov=&lang=e&dCode=4&dispBack=1&StationName=La_Tuque&SearchType=Contains&province=ALL&provBut=&month1=0&month2=12>. Consulté le 26/09/2012.

Etheridge, D.A., D.A. MacLean, R.G. Wagner et J.S. Wilson. 2006. «Effects of intensive forest management on stand and landscape characteristics in northern New Brunswick, Canada (1945-2027)». *Landscape Ecology*. vol. 21, no 4, p. 509-524.

European Environment Agency. 2000. «Corine Land Cover». En ligne. <http://www.eea.europa.eu/themes/landuse/interactive/clc-download>. Consulté le 2011-09-15.

FAO. 1992. «Summary of potential impacts of forestry activities». FAO. En ligne. <http://www.fao.org/forestry/11787/en/>. Consulté le 23 décembre 2008

FAO. 2003. *Aménagement des pêches. 2. L'approche écosystémique des pêches.*, 2. Rome: FAO, Département des pêches,120 p.

Finnish Meteorological Institute. 2012. «Normal period 1981-2010: Climate elements». Finnish Meteorological Institute. En ligne. <http://en.ilmatieteenlaitos.fi/climate-elements>. Consulté le 26/09/2012.

Fischer, J., D.B. Lindenmayer et A.D. Manning. 2006. «Biodiversity, ecosystem function, and resilience: ten guiding principles for commodity production landscapes». *Frontiers in Ecology and the Environment*. vol. 4, no 2, p. 80-86.

Folke, C. 2006. «Resilience: The emergence of a perspective for sociale-ecological systems analyses». *Global Environmental Change*. vol. 16, no 3, p. 253-267.

Folke, C., C.S. Holling et C. Perrings. 1996. «Biological diversity, ecosystems, and the human scale». *Ecological Applications*. vol. 6, no 4, p. 1018-1024.

Forestry Development Centre TAPIO. 2006. En ligne. <www. tapio.fi>. Consulté le 08/08/2013.

Franklin, J.F. 1993. «Preserving biodiversity- Species, ecosystems or landscapes». *Ecological Applications*. vol. 3, no 2, p. 202-205.

Frechette, A. 2013. «An analytical inquiry into the evolution of forest governance institutions in Québec». Montreal, Institut des sciences de l'environnement, Université du Québec à Montréal, 404 p.

Freedman, B., V. Zelazny, D. Beaudette, T. Fleming, G. Johnson, S. Flemming, J.S. Gerrow, G. Forbes et S. Woodley. 1996. «Biodiversity implications of changes in the quantity of dead organic matter in managed forests». *Environ. Rev./Dossiers environ.* vol. 4, no 3, p. 238-265.

Freedman, R.E., et J. McVea. 2001. In *The Blackwell Handbook of Strategic Management,* Michael A. Hit, p. 744: Wiley-Blackwell.

Friedman, A.L., et S. Miles. 2002. «Developing Stakeholder Theory». *Journal of Management Studies.* vol. 39, no 1, p. 1-21.

Gachet, S., A. Leduc, Y. Bergeron, T. Nguyen-Xuan et F. Tremblay. 2007. «Understory vegetation of boreal tree plantations: differences in relation to previous land use and natural forests». *Forest Ecology and Management.* vol. 242, p. 49-57.

Gauthier, S., M.-A. Vaillancourt, A. Leduc, L.D. Grandpré, D. Kneeshaw, H. Morin, P. Drapeau et Y. Bergeron. 2008a. *Aménagement écosystémique en forêt boréale.* Québec: Presse de l'Université du Québec.

Gauthier, S., M.-A. Vaillancourt, A. Leduc, L.D. Grandpré, D. Kneeshaw, H. Morin, P. Drapeau et Y. Bergeron. 2008b. *Aménagement écosystémique en forêt boréale: pour une foresterie qui s'éduque de la dynamique naturelle.* Québec: Presse de l'Université du Québec.

Gavin, D.G., L.B. Brubaker et K.P. Lertzman. 2003. «Holocene fire history of a coastal temperate rain forest based on soil charcoal radiocarbon dates». *Ecology.* vol. 84, no 1, p. 186-201.

Geobase. 2011. «Land Cover Circa 2000 ». En ligne. <http://www.geobase.ca/geobase/en/data/landcover/csc2000v/description.html>. Consulté le 2011-09-15.

Glaser, M., G. Krause, B. Ratter et M. Welp. 2008. «Human-nature interaction in the Anthropocene: Potential of social-ecological systems». *GAIA.* vol. 1, no 08, p. 77-80.

Glaser, M., G. Krause, B.M.W. Ratter et M. Welp. 2012. *Human-nature interaction in the Anthropocene: Potentials of socio-ecological systems analysis.* New York: Routledge.

Glasmeier, A.K., et T. Farrigan. 2005. «Understanding community forestry: a qualitative meta-study of the concept, the process, and its potential for poverty alleviation in the United States case». *Geographical Journal.* vol. 171, no 1, p. 56-69.

Gower, J.C. 1971. «A general coefficient of similarity and some of its properties». *Biometrics*. vol. 27, no 4, p. 857-871.

Graae, B.J., et P.B. Sunde. 2000. «The impact of forest continuity and management on forest floor vegetation evaluated by species traits». *Ecography*. vol. 23, no 6, p. 720-731.

Gray, A.N., et T. Spies. 1997. «Microsite controls on tree seedling establishment in conifer forest canopy gaps». *Ecology*. vol. 78, no 8, p. 2458-2473.

Grumbine, R.E. 1994. «What is ecosystem management?». *Conservation Biology*. vol. 8, no 1, p. 27-38.

Gunderson, L.H. 2000. «Ecological resilience in theory and application». *Annual Review of Ecology and Systematics*. vol. 31, no 1, p. 425.

Gustafsson, L., S. Baker, J. Bauhus, W. Beese, A. Brodie, J. Kouki, D. Lindenmayer, A. Lõhmus, G. Martinez Pastur, C. Messier, M. Neyland, B. Palik, A. Sverdrup-Thygeson, W.J. Volney, A. Wayne et J. Franklin. 2011. «Retention Forestry to Maintain Multifunctional Forests: a World Perspective». *BioScience*. vol. sumit.

Gustafsson, L., J. Kouki et A. Sverdrup-Thygeson. 2010. «Tree retention as a conservation measure in clear-cut forests of northern Europe: a review of ecological consequences». *Scandinavian Journal of Forest Researche*. vol. 25, p. 295-308.

Haeussler, S., P. Bartemucci et L. Bedford. 2004. «Succession and resilience in boreal mixedwood plant communities 15-16 years after silvicultural site preparation». *Forest Ecology and Management*. vol. 199, no 2-3, p. 349-370.

Haeussler, S., L. Bedford, A. Leduc, Y. Bergeron et J.M. Kranabetter. 2002. «Silvicultural disturbance severity and plant communities of the southern Canadian boreal forest». *Silva Fennica*. vol. 36, no 1, p. 307-327.

Haeussler, S., et Y. Bergeron. 2004. «Range of variability in boreal aspen plant communities after wildfire and clear-cutting». *Canadian Journal of Forest Research*. vol. 34, no 2, p. 274-288.

Halpern, C.B. 2005. «Initial responses of forest understories to varying levels and patterns of green-tree retention». *Ecological Applications*. vol. 15, no 1, p. 175-195.

Halpern, C.B., S.A. Evans, C.R. Nelson, D. McKenzie, D.A. Liguori, D.E. Hibbs et M.G. Halaj. 1999. «Response of forest vegetation to varying levels and patterns of green-tree retention: An overview of a long-term experiment». *Northwest Science*. vol. 73, p. 27-44.

Handcock, R.N., et F. Csillag. 2004. «Spatio-temporal analysis using a multiscale hierarchical ecoregionalization». *Photogrammetric Engineering and Remote Sensing*. vol. 70, no 1, p. 101-110.

Hanski, I. 2000. «Extinction debt and species credit in boreal forests: modelling the consequences of different approaches to biodiversity conservation». *Annales Zoologici Fennici*. vol. 37, p. 271-280.

Harris, G.P. 2012. «Introduction to the special issue: 'Achieving ecological outcomes'. Why is translational ecology so difficult?». *Freshwater Biology*. vol. 57, p. 1-6.

Harvey, B. (2012). Consultation publique relative à la création du parc national d'Opémican. Rouyn Noranda: 30 p

Hasenauer, H., et G. Kindermann. 2002. «Methods for assessing regeneration establishment and height growth in uneven-aged mixed species stands». *Forestry*. vol. 75, no 4, p. 385-394.

Heller, N.E., et E.S. Zavaleta. 2009. «Biodiversity management in the face of climate change: A review of 22 years of recommendations». *Biological Conservation*. vol. 142, no 1, p. 14-32.

Hermy, M., O. Honnay, L. Firbank, C. Grashof-Bokdam et J.E. Lawesson. 1999. «An ecological comparison between ancient and other forest plant species of Europe, and the implications for forest conservation». *Biological Conservation*. vol. 91, no 1, p. 9-22.

Hessburg, P.F., J.K. Agee et J.F. Franklin. 2005. «Dry forests and wildland fires of the inland Northwest USA: Contrasting the landscape ecology of the pre-settlement and modem eras». *Forest Ecology and Management*. vol. 211, no 1-2, p. 117-139.

Hiederer, R., E. Michéli et T. Durrant (2011). Evaluation of BioSoil Demonstration Project - Soil Data Analysis. Publications Office of the European Union: 155 p

Holling, C.S. 1973. «Resilience and stability of ecological systems». *Annual Review of Ecology and Systematics*. vol. 4, p. 1-23.

Holling, C.S., F. Berkes et C. Folke. 1998. «Science, sustainability and resource management». In *Linking Social and Ecological Systems,* F. Berkes, C. Folke et J. Colding, p. 342-362: Cambridge Press.

Holmgren, P. 2012. «Communication challenges in science for forest policy». Center for International Forestry Research En ligne. <http://www.cifor.org/online-library/polex-cifors-blog-for-and-by-forest-policy-experts/english/detail/article/1222/communication-challenges-in-science-for-forest-policy.html>. Consulté le 26/10/2012.

Holsman, R.H., et R.B. Peyton. 2003. «Stakeholder attitudes toward ecosystem management in southern Michigan». *Wildlife Society Bulletin.* vol. 31, no 2, p. 349-361.

Hopwood, D. 1991. *Principles and practices of new forestry*, 71. Victoria BC.: BC. Ministry of Forests, BC. Ministry of Forests,95 p.

Houde, N., et L.A. Sandberg. 2003. «To Have Your Cake and Eat It Too?' Utility, Ecology, Equity and Québec's New Forest Act, 2001». *Cahier de géographie du Québec.* vol. 47, no 132, p. 413-432.

Howlett, M., et J. Rayner. 2006. «Globalization and Governance Capacity: Explaining Divergence in National Forest Programs as Instances of "Next-Generation" Regulation in Canada and Europe». *Governance.* vol. 19, no 2, p. 251-275.

Hunter, M.L. 1993. « Natural fire regimes as spatial models for managing boreal forests». *Biological Conservation.* vol. 65, no 2, p. 115-120.

Hunter, M.L. 1999. *Maintaining biodiversity in forest ecosystems.* Cambridge, UK ; New York, NY, USA: Cambridge University Press.

IUCN. 2012. «The IUCN Red List of Threatened Species». En ligne. <http://www.iucnredlist.org/search>. Consulté le 26/02/2013.

Jonsson, B.G., N. Kruys et T. Ranius. 2005. «Ecology of species living on dead wood – Lessons for dead wood management». *Silva Fennica.* vol. 39, no 2, p. 289-309.

Kaval, P. 2010. «Understanding stakeholder values using cluster analysis». *International Journal of Ecology and Development.* vol. 15, no W10, p. 74-84.

Keddy, P.A. (1992). Assembly and response rules: two goals for predictive community ecology, Blackwell Publishing Ltd. 3: 157-164 p

Kembel, S.W., I. Waters et J.M. Shay. 2008. «Short-term effects of cut-to-length versus full-tree harvesting on understorey plant communities and understorey-regeneration associations in Manitoba boreal forests». *Forest Ecology and Management.* vol. 255, no 5-6, p. 1848-1858.

Kimmins, J.P. 2002. «Future shock in forestry: Where have we come from; where are we going; is there a "right way" to manage forests? Lessons from Thoreau, Leopold, Toffler, Botkin and Nature». *Forestry Chronicle.* vol. 78, no 2, p. 263-271.

Kimmins, J.P. 2004. «Emulating natural forest landscape disturbances: What does this mean?». In *Emulating Natural Forest Landscape Disturbances: Concepts and Applications,* Ajith H. Perera, Lisa J. Buse et M. G. Weber, p. 8-28. New York, NY: Columbia University Press.

Klenk, N.L., G.Q. Bull et J.I. MacLellan. 2009. «The "emulation of natural disturbance" (END) management approach in Canadian forestry: A critical evaluation». *Forestry Chronicle*. vol. 85, no 3, p. 440-445.

Kleyer, M., R.M. Bekker, I.C. Knevel, J.P. Bakker, K. Thompson, M. Sonnenschein, P. Poschlod, J.M. Van Groenendael, L. Klimes, J. Klimesová, S. Klotz, G.M. Rusch, M. Hermy, D. Adriaens, G. Boedeltje, B. Bossuyt, A. Dannemann, P. Endels, L. Götzenberger, J.G. Hodgson, A.-K. Jackel, I. Kühhn, D. Kunzmann, W.A. Ozinga, C. Römermann, M. Stadler, J. Schlegelmilch, H.J. Steedam, O. Tackenberg, B. Wilmann, J.H.C. Cornelissen, O. Eriksson, E. Garnier et B. Peco. 2008. «The LEDA Traitbase: A database of life-history traits of Northwest European flora». *Jounal of ecology*. vol. 96, p. 1266-1274.

Klimeš, L., et J. Klimeš. 2000. «Plant rarity and the type of clonal growth». *Zeitschrift fur Okologie und Naturschutz*. vol. 9, no 1-2, p. 43-52.

Klotz, S., I. Kühn et W. Durka. 2002. «BIOLFLOR - Eine Datenbank mit biologisch-ökologischen Merkmalen zur Flora von Deutschland.». Bundesamt für Naturschutz, Bad Godesberg. DE. En ligne. <http://www2.ufz.de/biolflor/index.jsp>. Consulté le 2010.

Koontz, T.M., et J. Bodine. 2008. «Implementing ecosystem management in public agencies: Lessons from the US Bureau of Land Management and the Forest Service». *Conservation Biology*. vol. 22, no 1, p. 60-69.

Kouki, J., K. Arnold et P. Martikainen. 2004. «Long-term persistence of aspen key host for many threatened species is endangered in old-growth conservation areas in Finland». *Journal for Nature Conservation*. vol. 12, no 1, p. 41-52.

Kouki, J., S. Loèfman, P. Martikainen, S. Rouvinen et A. Uotila. 2001. «Forest fragmentation in Fennoscandia: Linking Habitat Requirements of Wood-associated Threatened Species to Landscape and Habitat Changes». *Scandinavian Journal of Forest Researche*. vol. 3, p. 27-37.

Kull, T., et J. Arditti. 2002. *Orchid biology: Reviews and perspectives, VIII*. Dordrecht: Kluwer Academic Publishers, 81 p.

Kuuluvainen, T. 2002. «Natural Variability of Forests as a Reference for Restoring and Managing Biological Diversity in Boreal Fennoscandia». *Silva Fennica*. vol. 36, no 1, p. 97-125.

Kuuluvainen, T. 2009. «Forest Management and Biodiversity Conservation Based on Natural Ecosystem Dynamics in Northern Europe: The Complexity Challenge». *AMBIO: A Journal of the Human Environment*. vol. 38, no 6, p. 309-315.

Kuuluvainen, T., A. Penttinen, K. Leinonen et M. Nygren. 1996. «Statistical opportunities for comparing stand structural heterogeneity in managed and primeval forests: An example from boreal spruce forest in southern Finland». *Silva Fennica*. vol. 30, no 2-3, p. 315-328.

Kuuluvainen, T., et J. Siitonen. 2013. «Fennoscandian boreal forests as complex adaptive systems: properties, management challenges and opportunities». In *Managing forests as complex adaptive systems in the face of global change,* C. Messier, K. Puttmann et D. Coates, p. 368: EarthScan Press.

Landres, P.B., P. Morgan et F.J. Swanson. 1999. «Overview of the use of natural variability concepts in managing ecological systems». *Ecological Applications*. vol. 9, no 4, p. 1179-1188.

Lavorel, S., et E. Garnier. 2002. «Predicting changes in community composition and ecosystem functioning from plant traits: Revisiting the Holy Grail». *Functional Ecology*. vol. 16, no 5, p. 545-556.

Lebel, L., J.M. Anderies, B. Campbell, C. Folke, S. Hatfield-Dodds, T.P. Hughes et J. Wilson. 2006. «Governance and the Capacity to Manage Resilience in Regional Social-Ecological Systems». *Ecology and Society*. vol. 11, no 1, p. 19.

Legendre, P., et L. Legendre. 1998. *Numerical ecology* Coll. «Collections : Developments in environmental modelling 20 »: Amsterdam Elsevier 853 p.

Levin, S.A. 1992. «The problem of pattern and scale in ecology». *Ecology*. vol. 73, p. 1943-1967.

Liira, J., T. Sepp et O. Parrest. 2007. «The forest structure and ecosystem quality in conditions of anthropogenic disturbance along productivity gradient». *Forest Ecology and Management*. vol. 250, no 1-2, p. 34-46.

Lilja, S. 2006. «Ecological restoration in forests in Fennoscandia: defining reference stand structures and immediate effects of restoration». Helsinki, Department of Forest Ecology, Faculty of Agriculture and Forestry, University of Helsinki, 51 p.

Lindenmayer, D.B. 2000. «Factors at multiple scales affecting distribution patterns and their implications for animal conservation - Leadbeater's Possum as a case study». *Biodiversity and Conservation*. vol. 9, no 1, p. 15-35.

Lindenmayer, D.B., et J.F. Franklin. 2002. *Conserving forest biodiversity : A comprehensive multiscaled approach*. Washington: Island Press.

Lindenmayer, D.B., J.F. Franklin et J. Fischer. 2006. «General management principles and a checklist of strategies to guide forest biodiversity conservation». *Biological Conservation*. vol. 131, no 3, p. 433-445.

Lindenmayer, D.B., J.F. Franklin, A. Lõhmus, S.C. Baker, J. Bauhus, W. Beese, A. Brodie, B. Kiehl, J. Kouki, G. Martínez Pastur, C. Messier, N. Neyland, B. Palik, A. Sverdrup-Thygeson, J. Volney, A. Wayne et L. Gustafsson. 2012. «A major shift to the retention approach for forestry can help resolve some global forest sustainability issues». *Conservation Letters*. vol. 5, p. 1-12.

Linder, P., et L. Ostlund. 1998. «Structural changes in three mid-boreal Swedish forest landscapes, 1885-1996». *Biological Conservation*. vol. 85, no 1-2, p. 9-19.

Lindkvist, A., E. Mineur, A. Nordlund, C. Nordlund, O. Olsson, C. Sandstrom, K. Westin et E.C.H. Keskitalo. 2012. «Attitudes on intensive forestry. An investigation into perceptions of increased production requirements in Swedish forestry». *Scandinavian Journal of Forest Research*. vol. 27, no 5, p. 438-448.

Lloret, F., F. MÉDail, G. Brundu, I. Camarda, E.V.A. Moragues, J. Rita, P. Lambdon et P.E. Hulme. 2005. «Species attributes and invasion success by alien plants on Mediterranean islands». *Journal of Ecology*. vol. 93, no 3, p. 512-520.

Logan, J.A., J. Regniere et J.A. Powell. 2003. «Assessing the impacts of global warming on forest pest dynamics». *Frontiers in Ecology and the Environment*. vol. 1, no 3, p. 130-137.

Macdonald, S.E., et T.E. Fenniak. 2007. «Understory plant communities of boreal mixedwood forests in western Canada: Natural patterns and response to variable-retention harvesting». *Forest Ecology and Management*. vol. 242, no 1, p. 34-48.

Matsuda, H. 2003. «Challenges posed by the precautionary principle and accountability in ecological risk assessment». *Environmetrics*. vol. 14, no 2, p. 245-254.

McCormick, M.K., D. Lee Taylor, K. Juhaszova, R.K. Burnett Jr, D.F. Whigham et J.P. O'Neill. 2012. «Limitations on orchid recruitment: Not a simple picture». *Molecular Ecology*. vol. 21, no 6, p. 1511-1523.

McFarlane, B.L., T.M. Beckley, E. Huddart-Kennedy, S. Nadeau et S. Wyatt. 2011. «Public views on forest management: value orientation and forest dependency as indicators of diversity». *Can. J. For. Ress*. vol. 41, p. 740–749.

McFarlane, B.L., et P.C. Boxall. 2010. «Factors influencing forest values and attitudes of two stakeholder groups: The case of the Foothills Model Forest, Alberta, Canada». *Society and Natural Resources*. vol. 13, no 7, p. 649-661.

McIntyre, S., S. Lavorel et R.M. Tremont. 1995. «Plant life-history attributes: Their relationship to disturbance response in herbaceous vegetation». *Journal of Ecology*. vol. 83, no 1, p. 31-44.

McLachlan, S., et D.R. Bazely. 2001. «Recovery patterns of understory herbs and their use as indicators of deciduous forest regeneration». *Conservation Biology*. vol. 15, no 1, p. 98-110.

McRae, D.J., L.C. Duchesne, B. Freedman, T.J. Lynham et S. Woodley. 2001. «Comparisons between wildfire and forest harvesting and their implications in forest management». *Environmental Reviews*. vol. 9, no 4, p. 223-260.

MDDEFP. 2010. «Portrait du réseau d'aires protégées au Québec: une contribution exceptionnelle à la protection de la biovidersité biologique». Developpement durable, environnement, faune et parcs. En ligne. < <http://www.mddefp.gouv.qc.ca/infuseur/communique.asp?no=1675>>. Consulté le 01/08/2013.

Messier, C., K.J. Puettmann et D.K. Coates. 2013. *Managing Forests as Complex Adaptive Systems - Building Resilience to the Challenge of Global Change*: Routledge.

METLA. 2011. «Forest management». Finnish Forest Research Institute. En ligne. <http://www.metla.fi/metla/finland/finland-forest-management.htm>. Consulté le 24/01/2013.

Mitchell, S.J., et W.J. Beese. 2002. «The retention system: Reconciling variable retention with the principles of silvicultural systems». *Forestry Chronicle*. vol. 78, no 3, p. 397-403.

Mosseler, A., J.A. Lynds et J.E. Major. 2003. «Old-growth forests of the Acadian Forest Region». *Environmental Reviews*. vol. 11, no 1 SUPPL.

Mouillot, D., A.J. Graham, S. Villéger, N.W.H. Mason et D.R. Bellwood. 2012. «A functional approach reveals community responses to disturbances». *Trends in Ecology and Evolution*, p. 1-11.

MRNF. 2013. «Nouveau régime forestier en 2013». Gouvernement du Québec. En ligne. <http://www.mrn.gouv.qc.ca/forets/gestion/nouveau-regime-2013.jsp>. Consulté le 30/06/2013.

Muro, M., et P. Jeffrey. 2008. «A critical review of the theory and application of social learning in participatory natural resource management processes». *Journal of Environmental Planning and Management*. vol. 51, no 3, p. 325-344.

Nadeau, S. (2011). Propriétaires de terrains boisés de l'île du Prince Édouard: Tendances actuelles relatives à l'usage, à la gestion et aux valeurs. Rapport d'information M-X-225F. Frederiction (N.-B.), Service canadien des forêts - Centre de foresterie de l'Atlantique

Nadeau, S., T.M. Beckley, E.H. Kennedy, B.L. McFarlane et S. Wyatt. 2007. *Opinions du public sur la gestion des forêts au Nouveau-Brunswick : rapport de l'enquête provinciale*. Fredericton, NB, Ressources naturelles Canada - Service canadien des forêts - Centre de foresterie de l'Atlantique,76 p.

Naeem, S., J.E. Duffy et E. Zavaleta. 2012. «The Functions of Biological Diversity in an Age of Extinction». *Science*. vol. 336, no 6087, p. 1401-1406.

Naveh, Z. 2000. «What is holistic landscape ecology? A conceptual introduction». *Landscape and Urban Planning*. vol. 50, no 1â€"3, p. 7-26.

Neufeld, H.S., et D.R. Young. 2003. «Ecophysiology of the herbaceous layer in temperate deciduous forest». In *The Herbaceous Layer in Forests of Eastern,* F. S. Gilliam et M. R. Roberts. New York,: Oxford University Press.

Newmaster, S.G., W.C. Parker, F.W. Bell et J.M. Paterson. 2007. «Effects of forest floor disturbances by mechanical site preparation on floristic diversity in a central Ontario clearcut». *Forest Ecology and Management*. vol. 246, no 2-3, p. 196-207.

Noss, R.F. 1999. «Assessing and monitoring forest biodiversity: A suggested framework and indicators». *Forest Ecology and Management*. vol. 115, no 2-3, p. 135-146.

OMNR. 2001. *Forest management guide for natural disturbance pattern emulation*, Version 3.1., Toronto, ON.: Queen's Printer for Ontario, , Ontario Ministry of Natural Resources,40 p.

OMNR. 2003. *Old Growth Policy for Ontario's Crown Forests*. Sault-Ste. Marie: Queen's Printer for Ontario, Forest Policy Section. Forest Management Branch,26 p.

Ostlund, L., O. Zackrisson et A.L. Axelsson. 1997. «The history and transformation of a Scandinavian boreal forest landscape since the 19th century». *Canadian Journal of Forest Research*. vol. 27, no 8, p. 1198-1206.

Ostrom, E. 2005. *Understanding institutional diversity*. Bloomington, Indiana: Princeton University Press.

Park, A., et E.R. Wilson. 2007. «Beautiful Plantations: can intensive silviculture help Canada to fulfill ecological and timber production objectives?». *The Forestry Chronicle*. vol. 83, no 6, p. 825-839.

Parkins, J.R., et R.E. Mitchell (2005). Public Participation as Public Debate: A Deliberative Turn in Natural Resource Management. Society & Natural Resources, Routledge. 18: 529-540 p

Pearson, A.F. 2010. «Natural and logging disturbances in the temperate rain forests of the Central Coast, British Columbia». *Canadian Journal of Forest Research*. vol. 40, no 10, p. 1970-1984.

Pedlar, J.H., J.L. Pearce, L.A. Venier et D.W. McKenney. 2002. «Coarse woody debris in relation to disturbance and forest type in boreal Canada». *Forest Ecology and Management*. vol. 158, no 1-3, p. 189-194.

Peltzer, D.A., M.L. Bast, S.D. Wilson et A.K. Gerry. 2000. «Plant diversity and tree responses following contrasting disturbances in boreal forest». *Forest Ecology and Management*. vol. 127, no 1-3, p. 191-203.

Perera, A.H., L.J. Buse et R.G. Routledge. 2007. *A review of published knowledge on post-fi re residuals relevant to Ontario's policy directions for emulating naturaldisturbance.* Sault Ste. Marie: Queen's Printer for Ontario, Ontario Forest Research Institute: Ontario Ministry of Natural Resources,41 p.

Perera, A.H., L.J. Buse et M.G. Weber. 2004. *Emulating natural forest landscape disturbances : Concepts and applications.* New York , NY: Columbia University Press.

Perron, N., L. Bélanger et M. Vaillancourt. 2008. «Organisation spatiale des peuplements et de la forêt résiduelle sous régimes de feu et de coupes». In *Aménagement écosystémique en forêt boréale,* Presse de l'Université du Québec, p. 157-163. Québec.

Pert, P.L., S.N. Lieske et R. Hill. 2013. «Participatory development of a new interactive tool for capturing social and ecological dynamism in conservation prioritization». *Landscape and Urban Planning*. vol. 114, no 0, p. 80-91.

Philpott, S.M., W.J. Arendt, I. Armbrecht, P. Bichier, T.V. Diestch, C. Gordon, R. Greenberg, I. Perfecto, R. Reynoso-Santos, L. Soto-Pinto, C. Tejeda-Cruz, G. Williams-Linera, J. Valenzuela et J.M. Zolotoff. 2008. «Biodiversity loss in Latin American coffee landscapes: Review of the evidence on ants, birds, and trees». *Conservation Biology*. vol. 22, no 5, p. 1093-1105.

Prell, C., K. Hubacek et M. Reed. 2009. «Stakeholder Analysis and Social Network Analysis in Natural Resource Management». *Society & Natural Resources*. vol. 22, no 6, p. 501-518.

Province of British Columbia. 1995. *Biodiversity guidebook: Forest practices code of British Columbia.* Victoria, B.C.: Gouv., British Columbia Ministry of Forests and British Columbia Environment,ix+99 p.

Puettmann, K.J. 2011. «Silvicultural challenges and options in the context of global change: "simple" fixes and opportunities for new management approaches». *Journal of Forestry*. vol. 109, no 6, p. 321-331.

Puettmann, K.J., K.D. Coates et C. Messier. 2009. *A critique of silviculture : Managing for complexity*. Washington, DC.: Island Press.

R Development Core Team (2011). A Language and Environment for Statistical Computing. The R Foundation for Statistical Computing. Vienna, Austria

Ramovs, B.V., et M.R. Roberts. 2005. «Response of plant functional groups within plantations and naturally regenerated forests in southern New Brunswick, Canada». *Canadian Journal of Forest Research*. vol. 35, no 6, p. 1261-1276.

Rapp, V. 2008. *Northwest Forest Plan: The First 10 Years (1994-2003): First-Decade Results of the Northwest Forest Plan*. Portland: Gouv, Forest Service U.S. Department of Agriculture, Pacific Northwest Research Station,42 p.

Rassi, P., E. Hyvärinen, A. Juslén et I. Mannerkoski. 2010. *The 2010 Red List of Finnish Species. Ympäristöministeriö & Suomen ympäristökeskus*. Helsinki: Gouv, Ministry of The Environment: Finnish Environment Institute,685 p.

Rauscher, H.M., F.T. Lloyd, D.L. Loftis et M.J. Twery. 2000. « Practical decision-analysis process for forest ecosystem management». *Computers and Electronics in Agriculture*. vol. 27, p. 195-226.

Rayfield, B., P.M.A. James, A. Fall et M.-J. Fortin. 2008. «Comparing static versus dymanic protected areas in the Quebec boreal forest». *Biological Conservation*. vol. 141, p. 438-449.

Reed, M.S., A.C. Evely, G. Cundill, I. Fazey, J. Glass, A. Laing, J. Newig, B. Parrish, C. Prell, C. Raymond et L.C. Stringer. 2010. «What is Social Learning?». *Ecology and Society*.

Reinikainen, A., R. Mäkipää, I. Vanha-Majamaa et J.-P. Hotanen. 2000. *Changes in the frequency and abundance of forest and mire plants in Finland since 1950*. Helsinki: Tammi, 384 p.

Rose, C.R., et P.S. Muir. 1997. «Green-tree retention: Consequences for timber production in forests of the western Cascades, Oregon». *Ecological Applications*. vol. 7, no 1, p. 209-217.

Rosenvald, R., et A. Lohmus. 2008. «For what, when, and where is green-tree retention better than clear-cutting? A review of the biodiversity aspects». *Forest Ecology and Management*. vol. 255, p. 1-15.

Rowe, J.S. 1983. «Concepts of Fire Effects on Plant Individuals and Species». In *The role of fire in Northern circumpolar ecosystems,* Ross W. Wein et David A. MacLean, p. 135-154: John Wiley and Sons Ltd.

Roy, M.-É. 2008. *Résultats de l'enquête téléphonique sur les valeurs forestières des résidants des régions de la Capitale-Nationale et du Saguenay–Lac-Saint-Jean.* Québec: Gouvernement du Québec, Ministère des Ressources naturelles et de la Faune,55 p.

Royo, A.A., et W.P. Carlson. 2006. «On the formation of dense understory layers in forests worldwide: consequences and implications for forest dynamics, biodiversity, and succession». *Can. J. For. Ress.* vol. 36, p. 1345-1362.

Ruckstuhl, K.E., E.A. Johnson et K. Miyanishi. 2008. «Introduction. The boreal forest and global change». *Phil. Trans. R. Soc. B.* vol. 363, p. 2245-2249.

Runkle, J.R. 1981. «Gap Regeneration in Some Old-growth Forests of the Eastern United States». *Ecology.* vol. 62, no 4, p. 1041-1051.

Saarikoski, H., M. Ã...kerman et E. Primmer. «The Challenge of Governance in Regional Forest Planning: An Analysis of Participatory Forest Program Processes in Finland». *Society and Natural Resources.* vol. 25, no 7, p. 667-682.

SAS Institute (2003). JUMP. 5.1. Cary, NC, USA

Satake, A., et Y. Iwasa. 2006. «Coupled ecological and social dynamics in a forested landscape: The deviation of individual decisions from the social optimum». *Ecological Research.* vol. 21, no 3, p. 370-379.

Scheiner, S.M., et M.R. Willig. 2007. «A general theory of ecology». *Theor Ecol.*

Schleicher, A., R. Biedermann et M. Kleyer. 2011. «Dispersal traits determine plant response to habitat connectivity in an urban landscape». *Landscape Ecology.* vol. 26, p. 529-540.

Schlesinger, W.H. 2010. «Translational Ecology». *Science.* vol. 329, no 5992, p. 609.

Schneider, M., J. Scholz, M. Lubell, D. Mindruta et M. Edwardsen. 2003. «Building Consensual Institutions: Networks and the National Estuary Program». *American Journal of Political Science.* vol. 47, no 1, p. 143-158.

Shahbaz, B., G. Mbeyale et T. Haller. 2008. «Trees, trust and the state: A comparison of participatory forest management in Pakistan and Tanzania». *Journal of International Development.* vol. 20, no 5, p. 641-653.

Sheppard, S.R.J. 2005. «Participatory decision support for sustainable forest management: a framework for planning with local communities at the landscape level in Canada». *Can. J. For. Res.* vol. 35, p. 1515-1526.

Shindler, B., M.W. Brunson et K.A. Cheek. 2004. «Social Acceptability in Forest and Range Management». In *Society and Natural Resources: A Summary of Knowledge,* M. Manfredo, J. Vaske, B. Bruyere, D. Field et P. Brown, p. 1-16: Modern Litho Press: Jefferson, MO.

Shindler, B., et L.A. Cramer. 1999. «Shifting Public Values for Forest Management: Making Sense of Wicked Problems». *Western Journal of Applied Forestry.* vol. 14, no 1, p. 28-34.

Shindler, B.A., M. Brunson et G.H. Stankey. 2002. «Social acceptability of forest conditions and management practices: A problem analysis». *USDA Forest Service - General Technical Report PNW,* no 537, p. 1-68.

Siitonen, J. 2001. «Forest Management, Coarse Woody Debris and Saproxylic Organisms: Fennoscandian Boreal Forests as an Example». *Ecological Bulletins,* no 49, p. 11-41.

Slocombe, D.S. 1998. «Defining goals and criteria for ecosystem-based management». *Environmental Management.* vol. 22, no 4, p. 483-493.

Statistique Canada. 2006. «Recensement ». Gouvernment of Canada. En ligne. <www.statcan.gc.ca>. Consulté le 29 may 2013.

Steel, B.S., P. List et B. Shindler (1994). Conflicting values about federal forests: A comparison of national and Oregon publics. Society & Natural Resources, Routledge. 7: 137-153 p

Steel, B.S., et E. Weber. 2001. «Ecosystem management, decentralization, and public opinion». *Global Environmental Change.* vol. 11, no 2, p. 119-131.

Stofer, S., A. Bergamini, G. AragÃ³n, P. Carvalho, B.J. Coppins, S. Davey, M. Dietrich, E. Farkas, K. KÃ¤rkkÃ¤inen, C. Keller, L. LÃ¶kÃ¶s, S. Lommi, C. MÃ¡guas, R. Mitchell, P. Pinho, V.J. Rico, A.M. Truscott, P.A. Wolseley, A. Watt et C. Scheidegger. 2006. «Species richness of lichen functional groups in relation to land use intensity». *Lichenologist.* vol. 38, no 4, p. 331-353.

Strittholt, J.R., D.A. DellaSala et H. Jiang. 2006. «Status of mature and old-growth forests in the Pacific Northwest». *Conservation Biology.* vol. 20, no 2, p. 363-374.

Sturtevant, B.R., A. Fall, D.D. Kneeshaw, N.P.P. Simon, M.J. Papaik, K. Berninger, F. Doyon, D.G. Morgan et C. Messier. 2007. «A Toolkit Modeling Approach for Sustainable Forest Management Planning: Achieving Balance between Science and Local Needs». *Ecology and Society.* vol. 12, no 2.

Sullivan, T.P., et D.S. Sullivan. 2001. «Influence of variable retention harvests on forest ecosystems. II. Diversity and population dynamics of small mammals». *Journal of Applied Ecology*. vol. 38, no 6, p. 1234-1252.

Sullivan, T.P., D.S. Sullivan et P.M.F. Lindgren. 2008. «Influence of variable retention harvests on forest ecosystems: Plant and mammal responses up to 8 years post-harvest». *Forest Ecology and Management*. vol. 254, no 2, p. 239-254.

Sutherland, E.K., B.J. Hale et D.M. Hix. 2000. «Defining species guilds in the Central Hardwood Forest, USA». *Plant Ecology*. vol. 147, no 1, p. 1-19.

Tappeiner, J., J. Zasada, P. Ryan et M. Newton. 1991. «Salmonberry clonal and population structure: the basis for a persistent cover». *Ecology*. vol. 72, no 2, p. 609-618.

Tarrant, M.A., H.K. Cordell et G.T. Green. 2003. «PVF: A scale to measure public values of forests». *Journal of Forestry*. vol. 101, no 6, p. 24-30.

Temesgen, H., P.J. Martin, D.A. Maguire et J.C. Tappeiner. 2006. «Quantifying effects of different levels of dispersed canopy tree retention on stocking and yield of the regeneration cohort». *Forest Ecology and Management*. vol. 235, no 1-3, p. 44-53.

Thiffault, E., N. Bélanger, D. Paré et A. Munson. 2007. «How do forest harvesting methods compare with wildfire? A case study of soil chemistry and tree nutrition in the boreal forest». *Can. J. For. Ress*. vol. 37, p. 1658-1668.

Thompson, I., B. Mackey, S. McNulty et A. Mosseler. 2009. *Forest Resilience, Biodiversity and Climat Change: A synthesis of the biodiversity/ resilence/ stability relationship in forest ecosystems*, Technical Series no 43. Montreal: Secretariat of the Convention on Biological Divesity,67 p.

Tittler, R., N. Beaulieu, P. Boudreau et H. Rheault (2010). Portrait de la forêt préindustrielle, actuelle, analyse d'écart, et principaux enjeux écologiques: Région administrative de la Mauricie. Montreal, Université du Québec à Montréal: 73 p

Traut, B.H., et P.S. Muir. 2000. «Relationships of remnant trees to vascular undergrowth communities in the western Cascades: A retrospective approach». *Northwest Science*. vol. 74, no 3, p. 212-223.

Uotila, A., et J. Kouki. 2005. «Understorey vegetation in spruce-dominated forests in eastern Finland and Russian Karelia: Successional patterns after anthropogenic and natural disturbances». *Forest Ecology and Management*. vol. 215, p. 113–137.

USDA and USDI. 1994. *Standards and guidelines for management of habitat for late-successional and old-growth forest related species within the range of the northern* *spotted owl*: Gouv, USDA (Forest Service) and the USDI (Bureau of Land Management),152 p.

Valverde, T., et J. Silvertown. 1997. «Canopy closure rate and forest structure». *Ecology*. vol. 78, no 5, p. 1555-1562.

Van Wagner, C.E. (1982). Practical aspects of the line intersect method. Information Report PI-X-12. Chalk River, Petawawa National Forestry Institute, Canadian Forestry Service: 11 p

Vanha-Majamaa, I., et J. Jalonen. 2001. «Green tree retention in Fennoscandian forestry». *Scandinavian Journal of Forest Research*. vol. 16 (Suppl. 3), p. 79-90.

Violle, C., M.-L. Navas, D. Vile, E. Kazakou, C. Fortunel, I. Hummel et E. Garnier. 2007. «Let the concept of trait be functional!». *Oikos*. vol. 116, no 5, p. 882-892.

Vitousek, P.M., H.A. Mooney, J. Lubchenco et J.M. Melillo. 1997. «Human Domination of Earth's Ecosystems». *Science*. vol. 277, no 5325, p. 494-499.

Vittoz, P., et R. Engler. 2007. «Seed dispersal distances: a typology based on dispersal modes and plant traits». *Botanica Helvetica*. vol. 117, p. 109-124.

Walker, B., S. Carpenter, J. Anderies, N. Abel, G. Cumming, M. Janssen, L. Lebel, J. Norberg, G.D. Peterson et R. Pritchard. 2002. «Resilience Management in Social-ecological Systems: a Working Hypothesis for a Participatory Approach». *Conservation Ecology*. vol. 6, no 1.

Wallenius, T. 2002. «Forest age distribution and traces of past fi res in a natural boreal landscape dominated by *Picea abies*. ». *Silva Fennica*. vol. 36, no 1, p. 201-211.

Wallin, D.O., F.J. Swason, B. Marks, J.H. Cissel et J. Kertis. 1996. «Comparison of managed and pre-settlement landscape dynamics in forests of the Pacific Northwest, USA». *Forest Ecology and Management*. vol. 85, p. 291-309.

Wang, S., et B. Wilson. 2007. «Pluralism in the economics of sustainable forest management». *Forest Policy and Economics*. vol. 9, no 7, p. 743-750.

Wedeles, C., et D.J.H. Sleep. 2008. «Fragmentation in the boreal forest and possible effects on terrestrial wildlife». *NCASI Technical Bulletin 2008*, no 959, p. 1-69.

Weiher, E., A.v.d. Werf, K. Thompson, M. Roderick, E. Garnier et O. Eriksson. 1999. «Challenging Theophrastus: A Common Core List of Plant Traits for Functional Ecology». *Journal of Vegetation Science*. vol. 10, no 5, p. 609-620.

Whitman, A.A., et J.M. Hagan. 2007. «An index to identify late-successional forest in temperate and boreal zones». *Forest Ecology and Management*. vol. 246, no 2-3, p. 144-154.

Wiersma, Y.F., P.N. Duinker, W. Haider, G.T. Hvenegaard et F.K.A. Schmiegelow. 2010. *Relationships between Protected Areas and Sustainable Forest Management: Many Shades of Green. A State of Knowledge report*. Coll. «Sustainable Forest Management Network». Edmonton, AB.: Sustainable Forest Management Network.

Wiersma, Y.F., et T.D. Nudds. 2009. «Efficiency and effectiveness in representative reserve design in Canada: The contribution of existing protected areas». *Biological Conservation*. vol. 142, no 8, p. 1639-1646.

Wilson, D.S., et K.J. Puettmann. 2007. «Density management and biodiversity in young Douglas-fir forests: Challenges of managing across scales». *Forest Ecology and Management*. vol. 246, p. 123-134.

Witté, I. 2012. «Toward complex forest management: Describing and measuring complexity in forests». Montreal, Université du Québec à Montréal, 151 p.

Wolfgang, S. 1999. *Planet Dialectics: Explorations in Environment and Development*. London: Zed books.

Work, T.T., D.P. Shorthouse, J.R. Spence, W.J.A. Volney et D. Langor. 2004. «Stand composition and structure of the boreal mixedwood and epigaeic arthropods of the Ecosystem Management Emulating Natural Disturbance (EMEND) landbase in northwestern Alberta». *Canadian Journal of Forest Research*. vol. 34, no 2, p. 417-430.

Yaffee, S.L. 1999. «Three faces of ecosystem management». *Conservation Biology*. vol. 13, no 4, p. 713-725.

Zaplata, M.K., S. Winter, D. Biemelt et A. Fischer. 2011. «Immediate shift towards source dynamics: The pioneer species Conyza canadensis in an initial ecosystem». *Flora - Morphology, Distribution, Functional Ecology of Plants*. vol. 206, no 11, p. 928-934.

Zurlini, G., K. Riitters, N. Zaccarelli, I. Petrosillo, K.B. Jones et L. Rossi. 2006. «Disturbance patterns in a socio-ecological system at multiple scales». *Ecological Complexity*. vol. 3, no 2, p. 119-128.