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Developing research approaches to understand biodiversity response to biomass removal

L.A. Venier, I. Aubin, K. Webster, A. Rive, D.M. Morris,
J.A. Rice, and P. Hazlett

BIOMASS / BIODIVERSITY WORKSHOP

FEBRUARY 22 - 23, 2012

Sault Ste. Marie, ON

2014
Natural Resources Canada
Canadian Forest Service
Great Lakes Forestry Centre

Information Report GLC – X – 12

Canada

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Natural Resources Canada
Canadian Forest Service
Great Lakes Forestry Centre
1219 Queen Street East
Sault Ste. Marie, ON P6A 2E1

Ontario Ministry of Natural Resources and Forestry
Centre for Northern Forest Ecosystem Research
Lakehead University Campus
955 Oliver Road
Thunder Bay, ON P7B 5E1

Ontario Ministry of Natural Resources and Forestry
Forests Branch
Roberta Bondar Place
70 Foster Drive
Sault Ste. Marie, ON P6A 6V5

Published by:
Natural Resources Canada
Canadian Forest Service
Great Lakes Forestry Centre
1219 Queen Street East
Sault Ste. Marie, Ontario P6A 2E5

Information Report Number: GLC-X-12
2014

Library and Archives Canada Cataloguing in Publication

Developing research approaches to understand biodiversity response to biomass removal (2012: Sault Ste. Marie, Ont.)
Report on the Forest Biomass-Biodiversity Workshop, Great Lakes Forestry Centre, Sault Ste. Marie, ON, February 22 and 23, 2012 / Venier, L.A., Aubin, I., Webster, K., Rive, A., Morris, D.M., Rice, J.A., Hazlett, P.

(Information report, 0832-7122; GLC-X-12)
Electronic monograph in PDF format.
Issued also in French under title: Élaborer des approches de recherche afin de comprendre la réaction de la biodiversité à l'enlèvement de biomasse, Centre de foresterie des Grand Lacs, Sault Ste. Marie (Ontario), 22 et 23 février 2012.

Includes bibliographical references.
ISBN 978-1-100-25020-5
Cat. no.: Fo123-2/12-2014E-PDF

1. Forest biomass--Environmental aspects--Canada--Congresses.
2. Forest biodiversity--Canada--Congresses. 3. Forests and forestry
--Environmental aspects--Canada--Congresses. I. Aubin, Isabelle, 1970-
II. Venier, L. A. (Lisa Ann), 1965- III. Great Lakes Forestry Centre
IV. Canadian Forest Service V. Title. VI. Series: Information report (Great
Lakes Forestry Centre) GLC-X-12

SD387 B48 F67 2014 333.75'160971 C2014-980043-6

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1. INTRODUCTION

1.1 Workshop Background

A workshop was held at the Great Lakes Forestry Centre on February 22-23, 2012 with the objective of developing a framework for assessing the sustainability of forest biomass harvest from a biodiversity perspective. The workshop was funded by Natural Resources Canada, Canadian Forest Service (NRCan, CFS) through the LEAF fund (Leadership for Environmental Advantage in Forestry). This funding was provided through the CFS Policy, Economics, and Industry Branch that is responsible for issues of market access and market acceptance, issues that present themselves in our international markets. International markets are developing sustainability criteria for biomass, and the Policy, Economics and Industry Branch wants to ensure that the criteria do not put Canadian industry at a disadvantage. Results from this workshop are intended to support these efforts, from a science-based perspective.

The development and implementation of a sustainable forest bioeconomy is also a vested interest for federal and provincial agencies. In Ontario a Canada-Ontario Memorandum of Understanding Concerning Cooperation in Forestry (MOU) was created by the Ontario Ministry of Natural Resources and Forestry (OMNRF) and NRCan, CFS to identify priority issues for cooperation in this area. This MOU resulted in the formation of a technical working group of science and policy staff from both governments (the Canada-Ontario Forest Bioeconomy Technical Working Group**)** to address bioeconomy science priorities of common concern to Ontario and Canada. The objective for this workshop, therefore, is closely aligned with the mandate of the Technical Working Group and the priorities of the governments of both Ontario and Canada. Although focusing on the Ontario perspective, we anticipate that the workshop objectives and outcomes will also meet some of the priorities of other provinces including Quebec, British Columbia and Newfoundland, which were represented at the workshop.

Invited participants were from a variety of disciplines and perspectives. They represented the forest industry, universities, federal and provincial organizations responsible for forest management, forest communities and First Nations. Participants from the science community had expertise in a wide array of taxa and disciplines including birds, mammals, invertebrates, soil micro-organisms, fungi, trees, understory vegetation, forestry, soil nutrition, conservation, modelling and dead wood (see Appendix 1: list of participants, and Appendix 2: participant biographies). It was hoped that this broad representation would provide a variety of perspectives that would be relevant for developing research approaches that could address policy questions related to biomass harvest.

1.2 Rationale

Governments are becoming increasingly interested in biomass harvesting, in part because of recently declining markets for traditional products and associated job losses, as well as heightened public and policy debate over climate change and the need to reduce Canada's growing greenhouse gas emissions. In a recent national scan of regulations relevant to biomass harvesting by the World Wildlife Fund and the Forest Products Association of Canada (2010), every province surveyed has made some sort of overarching policy commitment to a greater reliance on renewable fuels; the scan also found that forest biomass harvesting and related concerns about resulting environmental impacts are becoming

increasingly discussed and debated across all provinces. All provinces assessed have also indicated that biomass harvesting must be conducted within existing forest management policies and guidelines.
Concerns have been raised about the scientific credibility and social acceptance of the developing bioenergy sector. The report entitled “Fuelling the BioMess” by Greenpeace Canada (2011) and an internal Environment Canada report on eNGO (environmental non-government organization) and conservation group views on forest biomass harvesting in Canada (Dagg et al. 2011) highlight concerns about ecological impacts of biomass harvest including impacts on biodiversity and wildlife habitat as well as soil fertility and forest productivity. It was the opinion of many organizations that forest residue is not an acceptable biomass resource because of its importance to biodiversity and productivity (Dagg et al. 2011). There is, however, very little scientific evidence, particularly within North American forest ecosystems, to either support or deny this statement.

1.3 Objective of the workshop

We know that forest biomass, including residue, is important to biodiversity and productivity, but we don’t know to what extent this is true. The objective of this workshop was to identify a framework of research and monitoring approaches that can determine the amount and quality of forest biomass that is required to be left on site without undermining the sustainability or integrity of the system. This framework is intended to (1) identify *current knowledge*, (2) identify *science priorities* including monitoring, and (3) propose *research approaches* to address priorities.

The workshop objectives were organized around a simple model of adaptive management. Adaptive management is a formal process for continually improving management practices by learning from outcomes of operational and experimental approaches (Figure 1).

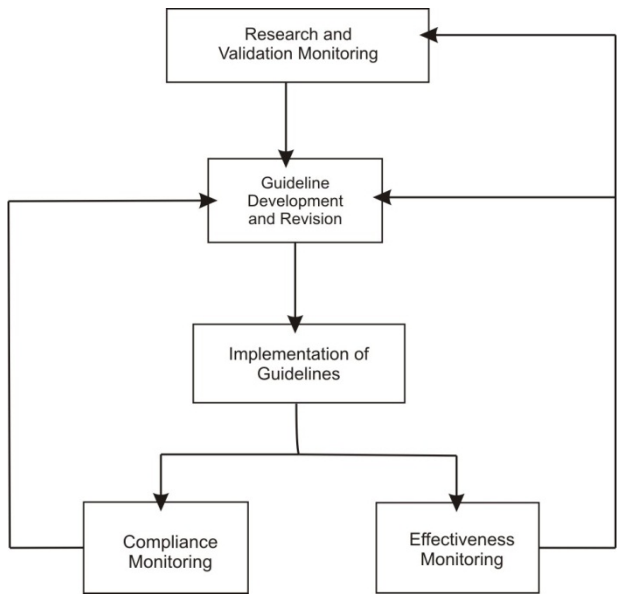

Figure 1. Simple schematic of the adaptive management framework.

Adaptive management has been embraced in Ontario and elsewhere as the dominant paradigm for the sustainable management of forests (OMNR 2009). Figure 1 is a very simple schematic of the adaptive management approach. Within this approach there are two areas where research plays a role. The first area is in the use of experimental approaches to identify patterns and elucidate cause and effect relationships (Research and Validation Monitoring in Figure 1). Results from such work provide the necessary information to develop and also to revise guidelines for forest management (Puddister et al. 2011). These research approaches also provide an opportunity to explore relationships beyond current practices through the experimental manipulation of sites. The second area is the use of mensurative experiments to conduct effectiveness monitoring, monitoring the effects of current implementation of the guidelines. Effectiveness monitoring asks the question "If currently approved practices are applied as intended, do they achieve the desired outcome?" These monitoring programs provide critical information for the revision of existing guidelines and suggest new areas of research (i.e., identify key uncertainties). We organized this workshop around this division between manipulative research and effectiveness monitoring. Effectiveness monitoring evaluates our current practices whereas manipulative research should help to evaluate practices that we might see in the future.

1.4 Objectives of the workshop report

The objective of this report is to document the events of the workshop, to make available the details of the workshop discussion and to synthesize the discussion into key messages and common themes. Based on the results of the workshop and additional consultations, we will be developing a position paper to define the state of the knowledge of this issue. To emphasize the key messages of the workshop we placed some details from the workshop in the Appendices including a list of participants (Appendix 1), biographical information about participants (Appendix 2), an outline of the workshop structure (Appendix 3), the results from our development of effects pathways conceptual models (Appendix 4), details of discussions on research priorities (Appendix 5), details of discussions on effectiveness monitoring approaches

(Appendix 6), the workshop agenda (Appendix 7) and the preparatory material sent to participants prior to the workshop (Appendix 8).

1.5 The science context

Our working definition of biodiversity is “The variety of life and its processes, including genes, species, communities, and ecosystems and the ecological and evolutionary processes that keep them functioning” (Noss and Cooperrider 1994). This definition is broad and provides considerable flexibility in the kinds of responses that we might want to measure in the context of both research and monitoring.

For the purposes of this workshop, we define bioenergy as energy derived from forest harvest and forest harvest residues, but not including short rotation woody crops (e.g., hybrid poplar, willow). However, within the workshop we focused on the specific additional impacts (effects) that might be associated with biomass harvest beyond traditional harvest (standard practice for the ecosystem in question). We defined biomass harvest as the intensification of biomass removal beyond traditional forest harvest, potentially including (1) removal of forest harvest residue, (2) removal of unmerchantable trees, and (3) shortening of rotations. The primary effect of biomass harvest is the removal of additional forest biomass from the forest, and one of the key areas that has been studied from a biodiversity perspective is the impact of change in presence and future supply of dead wood.

Dead wood is a critical component of forest ecosystems for biodiversity. Dead wood is defined as coarse woody debris (CWD), fine woody debris (FWD) and standing dead wood. The importance of dead wood is most strongly evidenced by the relationship of threatened and endangered species in Scandinavia to the loss of dead wood. Large proportions of forest organisms are dependent on dead or dying wood (saproxylic; 20-25% in Finland; Siitonen (2001)) and many threatened and endangered species (according to the International Union for the Conservation of Nature) are saproxylic. In Sweden, greater than 60% of threatened forest invertebrates use logs or snags (Berg et al. 1994) and 44% of threatened species in Finland are critically impacted by reduction in dead wood (Rassi et al. 1992, cited by Siitonen 2001).

Evidence also suggests that levels of dead biomass in managed Scandinavian forests are much lower than in naturally disturbed Scandinavian forests and managed forests in Ontario, although plantations in Ontario can have relatively low volumes of dead wood (Table 1). Based on extensive, provincial-scale sampling of Ontario’s Growth and Yield permanent plot network (i.e., DWD (down woody debris) was measured on 2,046 forested sites). Ontario’s State of the Forest Report suggests that reductions of nearly 50% in the volume of DWD occur on managed jack pine stands (Ontario’s State of the Forest Report - Criteria and Indicators 2012). Direct comparisons between managed and natural stands, however, can be problematic due to the large variation in stand age both pre- and post-disturbance, stand type, as well as variation in methods used to measure biomass or volume of dead wood.

Table 1. Estimates of CWD (coarse woody debris) biomass (T · ha $^{-1}$) and volume (m^3 · ha^{-1}) for unmanaged and managed stands in North America and Scandinavia.

Location	Stand Type (natural/managed)	Stand Age (years)	Volume (m^3 · ha^{-1})	Biomass (T · ha^{-1})	Reference
Ontario	post fire young stands	10 - 14	42 - 78	n/a	Wang et al. 2003
Michigan	post fire - jack pine	1 - 75	n/a	0.5 - 31	Rothstein et al. 2004
Ontario	fire origin, jack pine stand	45 - 68	n/a	1.2 - 2.8	Foster et al. 1995
New Brunswick	natural boreal mixedwood	55 - 105	n/a	4 - 20	Fleming and Freedman 1998
Saskatchewan	post fire – jack pine	79	n/a	6.4	Howard et al. 2004
Southern Fennoscandia	old-growth and mature forests	80 - 500	60 - 90	n/a	Siitonen 2001
Saskatchewan	harvested jack pine stands	0 - 29	n/a	4.0 - 14.2	Howard et al. 2004
New Brunswick	black spruce plantations	3 - 21	n/a	0.6 - 25	Fleming and Freedman 1998
Ontario	young spruce plantations (full tree harvest)	10 - 14	10.6	2.2	Hunt 2010
Ontario	young pine plantations (full tree harvest)	10 - 14	19.4 - 34.9	3.6 - 9.2	Hunt 2010
Ontario	mid-aged spruce plantations (tree length harvest)	31 - 40	0.3 - 5.9	0.1 - 1.6	Hunt 2010
Ontario	mid-aged pine plantations (tree length harvest)	31 - 40	1.2 - 24.6	0.3 - 5.4	Hunt 2010
Ontario	older pine plantations (tree length harvest)	47 - 53	6.7 - 33.3	1.9 - 11.5	Hunt 2010
Ontario	boreal mixedwoods (full tree harvest)	96 - 101	94 - 225 (41-59%) but with 9 and 17% in roadside piles	n/a	Ralevic et al. 2010
Ontario	black spruce (full tree harvest)	101	53 (25%) but with 7% in roadside piles	n/a	Ralevic et al. 2010
Southern Fennoscandia	managed forests	1 - 140	2 - 10	n/a	Siitonen 2001
Southern Fennoscandia	managed forests >140 years	>140	15.9	n/a	Siitonen 2001

Although dead wood quantity is certainly important, its quality also needs to be considered. For example, forest operations such as selective logging in the boreal forest of eastern Finland (Sippola et al. 2001) resulted in over 40% less volume of dead wood in post-harvest old-growth compared to natural forests with particular depletion of relatively intact logs (decay classes 1 to 3). Similar results were found in Sweden where selective logging (22 to 26 stems · ha^{-1}) a century earlier resulted in a reduced number of decaying logs relative to uncut stands (Josefsson et al. 2010). In British Columbia, sites harvested during 1998-2004 had coarse wood volumes after harvesting that were comparable to unharvested reference stands but a noticeably lower density of pieces of large coarse woody debris (i.e., >10m length, BCMFR 2008).

There are known effects of biomass removal on biodiversity in many different taxa but there is very little evidence for any thresholds of effect or even levels above which effects are unsustainable (Table 2). Exceptions include papers by Work and Hibbert (2011) that suggest 40 $m^3 \cdot ha^{-1}$ deadwood is required to maintain the full complement of saproxylic flies, Work et al. (2004) suggested a threshold of 43 $m^3 \cdot ha^{-1}$ to maintain ground beetle assemblages, and Kappes et al. (2009) recommended at least 20 $m^3 \cdot ha^{-1}$ in deciduous forests when considering Gastropods, Diplopods, Isopods, Chilopods and Coleoptera. We provide below a brief state of knowledge on effects of biomass harvesting on biodiversity:

Vegetation

- European boreal forests have a long list of rare and endangered vegetation species while North American forests do not (Haeussler et al. 2004)
- Non-vascular coverage increases with increasing dead wood. Vascular species appear to be less dependent on CWD, although saproxilic vascular species and species dependent on nurse logs for their recruitment may be affected as well with loss of CWD (Crites and Dale 1998; Haeussler and Bergeron 2004; Cole et al. 2008)

Fungi

- It is estimated that only 5% of species are known (Hawksworth 2006), which limits this groups's utility as an indicator
- Retaining logs and slash of different age, size and state of decay is important to the maintenance of saprotrophic fungal diversity (Bunnell and Houde 2010)
- FWD from slash is important habitat for wood decay fungi (Allmér et al. 2009)
- Removing logging residues from conifer stands had no effect after 25 years on litter layer saprotrophic fungal richness or frequency of occurrence of abundant species (Allmér et al. 2009)
- Majority of red-listed fungal species in Sweden use CWD as a primary substrate (Allmér et al. 2009)

Invertebrates

- In boreal mixedwoods of Alberta, stands with <43 $m^3 \cdot ha^{-1}$ of dead wood differed from stands with more dead wood in terms of ground beetle species assemblages (Work et al. 2004)
- Although CWD is likely more important, some species are specifically associated with FWD (Jonsell 2008)
- High microhabitat heterogeneity (slash left on site) has been associated with increased micro- and macroarthropods (e.g., Janssen et al. 2009)

- Presence of dead wood increased richness of mites with greatest (and unique) richness on decaying logs (Déchêne and Buddle 2010)
- More than 20 $m^3 \cdot ha^{-1}$ of downed wood are needed to provide habitat connectivity for litter dwelling arthropods in deciduous forest (Kappes et al. 2009)
- 15-18 years post-harvest comparison of logging residue removed vs doubled; soil macro and micro invertebrate communities and food webs were impacted by full tree harvesting with reductions in abundance ranging from 29 to 55 % depending on the taxon (Bengtsson et al. 1997)
- Initial responses after residue removal are generally stronger and more prevalent than long-term effects
- Removing FWD in Appalachian forests decreased spider density (Castro and Wise 2009)

Vertebrates

- Among forest dwelling vertebrates in Ontario, an estimated 26% use tree cavities and 36% use dead wood (Naylor 1994)
- Numerous studies have shown examples of the importance of CWD to small ground-dwelling mammals (e.g., as corridors for movement, as part of trophic web, to maintain soil moisture)
- Meta-analysis concluded that there were no consistent effects for small mammals (Riffell et al. 2011)
- Birds respond negatively to loss of snags (nesting) and CWD (foraging) (Riffell et al. 2011)
- Removal of DWD and snags had a small negative effect on amphibians; based on only 2 studies (Riffel et al. 2011)

Overall Patterns

- Dead wood is a key resource for forest biota
- There has been much more research in Scandinavia than in North America
- Biomass retention levels in managed forests in Scandinavia are often much lower than in Ontario
- Species impacts are much more severe in Scandinavia as evidenced by red-listed species
- Some species are dependent on fine woody debris (FWD) but there is very little information on the relationship of biodiversity to FWD
- Long-term studies are rare
- Most studies are at the stand scale
- Identifying thresholds of response is rare
- For most taxa and forest types we don't know how much woody debris retention is sufficient to maintain biodiversity

2. STAKEHOLDERS PERSPECTIVE

For adaptive management to work effectively, the involvement of all the stakeholders is necessary. Stakeholders' views and values should be taken into account when developing goals and approaches in any research agenda. The following section highlights perspectives of different stakeholders expressed during the workshop with respect to the goal and content of research on the impact of biomass harvesting for bioenergy on biodiversity.

2.1 Forest communities and First Nation perspective

One representative from the Northeast Superior Regional Chiefs' Forum (NSRCF) and two representatives from the Northeast Superior Forest Community (NSFC) were present at the workshop (see Appendix 1). We asked them to identify their concerns about harvesting biomass.

Forest community representatives stressed the need for researchers to better articulate their research objectives and create better linkages between science and forest communities. Biomass harvesting represents a beacon of hope for many people who have lost work as a result of the continuing reduction in demand for conventional Canadian wood products. Better communication between forest users and scientists will encourage collaborative science initiatives, and, in turn, ensure that forestry practices are sustainable.

The First Nations representative perceives increases in biofibre demand as mostly inevitable. First Nations stressed the importance of tackling research questions through a more holistic methodology, also placing an emphasis on the importance of adaptive management and the necessity of involving all stakeholders in potential forest management projects, whether research-based, economic in nature or simply recreational. From their perspective, the "science agenda" usually lags behind the "policy agenda". In the case of biomass harvesting, they see market demands for biofibre as dictating the intensity and frequency at which biomass harvesting activities will occur. In response to market demands, policy makers will have to rapidly create guidelines and measures to evaluate biomass harvesting practices for bioenergy to ensure sustainable harvesting. As a result, policy makers are prompting researchers to identify the thresholds of biomass retention required for sustainability.

However, First Nations outline that it takes time to fully understand the effects of intensified biomass harvesting on biodiversity and ecosystem processes. In this case, scientists are limited in their capacity to give results in a short timeframe. First Nations also challenged researchers to identify if thresholds of effect exist. For instance, responses can vary considerably among species. Responses can be linear rather than with an inflection point, leaving the policy makers to make the decision where increased removal means reduced biodiversity. In fact, identifying how much biomass should be left on site is not just a science issue but requires a community and social response as well. Communities must decide what level of impact is acceptable.

We also asked Forest Communities and First Nations to identify the important issues on which research should be focused to effectively and efficiently evaluate the impacts of intensive biomass harvesting. They suggested the following ideas:

- respect the intrinsic value of the ecosystem
- take a precautionary ecological approach
- ensure proper long-term timelines
- ensure that measurable results are properly quantified
- include a strong social science approach that is community focused with a convergent agenda
- more accurately quantify biomass levels
- acknowledge that biodiversity is as important as regeneration of trees

- complete a best practices review to make sure we are not reinventing the wheel - NRCan and OMNR already have detailed biodiversity strategies and forest management planning frameworks centered around sustainability.

Forest communities and First Nation representatives perceive adaptive management as a good way to deal with these issues. They suggest fully embracing an adaptive management approach to learn while doing rather than thinking that we can learn then do.

2.2 Industry perspective

Representatives from Tembec, Resolute Forest Products, and Ontario Power Generation were present at the workshop (see Appendix 1). Industry representatives stressed that they are committed to the Forest Stewardship Council (FSC) certification system. As such, they are committed to ensure the ecological requirements of their operations are met. Once these requirements are achieved, they will continue to explore opportunities for using biomass material in addition to the other forest products they traditionally harvest. This should help the overall economics and optimize operations. The certification system is also perceived as an opportunity for improved silviculture renewal or, in some cases, stand rehabilitation.

We asked the industry representatives to identify the current status of harvesting for bioenergy and predict the future of biomass harvesting as biomass becomes a more valuable commodity.

Industry does not foresee significant increases in the demand for biomass in the foreseeable future due to the lack of viable markets. Bioenergy demands for forest residues are very slowly rising in Canada. Industry does not predict the same degree of intensification as seen in Fenno-Scandinavia because market demand is not high enough to generate that level of intensification any time in the foreseeable future. Industry believes that shifts to highly intensive biomass harvesting operations are not likely to occur in the near future. Instead, the forest industry foresees only minor changes in field operations with an increased demand for forest biomass, resulting in: less tops and branches left in the cutover, more undersized material being brought to roadside to be processed, and increased harvest of species previously viewed as undesirable.

Industry identified the effects of the intensification of biomass harvesting on site characteristics or on abiotic factors:

In the boreal forest

- Potential partial removal of non-merchantable and non-marketable fibre
- Nutrients left from slash pile burning at roadside will be replaced with smaller volumes of unburnt material
- Biomass harvesting will closely align with the impact of full-tree harvesting practices
- Intensification will facilitate the achievement of forest management objectives (i.e., stand conversion)
- Opportunities to practice intensive biomass management in a triad approach will be provided.

In the Great Lakes-St. Lawrence forest

- Fewer tops and branches left in the cutover (all harvest types: clearcut, selection and shelterwood), which may result in the reduction of available habitat and nutrients
- Partial removal of unmerchantable and unmarketable species.

We also asked industry to identify the important questions that should drive research to properly and efficiently evaluate the impacts of intensive biomass harvesting.

A major point for them is the determination of the economic threshold for biomass harvesting operations (i.e., how much biomass do you need to remove to make it economically viable?). In contrast, they would like research to give them an ecological threshold by identifying the maximum fibre extraction that is achievable without affecting biodiversity and ecosystem integrity.

Research priorities identified by industry are summarized below:

- The potential impact of a higher unmerchantable species removal (e.g., cedar, hemlock and tamarack) on animal populations. These trees provide important habitat attributes to many mammals.
- Determine threshold levels of retention to ensure site productivity, biodiversity, and associated ecosystem services are maintained.
- The relevance of the Scandinavian experience to Canada. Identify sites on which extremely intense removal could apply.
- Applicability of full-tree harvesting in different stand types.
- Impact on silvicultural renewal and species composition.
- Short- and long-term effects on ecological values including biodiversity, soil productivity and water conservation.

2.3 Forest Policy perspective

Forest policy representatives from the Canadian Forest Service, Ontario Ministry of Natural Resources, and the British Columbia Ministry of Forests were present at the workshop. We asked them to identify the gaps in knowledge and the research priorities that need to be addressed to inform biomass harvesting policy.

The forest policy representatives understand the importance of maintaining biomass on-site to help ensure the current and long-term health of the forest. The group recognizes the role biomass plays in maintaining nutrient cycles and other ecological processes, in helping to sustain micro-organism populations and the diversity of flora and fauna, as well as its role in supporting the productivity of current and future forest stands.

While the development of any policy on biomass usage will need to fit within the province’s broader legislative and strategic policy framework, any such policy, which would have a direct impact at the stand or operational level, would also need to be practical enough to be implemented and assessed in an effective and efficient manner.

In most jurisdictions, policy documents are reviewed and revised on a regular basis, so science input into policy direction should be based on current knowledge. Where ongoing experiments, trials, and/or monitoring cannot offer clear results and recommendations, policy is normally developed with a precautionary approach, and future advances from the science community are incorporated during later policy revisions.

As such, the forest policy group at the workshop looks to the science community for direction on the amount of biomass needed to be retained after forest operations that will support healthy forests. If such information is not immediately available, forest policy staff would then look to the science community for an estimate of when such information would be available – to allow for policy planning with the appropriate precautionary approaches to be put into place

Critical direction should include:

- The quantity and quality of biomass that should be left in the forest; including, if possible, the range of piece sizes, desired species, and level of decay of wood that should be targeted to be maintained.
- Whether the amount of biomass needed to be maintained should differ by forest type (e.g., pine vs hardwood vs mixedwood), stand age, site type, etc.
- In describing the amount needed to be maintained, what proportion should be in coarse woody material, fine woody material, and stumps?
- Are there sensitive sites where no removal of biomass should be considered?
- An economic model that describes the cost of removing or maintaining biomass on the site.

2.4 Key messages and common themes in stakeholder perspectives

Communication

Communication needs to be improved among stakeholders. Efforts need to be made among all stakeholders to create and maintain linkages among groups. In particular, researchers need to strive to better articulate their objectives to forest communities and include them in the delivery of their research and monitoring programs. Common definitions among stakeholders are essential for achieving communication among groups.

Thresholds

Thresholds of biomass retention must not just consider “science-based” criteria, but also socially acceptable thresholds. Furthermore, economic thresholds to optimize viability (take out as much as possible) must be balanced with minimizing impacts (amount to be retained). Policy makers need to know how applicable thresholds developed at one site can be applied to different site types that may differ in their site sensitivity.

Focus

The focus of biomass harvest research needs to be holistic, including impacts on future productivity, biodiversity, other ecosystem services, and society.

Timeframes

Science activities may take longer than is ideal for the development of policy on biomass retention. This lends urgency to these activities but is somewhat constrained by available resources. For example, although some short-term impacts may be observed within 2-3 years of biomass harvest (e.g., Island Lake Biomass Harvest Trial), longer term impacts may not be observed until crown closure and beyond (>15 years; e.g., Long-term Soil Productivity Trials).

3. RESEARCH PRIORITIES

Under an adaptive management process, manipulative research projects are important for determining the potential impacts of a given disturbance on biodiversity. The results from such research experiments provide crucial information needed for the development, and subsequent revisions, of guidelines for biomass harvesting for bioenergy.

In an ideal world, research experiments would elucidate the impacts of biomass harvesting on biodiversity across all biodiversity elements, in all ecosystem types and at a range of temporal and spatial scales. However, under the constraints of limited resources, prioritization of elements to be measured is necessary to ensure we measure elements that will effectively help answer our research questions within a set budget and timeline. (Discussion related to this section can be found in Appendix 5)

3.1 Key messages and common themes in research priorities

3.1.1 The dead wood profile

Some participants raised the importance of looking at dead wood from the perspective of a profile through time. Dead wood is a dynamic resource (i.e., there is a temporal succession in dead wood availability and decomposition). The availability of CWD is expected to change over time in harvested stands relative to natural disturbance depending on the ecosystem. In the boreal region, following clear-cutting there is less residual material than what is left following a natural disturbance (Brassaard and Chen 2006). In young forests, CWD volume, snag abundance and volume of large logs are significantly higher in naturally disturbed stands than in clearcut stands (Brassard and Chen 2006). In the short-term, fire disturbed stands are expected to have a pulse of CWD as fire-killed stems fall. Recruitment of new DWD is expected to be delayed in both naturally disturbed and clearcut stands after the initial pulse while the young replacement stands develop. Over the long-term, CWD volumes are expected to converge as pioneer trees die, via self-thinning, and fall. Stage of stand development at disturbance is extremely important because if stands are disturbed again before convergence there will be cumulative loss of CWD over multiple generations.

The study design should not only compare volume left on site, but should examine the distribution of different qualities of dead wood (i.e., size, species, decay class), across the landscape, stand type, and successional stage. There was general consensus that intensification of biomass harvesting will likely result in a shift to lower quality dead wood. The dead wood profile should be compared between forests that have been harvested and those originating from natural disturbance.

3.1.2 Treatment intensity

There was a consensus among the participants for the need for manipulative experiments that would include a broad gradient of biomass removal treatments. It was stressed that the study design, and the resulting gradient of biomass removals, should not be restricted to what is currently done in practice (e.g., classical comparison of stem only versus full-tree) but instead should push the system far enough, in terms of biomass removal, to get a signal. The following treatment intensity was suggested (above-ground CWD volumes retained on site): 0, 10, 40, 80 $m^3 \cdot ha^{-1}$.

Both industry and researchers were interested in this approach but for different reasons. Researchers wanted a study design that contained treatments of biomass removals with a broad enough gradient to elucidate the shape of the whole response curve. This would provide information on the existence of a threshold or the relative impact of a variety of silvicultural options. Additionally, researchers were interested in the impact of multiple rotations of biomass harvesting. To some extent, the inclusion of an extreme removal treatment could be considered a surrogate for less extreme removals repeated over multiple rotations. Industry participants indicated little interest in the development of a study design on the stem only vs. full-tree comparison, as it is already studied and utilization of roadside slash is already an approved practice. From an economic efficiency perspective, industry is interested to know if it is possible to have a higher utilization of a stand without compromising biodiversity, and if so, in which stands, and under which circumstances. Some participants also highlighted the fact that it can take decades for the results from a research experiment to be available. The experiment should thus be designed to allow measurements over the longer term and to answer questions that may be of future importance (e.g., under a scenario of an even further increase in demand for biomass when oil is scarce and/or more expensive).

There was discussion about whether we should measure intensity of biomass removal based on what is removed or what is retained on site. Although the primary interest from an industry perspective is to know how much biomass can be removed without affecting biodiversity, the issue for biodiversity and ecosystem processes is more likely to be about how much is retained because what is retained is the resource for the biodiversity. Removal rates would therefore have to be adjusted based on how much is on site before harvesting. From a management and policy perspective, retention targets are far easier to achieve.

3.1.3 Species response curves

There are a number of different potential species response curves that could be associated with the removal of biomass. Identifying the nature of the response curve will help in decision making. Species may be resistant to change over a wide range of biomass removal, or extremely sensitive. In the case of the existence of a threshold, species may be resilient to a point (the threshold) and then undergo an abrupt ecological change (Berch et al. 2011). Although the existence of thresholds makes management decisions somewhat easier, empirical support for thresholds is limited. A further complicating factor is that different species are likely to have different response curves including different thresholds if they exist. Therefore, even if science can provide an adequate picture of biodiversity response to biomass removal, there will still be a requirement for a social evaluation of what level of impact we are willing to live with.

3.1.4 Reference conditions and desired future conditions

An important discussion during the workshop centered around whether the natural disturbance regime is the appropriate reference condition or if it should be managed forests under current practices. Ontario forest managers have raised the point that they are mandated under the crown forest sustainability act, to emulate natural disturbance regime and landscape patterns within the limits of silvicultural requirements. However, the assumption is that current practices are sustainable. This claim of sustainability has not been based on science related to biomass removal but on other forest characteristics like landscape pattern. Sustainability should be assessed with respect to the amount of biomass removed from the forest which requires a comparison to natural disturbance.

> *The long term health and vigor of Crown forests should be provided for by using forest practices that, within the limits of silvicultural requirements, emulate natural disturbances and landscape patterns* [coarse filter] *while minimizing adverse effects on plant life, animal life, water, soil, air and social and economic values, including recreational values and heritage values* [fine filters] (CFSA s. 2(3)2).

The use of natural disturbance as a "control" does bring its challenges. First, natural disturbance is highly variable so there is a need to understand the full range of variability associated with natural disturbance, commonly referred to as "the bounds of natural variability". Also, natural disturbance regimes themselves are being altered by climate change (e.g., increase in fire frequency and intensity, wind, extreme events, and exotic/invasive species). These changes may produce unknown cumulative effects, thus using an historical point of view of natural disturbance regime as a benchmark may prove to be problematic.

3.1.5 Scale

All groups brought up the issue of dealing with both spatial and temporal scales.

3.1.5.1 Temporal scale: As noted previously, dead wood availability changes through the development and succession of a stand and is particularly divergent between immediate post harvest and post fire stands. Additionally, individual pieces of dead wood go through a succession of decomposition where they provide suitable resources for a progression of organisms (see Group C discussion in Appendix 5). Predicting dead wood through time will be critical for assessing long-term impacts on biodiversity.

3.1.5.2 Spatial scale: Spatial scale was also raised as a critical issue because the ability to examine it is dependent on funding availability and will have a strong impact on the capacity to generalize the findings to other regions. Groups with budget constraints suggested a study design at the stand level using one sensitive key ecosystem/developmental stage (see Group A, Appendix 5). Groups with more resources (Group D, Appendix 5) suggested a stratified design among landscapes and chronosequences, notably to capture variability in ecosystem processes (e.g., dispersal, fire, hydrology, species associations) at these scales.

3.1.5.3 Size of the plots: Plot sizes from 70m x 70m (0.5ha) to 100m x 100m (1.0ha) were suggested as being reasonable to study key taxa related to the dead wood profile (e.g., insects and fungi). These plot sizes were considered as a good trade-off between capturing the natural variability, large enough to study key taxa while maintaining operational and financial feasibility. Certainly the scale of the plots necessarily dictates the taxa suitable for study. For example, it would not be feasible to study birds or mammals using 0.5ha treatment plots; 10ha treatment blocks would be more suitable. Group D recommended a nested design that would incorporate nested spatial scales to address a wider range of taxa.

3.1.6 Response variables

A set of intensive and extensive measurements were suggested:

3.1.6.1 Intensive measurements should be made on selected taxa. The choice of these taxa to be studied should be based on retrospective studies conducted in similar forest ecosystems with a longer history of intensive biomass removals. Focus should be put on:

- Taxa/group sensitive to change in dead wood (e.g., saproxylic species that use dead wood as habitat or resource).
- Taxa that possess the most linkages to other taxa and to ecosystem processes.
- Species that have a strong linkage with stand productivity (e.g., driving nutrient cycling).
- Species with cultural or social value.

3.1.6.2 Extensive measurement would focus on the dead wood profile (quantity and quality) as a surrogate measure of habitat and resource availability for sensitive key species. These empirical measurements could then be accompanied by modeling to predict the availability of dead wood resources over time under various management scenarios.

4. EFFECTIVENESS MONITORING

Effectiveness monitoring is the evaluation phase of an adaptive management approach to resource management (Rempel et al. 2004). It entails monitoring the outcome of management practices to see if they meet the management objectives. Effectiveness monitoring needs to be hypothesis driven in that the hypothesis is the proposed link between the management action and the desired outcome. For example, within the context of biomass harvesting, a proposed management action may require leaving X $m^3 \cdot ha^{-1}$ of biomass on site to maintain ecological integrity. The evaluation would involve compliance monitoring to confirm that the required amount was left on site, and effectiveness monitoring to confirm that invertebrate communities had not changed beyond a specified range. This would be one of many possible hypotheses that could be generated from this single management application. Discussion on effectiveness monitoring approaches can be found in Appendix 6.

4.1 Key messages and Common Themes in Effectiveness Monitoring

4.1.1 Extensive and intensive approaches

All three participant groups advocated for detailed measurement of the down wood profile (quantity, quality, decay class, size, distribution), and suggested the use of down wood measurements over extensive (landscape scale) areas as a surrogate for biodiversity. One group took this further to suggest modelling down wood dynamics to predict future levels of down wood and biodiversity. In conjunction with this extensive approach, all three groups argued for a smaller scale, intensive component that would help to establish the linkages between down wood characteristics and dynamics and the associated biodiversity. An ongoing intensive component would provide validation for the assumption that down wood levels are adequate to support biodiversity.

4.1.2 Indicator species

All three groups made the case for using indicator species that were directly affected by the removal of biomass. In some cases, it was suggested that the Scandinavian example could provide insight into choosing appropriate indicator species, i.e., species that are known to be sensitive to biomass removal. In other cases, it was simply argued that sensitivity to biomass removal needed to be one of the criteria in an indicator selection filter. Other criteria for indicator selection have been identified in the literature (e.g., Heink and Kowarik 2010).

4.1.3 Stratification

The need to stratify the sampling over a variety of variables was noted by all groups. Suggested variables included cover type (hardwood, conifer, mixedwood), age, (early, mid and late seral stages), natural disturbance types (fire, insect outbreak, gap phase dynamics), and time since disturbance. These variables will all impact the amounts of biomass on a given site at the time of harvest, as well as the relationship between biomass and biodiversity.

4.1.4 Dead wood profile

Lastly, it was apparent from much of the discussion that understanding woody debris dynamics was critical to meet the objective. Woody debris characteristics change over time and the impact of biomass removal will therefore change with time. Understanding how availability of woody debris will differ between naturally disturbed stands versus managed forest stands over time is key to predicting the impacts of biomass removal on biodiversity both now and in the future. Modelling is likely the best way to generate sound predictions of woody debris availability and therefore biodiversity in the future.

5. CONCLUSIONS

This workshop highlighted both the need for and importance of communication and engagement among stakeholders. This communication is key to understanding different forest values when considering biomass harvesting. Furthermore, understanding impacts on biodiversity from biomass harvesting requires a holistic science and socio-economic approach. Determining thresholds for biomass removal will depend not only on scientific information, but also social and economic tradeoffs.

Biodiversity and the trophic food webs they create are a complex system. Despite the complexity there is also the need to simplify our knowledge of the system without compromising interconnections, cascading effects and feedbacks among trophic levels. One of the key groups identified as a first order indicator are the saproxylics (i.e., fungi, bacteria, insects, birds and mammals), that are dependent on the dead wood resource, although other trophic levels may contain other pieces to the biodiversity puzzle. This lack of information about trophic interactions is a critical knowledge gap in understanding the immediate and long-term impacts of biomass harvesting.

Studies addressing biomass harvesting impacts on biodiversity will initially need to be focused at a site specific, stand-level scale, and incorporate treatments that include removals that go beyond stem only and full-tree harvesting, and even go beyond current biomass demands to consider future demands. After working out connections, interactions and impacts at finer scales and on sensitive sites, experiments can include a broader range of site types, across larger spatial scales.

The Scandinavian experience and decades of research of stem only and full-tree harvesting have provided useful knowledge from which we can build on understanding the impacts of biomass harvesting in Canadian forests. Currently, several meta-analyses are under way that will provide a solid foundation to identify knowledge gaps, in the design of new/innovative experiments, and assist in the development of effectiveness monitoring strategies.

5.1 The next steps forward

Based on the outputs of the workshop, we suggest that the following are the important next steps towards developing research to determine the amount and quality of forest biomass required to be left on site to maintain the sustainability and integrity of forested ecosystems:

1. Given that current biomass harvest practices do not differ substantially, in terms of biomass removals, from traditional harvests, effectiveness monitoring is unlikely to show a biodiversity response specific to biomass harvest. For this reason, research emphasis should be placed on manipulative research where the variation in treatments can be greater and therefore produce a more informative signal.
2. Emphasis should be placed on measuring and modelling dead wood dynamics to understand how biomass harvesting impacts ecosystems relative to natural disturbance and standard harvesting practices over time and space.
3. Conceptual models and current literature should be used to develop and apply a biodiversity indicator filter to select and prioritize potential indicators.
4. Stand level experiments should be conducted with a wide range of treatments and taxa studied to develop species response curves to biomass removal and to explore the potential of developing multitrophic indicators that capture the impacts on ecosystem processes (e.g., Island Lake Biomass Harvest Project, contact lead author for information).
5. Current landscapes should be explored via GIS to assess their potential to be examined for long-term impacts of biomass removal on biodiversity using a chronosequence approach.
6. Large spatial and long temporal scaled studies should be designed and costed to provide incentive to identify potential funding. If possible, study designs should be modular so that pieces can be carved off as funding becomes available.
7. All stakeholders should be consulted during each of the above steps.

5.2 Was the workshop objective met?

The objective of the workshop was to develop a framework of research and monitoring approaches that can determine the amount and quality of forest biomass that is required to be left on site without undermining the sustainability or integrity of the system. The key messages and common themes identified throughout the report provide elements of the desired framework although a complete framework was not identified. Development of each of the next steps forward using the key messages and common themes as a guide would lead to a more complete research framework. The framework would include suggested approaches to modelling dead wood dynamics, identifying indicator species, designing stand level experiments to develop species response curves, designing and costing landscape level chronosequence studies, and designing large scale, long-term nested studies. All of these components would guide future research towards determining the amount and quality of forest biomass that is required on site to maintain system integrity.

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APPENDICES

APPENDIX 1: List of Participants

Lisa Venier	Workshop Organizer, Research Scientist, Natural Resources Canada, Canadian Forest Service, Great Lakes Forestry Centre, Sault Ste. Marie, Ontario. Lisa.Venier@nrcan-rncan.gc.ca
Isabelle Aubin	Workshop Organizer, Research Scientist, Natural Resources Canada, Canadian Forest Service, Great Lakes Forestry Centre, Sault Ste. Marie, Ontario. Isabelle.Aubin@nrcan-rncan.gc.ca
Kara Webster	Workshop Organizer, Research Scientist , Natural Resources Canada, Canadian Forest Service, Great Lakes Forestry Centre, Sault Ste. Marie, Ontario. Kara.Webster@nrcan-rncan.gc.ca
Dave Morris	Workshop Organizer, Research Scientist, Ontario Ministry of Natural Resources and Forestry, Centre for Northern Forest Ecosystem Research, Thunder Bay, Ontario. dave.m.morris@ontario.ca
Andre Arsenault	Research Scientist, Natural Resources Canada, Canadian Forest Service, Cornerbrook, Newfoundland. Andre.J.Arsenault@nrcan-rncan.gc.ca
Jim Baker	Science Business Coordinator, Applied Research and Development Branch, Ontario Ministry of Natural Resources and Forestry, Guelph, Ontario. Jim.Baker@ontario.ca
Nathan Basiliko	Professor, University of Toronto, Toronto, Ontario. Nathan.Basiliko@utoronto.ca
Wayne Bell	Forest Researcher, Ontario Forest Research Institute, Ontario Ministry of Natural Resources and Forestry, Sault Ste. Marie, Ontario. Wayne.Bell@ontario.ca
Heather Cole	Research Associate, Great Lakes Forestry Centre, Natural Resources Canada, Canadian Forest Service, Sault Ste. Marie, Ontario. Heather.Cole@nrcan-rncan.gc.ca
Phyllis Dale	Senior Science Advisor, Natural Resources Canada, Canadian Forest Service, Ottawa, Ontario. Phyllis.Dale@nrcan-rncan.gc.ca
Nancy Densmore	Director of Forest and Range Evaluation Program, Ministry of Forests, Lands and Natural Resource Operations, Victoria, British Columbia. Nancy.Densmore@gov.bc.ca
Robert Fleming	Research Scientist, Natural Resources Canada, Canadian Forest Service, Great Lakes Forestry Centre, Sault Ste. Marie, Ontario. Rob.Fleming@nrcan-rncan.gc.ca
Dominique Gravel	Professor, Université du Québec à Rimouski. Dominique_Gravel@uqar.qc.ca
Tanya Handa	Université du Québec à Montreal, Montréal, Québec.
Paul Hazlett	Research Scientist, Natural Resources Canada, Canadian Forest Service, Great Lakes Forestry Centre, Sault Ste. Marie, Ontario, Paul.Hazlett@nrcan-rncan.gc.ca

Steve Hounsell	Senior Advisor, Corporate Sustainable Development Group, Ontario Power Generation, Toronto, Ontario. steve.hounsell@opg.com
Trevor Jones	Research Scientist, Ontario Forest Research Institute, Ontario Ministry of Natural Resources and Forestry, Sault Ste. Marie, Ontario. Trevor.Jones2@ontario.ca
Martin Kaiser	Manager, Strategic Business Development, Resolute Forest Products, Thunder Bay, Ontario. martin.kaiser@resolutefp.com
Colin Lachance	Corporate Secretary and Cultural Advisor, Northeast Superior Regional Chiefs' Forum. colinlachance@msn.com
Maxime Larivee	Post-doctoral Fellow, University of Ottawa, Ottawa Ontario. mlarrive@uottawa.ca
Jason Linkewich	Vice President, Fibre Supply Strategy, Tembec, Témiscaming, Québec. Jason.Linkewich@tembec.com
Clara Lauziere	General Manager of the Northeast Superior Forest Community, Chapleau, Ontario. Clara.Lauziere@nsfc.ca
Joe Maure	Forest Bioeconomy Specialist, Ontario Ministry of Natural Resources and Forestry, Industry Relations Branch, Sault Ste. Marie, Ontario. Joe.Maure@ontario.ca
Jay Malcolm	Professor, University of Toronto, Toronto, Ontario. Jay.Malcolm@utoronto.ca
Christian Messier	Professor, Université de Québec à Montréal, Montréal, Québec, messier.christian@uquam.ca
Marco Moretti	Research Scientist, Swiss Federal Research Institute WSL, Switzerland
David Nanang	Director General, Great Lakes Forestry Centre, Natural Resources Canada, Canadian Forest Service, Sault Ste. Marie, Ontario. David.Nanang@nrcan.gc.ca
David Paré	Research Scientist, Laurentian Forestry Centre, Natural Resources Canada, Canadian Forest Service, St. Foy, Québec. David.Pare@nrcan-rncan.gc.ca
Dan Puddister	Science Management Coordinator, Ontario Forest Research Institute, Ontario Ministry of Natural Resources and Forestry, Sault Ste. Marie, Ontario. Dan.Puddister@ontario.ca
Robert Rempel	Research Scientist, Ontario Ministry of Natural Resources and Forestry, Centre of Northern Forest Ecosystem Research, Thunder Bay, Ontario. Rob.Rempel@ontario.ca
Jim Rice	Forest Management Guides Forester, Ontario Ministry of Natural Resources and Forestry, Forests Branch, Sault Ste. Marie. Ontario Jim.Rice@ontario.ca
Laura Sanderson	Research Assistant, Invasive Species Centre, Sault Ste. Marie, Ontario.
Al Stinson	Forest Science Partnership Specialist, Ontario Ministry of Natural Resources and Forestry, Science and Information Branch, North Bay, Ontario. Al.Stinson@ontario.ca

Brian Titus	Research Scientist, Natural Resources Canada, Canadian Forestry Service, Pacific Forestry Centre, Victoria, British Columbia. Brian.Titus@nrcan-rncan.gc.ca
Melissa Todd	Research Wildlife Ecologist, BC Ministry of Forests, Lands and Natural Resource Operations, Nanaimo, British Columbia. Melissa.Todd@gov.bc.ca
Suzanne Wetzel	Research Scientist, Natural Resources Canada, Canadian Forest Service, Great Lakes Forestry Centre, Sault Ste. Marie, Ontario. Suzanne.Wetzel@nrcan-rncan.gc.ca
Tim Work	Professor, Université du Québec à Montréal, Montréal, Québec. timothy@uqam.ca
Alix Rive	Workshop Technician, Natural Resources Canada, Canadian Forest Service, Great Lakes Forestry Centre, Sault Ste. Marie, Ontario.
Jean-Lionel Payeur-Poirier	Workshop Technician, Natural Resources Canada, Canadian Forest Service, Great Lakes Forestry Centre, Sault Ste. Marie, Ontario.
Craig Zimmerman	Workshop Technician, Natural Resources Canada, Canadian Forest Service, Great Lakes Forestry Centre, Sault Ste. Marie, Ontario.
Idaline Laigle	Internship, Natural Resources Canada, Canadian Forest Service, Great Lakes Forestry Centre, Sault Ste. Marie, Ontario.

APPENDIX 2: Biographical Information of Workshop Participants

André Arsenault
André is a forest ecologist with NRCan, CFS, Atlantic Forestry Centre based in Corner Brook, Newfoundland as well as an adjunct professor with Thompson Rivers University in Kamloops and Memorial University, Grenfell campus in Corner Brook. André is fascinated by forest ecosystems, science and how society uses information to manage forests. He had the privilege to study the dynamics of the maple forests of Quebec undergoing a mysterious decline in the late 1980s for his M.Sc, and the pattern and process of old-growth coastal rainforests of British Columbia during the early 1990s for his PhD. André worked as a biologist for the BC Forest Service in Kamloops for 15 years on a variety of topics including studies on the ecology of old-growth forests and disturbance regimes of a variety of forest types of the Montane Cordillera ecozone, and studied ecosystem response to large scale natural experiments and integrated silviculture systems experiments. André's current research projects include the study of forest dynamics and disturbance in coniferous forest of Newfoundland and Labrador along latitude and elevation gradients, ecosystem response following different multidisciplinary silviculture systems experiments in British Columbia and in Newfoundland, distribution ecology of arboreal lichens in British Columbia and Newfoundland, and disturbance ecology of dry forest ecosystems of western North America.
Andre.J.Arsenault@NRCan-RNCan.gc.ca

Pedro Antunes
Dr. Pedro Antunes is a Research Chair in Invasive Species Biology (funded by the OMNRF) and Associate Professor (Department of Biology, Algoma University) since 2010. Currently, he is also the Chair of the North American Invasive Species Network and editor of the international journal Symbiosis. Dr. Antunes has BSc in Biology (University of Évora, Portugal; 1999) and a PhD in Soil Science (University of Guelph; 2005). He did post-doctoral research in Molecular Microbial Ecology (2005-07) and, in 2008, moved to Berlin, Germany, to assume a Research Assistant Professor position in Ecology at the Freie Universität. Currently, Dr. Antunes' research focuses primarily on the roles that soil organisms play in either controlling or facilitating invasion by non-native plants
Pedro.Antunes@algomau.ca

Isabelle Aubin
Isabelle Aubin is a Research Scientist in Vegetation Ecology at NRCan, CFS, Great Lakes Forestry Centre (GLFC) in Sault Ste. Marie and Adjunct Professor at University of Quebec in Rimouski. The subjects of her investigations are the impacts of human-mediated disturbances on forest ecosystems with a focus on the application of ecological theory to practical problems in forest management. Head researcher of the TOPIC ("Traits of plants in Canada") network database, she is committed to addressing the challenge of data networking,
Isabelle.Aubin@NRCan-RNCan.gc.ca, 705-541-5516

Jim Baker
Jim Baker is the Science Business Coordinator with the Applied Research and Development Branch of the OMNRF. He is located in Guelph. He assists with various science and policy initiatives involving OMNRF, NRCan, academia, the forest industry and other partners. One of these initiatives is the Caribou Field Study Team, which is addressing policy uncertainties concerning long-term sustainability of woodland caribou in Ontario. Among other jobs, he serves as one half of the secretariat of the Canada-Ontario MOU Concerning Cooperation in Forestry. Jim is also currently collaborating with a science and policy team from OMNRF and NRCan to address policy uncertainties concerning bioeconomy initiatives.
Jim.Baker@ontario.ca, 519-826-6543

Nathan Basiliko
Nathan Basiliko is an assistant professor in the Department of Geography (Mississauga campus) with a cross appointment in the Faculty of Forestry at the University of Toronto. His research focuses on soil microbial biogeochemistry in temperate and boreal wetlands and forests with a key emphasis on soil carbon, greenhouse gas and nutrient dynamics. His current collaborative funded projects focus on 1) climate change impacts in Ontario's Far North and boreal shield peatlands, 2) benefits and drawbacks of modifying conventional selection and shelterwood silvicultural systems to supply additional biomass for energy feedstock in the Great Lakes St. Lawrence ecoregion, 3) pyrolysis-based forest biomass bioenenergy systems and the use of biochar as a soil amendment, 4) controls on methane fluxes in managed forest soils.
Nathan.
basiliko@utoronto.ca, 905-569-4515

Wayne Bell
Wayne Bell is a forest researcher at OFRI (Ontario Forest Research Institute), OMNRF in Sault Ste. Marie, Ontario. He studies the effects of human activities and natural disturbance on the ecology, diversity, and succession of forest plants. Current focuses include intensive forest management, biodiversity, biomass harvesting and vegetation management alternatives.
Wayne.Bell@ontario.ca, 705-946-7401

Heather Cole
Heather Cole is an employee at NRCan, CFS, GLFC. She recently completed her PhD at the Swiss Federal Research Institute, investigating the use of natural history data for species distribution modelling. She is currently working with Isabelle Aubin, focusing on the trait approach and the use of plant functional traits as the basis of quantitative evaluation of natural ecosystems.

Phyllis Dale
Phyllis Dale is a science advisor with NRCan, CFS in Ottawa. Her PhD was in plant molecular biology at the University of Alberta (1996). She maintains the Pacific Forestry Centre Forest Pathology Herbarium and databases of forest disease as well as conducting field research on forest diseases. She verifies forest disease identification using advanced molecular tools.
Phyllis.Dale@NRCan-RNCan.gc.ca, 613-947-8992

Nancy Densmore

Nancy Densmore, is a professional forester with the British Columbia Ministry of Forests, Lands, and Natural Resource Operations. As a Biodiversity Specialist with the Resource Practices Branch in Victoria BC, she is responsible for legislation and policy regarding stand-level biodiversity, specifically wildlife trees and coarse woody debris. Since 2004 Nancy has been part of a province-wide monitoring program, the Forest and Range Evaluation Program (FREP) as the biodiversity team lead. FREP monitors 11 values as listed in the provincial legislation (Forest and Range Practices Act and Regulations) inclusive of biodiversity, fish/riparian, water quality, soils, visuals and cultural heritage. The biodiversity monitoring looks at harvested cutblocks and the quantity and quality of both standing tree retentions and coarse woody debris. The website for FREP program and published results from monitoring is: http://www.for.gov.bc.ca/hfp/frep/index.htm.

nancy.densmore@gov.bc.ca, 250-356-5890

Rob Fleming

Rob Fleming is a forest ecologist with NRCan, CFS, GLFC in Sault Ste. Marie. His MScF was in silviculture and tree physiology, and his PhD in Soil Science (microclimate). One of his current projects looks at the effects of harvest intensity on evolving overstory and understory development, and environmental constraints.

Rob.Fleming@NRCan-RNCan.gc.ca, 705-541-5632

Dominique Gravel

Dominique Gravel is a professor at Université du Québec à Rimouski and holder of a Tier II Canada Chair in ecosystem ecology. He is interested by the complex interactions between species distribution, community structure and ecosystem functioning. One of the major objectives of his current research program is to develop new tools and methods to better understand the role of biodiversity for the functioning of complex ecosystems such as interaction networks. His research activities are oriented by specific questions, and to answer these questions he studies different ecosystems and models, from bacteria to forest stands.

dominique_gravel@uqar.ca, 418-723-1986 ext.1752

Paul Hazlett

Paul Hazlett is a forest soils scientist with NRCan, CFS, GLFC in Sault Ste. Marie. His research over the last 15 years has focused on terrestrial/aquatic linkages in forest ecosystems and the impact of forest management practices on the nutrient cycling and forest sustainability. He is currently a co-investigator for the Jack Pine LTSP (Long-Term Soil Productivity) experiment in Ontario with research examining the impact of a range of biomass removals on soil nutrient pools and availability. He is a member of the NRCan-CFS/OMNRF Bioeconomy Technical Working Group.

Paul.Hazlett@NRCan-RNCan.gc.ca, 705-541-5630

Steve Hounsell

Steve Hounsell is a biologist with over thirty-six years of experience working with Ontario Power Generation (OPG) and the former Ontario Hydro. Steve works in the Corporate Sustainable Development Group of Ontario Power Generation, where he manages OPG's biodiversity programs. He was responsible for the development and implementation of a biodiversity policy, the first of its kind in the electricity industry. He has made many contributions to woodland conservation in southern Ontario. Steve is also the President of Trees Ontario, a member of the Ontario Biodiversity Council, and a founding director of the Canadian Business and Biodiversity Council. Steve is also the past president of Ontario Nature.

Steve.hounsell@opg.com;
steve.hounsell@rogers,com,
Work: 416-592-2766
Home: 905-276-4462

Trevor Jones

Trevor Jones is a hardwood ecosystem research scientist with OFRI. He has a PhD in forestry from the University of Toronto (2006). He studies the effects of human activity and natural disturbance on Great Lakes- St. Lawrence forests. Current work includes the effects of biomass harvesting. Other expertise: dendrochronology (tree ring science)

Trevor.Jones2@ontario.ca, 705-946-7487

Martin Kaiser

Martin Kaiser is the Fibre Optimization Manager at Resolute Forest Products, in Thunder Bay, Ontario. He joined the company in 1995 as part of its operations continuous improvement program, then moved through a series of supervisory and management positions in both the woodlands operations and pulp and paper mill operations of the company's Ontario and Newfoundland divisions. He has spent the last 5 years focused on developing biomass-based business opportunities in Ontario. Martin has a BSc in forestry from Lakehead University (1985) and a Masters of Business Administration from York University (1991). He is also a registered Professional Forester. His current projects focus on the biomass supply development to support bio-energy (CHP, Wood Pellets) and other biomass based opportunities like: forest biomass, agricultural biomass, dedicated energy crops and the biofuel quality management program.

Martin.Kaiser@resolutefg.com, 807-475-2356

Colin Lachance

Colin Lachance has a BA in physical geography and a Masters in Environmental studies, with a focus on natural resources planning. As a past federal government employee (16 years in all) he has held a multitude of positions including the National Director of Environment and Natural Resources with Indian and Northern Affairs Canada (INAC). Colin has also spent many years assisting First Nations in a number of areas including wellness, cultural and spiritual development, governance, economic development, environmental protection and capacity development. He has worked directly with a multitude of First Nations across Canada, several Tribal Councils and two Ontario-based Provincial-Territorial organizations. For the last five years he has been assisting in the advancement of comprehensive and culturally appropriate approaches to Aboriginal community development. He is currently the Corporate Secretary and a cultural advisor with Northeast Superior Regional Chiefs' Forum (NSRCF). This group, comprised of five Chiefs, was formed in support of advancing a regionally based approach to resolving resource conflicts between First Nations and the Crown.

colinlachance@msn.com, 819-360-6725

Idaline Laigle

Idaline Laigle has come from France to do an internship with Isabelle Aubin at GLFC on the Emerald ash borer. With this 6-month internship she will complete her Master's degree in forest ecology and management. She is very interested in attending this workshop because she would like to stay in Canada to do a PhD on the subject of biomass harvesting impacts and ecological integrity of forests

idaline.laigle@gmail.com, 705-541-5672

Clara Lauziere

Clara Lauziere, the General Manager of the Northeast Superior Forest Community, has been an advocate of regional development and collaborative engagement as a strategy to help communities respond to the changing forest economy. With a background in Policy and Administration at the undergrad and masters level, Clara has spent 10 years in Northern Ontario community economic development and the past four years in the Northeast Superior Region, helping build a regional development organization that focuses on the forest sector. Clara has been advocating aggressively throughout the region about the importance of looking at the forest as a full resource and looks to develop more opportunities for non-timber forest products as economic drivers for this region.

clara.lauziere@nsfc.ca, 705-864-2031

Jason Linkewich

Jason is currently Vice President-Fibre Supply Strategy for Tembec and has been employed with Tembec since April 2003. He started with the Forest Products Industry as a sawmill controller and has progressed to his current position of Vice President- Fibre Supply Strategy. He has been involved in forest products strategy throughout his career and has been active in optimizing the forest products supply chain both to procure and sell products for Tembec. Originally from Thunder Bay, Jason graduated from Lakehead University with an Honours Bachelor of Commerce in 1993 with a concentration in Accounting and Marketing. He also obtained his Certified Management Accountant designation in 1995. In addition to acquiring his designation, Jason has been active within the Ontario Society of Management of Accountants, serving two terms on their board of governors and one term as chair of the board (2004-2005).

jason.linkewich@tembec.com, 819-627-4879

Jay Malcolm

Dr. Jay R. Malcolm received his BSc and MSc from the University of Guelph and his PhD from the University of Florida. After a post-doc at Queen's University, he joined the Faculty of Forestry at the University of Toronto in 1997. His areas of specialty include conservation biology, tropical ecology, landscape ecology, and ecological impacts of climate change. Research interests include mammalian ecology and biogeography; the diversity and abundance of tropical organisms; the impacts of global warming on natural ecosystems; relationships between landscape structure and biological diversity; mammalian adaptations to arboreality and seasonality; and the importance of dead wood as habitat. Dr. Malcolm has conducted extensive fieldwork in the boreal forest of Canada, the Brazilian Amazon, and the Central African Republic.

jay.malcolm@utoronto.ca. 416-978-0142

Joe Maure

Joe Maure is the Coordinator of a Forest Bioeconomy Unit with Forestry Division of the OMNRF in Sault Ste. Marie. Joe's interest in the bioeconomy started while working at his parents' sawmill near North Bay as they pondered options to utilize sawdust and slabs. He studied forestry at Lakehead University and spent time with industry conducting forest inventories, working in logging camps and haul operations, and working on the river drive. Joe joined the OMNRF as a Unit Forester in Temagami in 1988 where he authored several timber management plans before moving to British Columbia where he worked as a Planning Specialist and Forest Analyst. Joe returned to Ontario with the OMNRF in 1999 and continued his analytical role as a Forest Industry Coordinator where he worked on the Provincial Wood Supply Strategies and several mill information and reporting systems. For the past seven years Joe has been directly involved in Ontario forest bioeconomy initiatives and has co-authored several bioeconomy related papers. He has indeed found a use for sawdust and slabs.

Joe.Maure@ontario.ca, 705-945-5892

Christian Messier

Christian Messier is professor of Forest Ecology in the Department of Biology, University of Québec in Montréal (UQAM). He obtained his bachelor in forestry (1984) and M.Sc. (1986) in forest ecology from Laval University, Québec City and his Ph.D. (1991) from the University of British Columbia, Vancouver. After one year at the University of Helsinki, Finland as a post-doc, he started his professorship at UQAM in 1992. His research interests are wide, ranging from the basic understanding of tree growth and death to decision-making tools to better manage natural and urban forests. His research has brought him to study various biomes across the world. He has published more than 150 refereed journal papers and recently co-edited a book on sustainable forest management for the boreal forest and another for the general public, called"Ecology in the City." He is also a co-author of a recent book titled, "A Critique of Silviculture: Managing for Complexity. He holds a New NSERC/Hydro-Quebec research chair on the control of tree growth.

messier.christian@uqam.ca, 514-987-3000 poste 4009
http://www.cef-cfr/index.php?n=Membres.ChristianMessier

Marco Moretti

Marco Moretti is a community ecologist at the Swiss Federal Research Institute WSL in Bellinzona (South Switzerland). He leads an interdisciplinary research group within the community – Ecology Unit. His main scientific interests are to assess the taxonomic and functional response to environmental changes across taxa, processes, and ecosystems at different spatial scales, from local (including spatial autocorrelation) to landscape (composition and configuration). The "taxa" include plants and animals) mainly invertebrates from different trophic guilds; "processes" are fire, forest management, urbanization, invasion by alien species, while "ecosystems" are forests, grasslands, and cities. During the last year he has been working on mechanisms that link traits across trophic levels for a better understanding or ecosystem functioning and underlying services.

marco.moretti@wsl.ch, +41-91-821-52-36

Dave Morris

Dr. Dave Morris received both his BScF and MScF from Lakehead University and his Ph.D. from the University of Guelph in Environmental Biology. Dave has been a research scientist with the OMNRF since 1986, and is currently the Stand Ecology Program Leader at the Centre for Northern Forest Ecosystem Research in Thunder Bay, Ontario. Dr. Morris' research progam focuses on nutrient cycling in boreal systems, with particular emphasis on evaluating the impacts of harvesting systems on stand structural development, stand nutrition, and productivity. In addition, Dr. Morris has been an Adjunct Professor at Lakehead University, in the Faculty of Natural Resource Management for over 15 years. During this time, Dr. Morris has been involved in the training of more than 25 graduate students at both the MSc and PhD level.

Dave.M.Morris@ontario.ca, 807-343-4006

David Paré

David Paré is a scientific researcher at NRCan, CFS, Laurentian Forestry Centre and Adjunct Professor with several universities through the CEF (Centre d'Étude de la Forêt). His research work aims at providing a better understanding of the effect of forestry practices, including intensive biomass harvesting, and of tree species on soils, on the carbon cycle and on forest productivity. Recently, he served as a Review Editor of the Bioenergy chapter of the IPCC special report on renewable energy that was released in June 2011.

David.Pare@NRCan-RNCan.gc.ca, 418-648-7598

Dan Puddister

Dan Puddister has been a science management coordinator with OFRI, OMNRF in Sault Ste. Marie since 2006. Dan joined the OMNRF in 1988, starting out as a district biologist responsible for assessing and managing fish and wildlife populations and habitat and participating in numerous forest management planning teams across Northern Ontario. In 1998, he moved to a main office position developing continuing education and Ontario's compliance inspector certification programs and a MNRF-forest industry partnership. Dan was on the writing team for the Fish Habitat and Environmental Guidelines for access road and water crossings and participated in the development of the Forest Management Guide for Conserving Biodiversity at Stand and Site Scales. He co-chairs the federal-provincial Forest Bioeconomy Technical Working Group and is co-leading the development of MNRF's Climate Change and Forest Integrated Science Action Plan.

Rob Rempel

Rob Rempel is a Research Scientist with OMNRF, and program lead for the Spatial Ecology Program at CNFER (Centre for Northern Forest Ecosystem Research). His interests are spatial ecology, habitat modeling, and experimental design, with special interests in songbirds, moose and wetland ecosystems. Rob's research at OMNRF began with a focus on evaluating the effectiveness of the moose habitat guidelines, but more recently he has been focusing on modeling forest songbird habitat use, and how these models can be used to evaluate the effectiveness of the Landscape Guide direction in meeting biodiversity conservation objectives. Recently, Rob has been helping to develop a strategic plan for evaluating the effectiveness of the new forest management guidelines.

Rob.Rempel@ontario.ca, 705-541-2165

Jim Rice

J.A. (Jim) Rice is a Forest Management Guides Forester with the Forest Policy Section of the OMNRF, based in Sault Ste. Marie, Ontario. Jim provides expertise in the implementation, monitoring and review of the Forest Management Guide for Conserving Biodiversity at the Stand and Site Scale (aka Ontario's Stand and Site Guide). Before joining the Ministry's Forest Policy Section in 2010, Jim spent more than 20 years working as a forest research specialist in Ontario with expertise in silviculture in the Boreal and Great Lakes-St. Lawrence forest regions.

Jim.Rice@ontario.ca, 705-541-2165

Alix C. Rive

Alix C. Rive is a research biologist with Consultants forestiers DGR Inc. in Québec City, and is also a casual employee with NRCan, CFS, GLFC in Sault Ste. Marie, Ontario. She is currently working with a team of scientists at NRCan in developing a framework to provide policy developers, forest managers and research biologists with research and monitoring approaches to assess sustainability of biomass harvest using biodiversity. She consults with Consultants forestiers DGR on FSC (Forest Stewardship Council) certification projects, rare plants, NTFPs species at risk, short rotation of woody crops (willow) for bioenergy, and conducts plant and forest inventories with the DGR field crew during the summer.

rivealix@gmail.com, alix.rive@dgr.ca, 418-802-0148

Al Stinson

Al Stinson is Forest Science Specialist with OMNRF, Science and Information Branch in North Bay. He has worked approximately 36 years in the field of resource management, holding numerous positions including Senior Forest Technician, Forester, Operations Manager and Aboriginal Liaison Officer. Background has included extensive operational experience preparing and implementing silvicultural prescriptions. Al has participated on numerous forest management planning teams. He has worked on the development and delivery of silvicultural training programs such as the Ontario silvicultural tree marking certification program. He participated on research project teams providing operational input, project coordination and guidance and in the development of provincial level policy and guidelines relating to silviculture. He is currently involved in numerous science projects, and bringing partnerships together to support these projects. Projects include: biomass harvesting in partial harvest operations in the Great Lakes-St. Lawrence (GLSL) forest region, biomass harvesting in the boreal forest, LiDAR technologies for forest inventory enhancement, numerous silvicultural trials in the boreal and GLSL forest regions and silvicultural training and certification in the GLSL. Currently he is a member of the team re-writing the Ontario's GLSL silviculture guidelines.

Al.Stinson@ontario.ca, 705-475-5613

Angela St. Michael

Angela St. Michael is the Forest Sector Project Specialist with Northeast Superior Forest Community (NSFC), and currently manages forest-based projects in the Northeast Superior region. These include implementation of blueberry farms on crown land, and participating with communities in alternative energy research and education and biomass sustainability research. Angela has a forestry degree from University of Toronto and a diverse background in both forest management planning and land use planning.

angela_st.michael@nsfc.ca, 705-870-0013

Brian Titus

Brian Titus has been a research scientist with NRCan, CFS for over 25 years, and currently works out of the Pacific Forestry Centre in Victoria, British Columbia. He is a forest ecologist and specializes in the effects of forest management on nutrient cycling and crop tree response. He began working on slash effects on nutrients in Scotland in the early 1980s and continued this work in Newfoundland before moving to British Columbia in the mid-1990s. He is a member of the CFS national team that works on the sustainability of intensive harvesting of managed forests, and also works closely with British Columbia provincial government colleagues on the same topic. He has an active interest in the science that informs development of indicators, guidelines and regulations that ensure sustainable management of biomass removals for bioenergy and other bio-products.

Brian.Titus@NRCan-RNCan.gc.ca, 250-298-2397

Melissa Todd

Melissa A. Todd is a Research Wildlife Ecologist with the Coast Area Research Section of the British Columbia Ministry of Forests, Lands, and Natural Resource Operations (formerly Forest Research), based in Nanaimo, British Columbia. She currently leads a group of research scientists exploring deadwood-associated biodiversity in BC to support guidance development for biomass harvest, one component project of the provincial woody biomass research program coordinated by Shannon Berch. She also provides support to the stump utilization (stump habitat classification) and life cycle analysis (biodiversity indicators) projects for that program. Melissa conducts research to support natural resource management information needs for the Coast Area of British Columbia, evaluating development effects on biodiversity, community ecology and species at risk. She is currently involved in several projects studying species and communities tightly associated with dead downed wood, including investigations of Coastal Tailed Frog terrestrial habitat requirements, Keen's Deer Mouse response to riparian restoration, Williamson's Sapsucker dependence on CWD-associated ant communities, and the response of ground arthropod communities to alternative silviculture. Prior to joining Forest Research, Melisa spent 10 years as a conservation biologist with BC Forest industry in the west-central interior, where she led regional research into coarse woody debris benchmarking and the development of retention strategies.

Melissa.Todd@gov.bc.ca, 250-751-3132

Lisa Venier

Lisa Venier is a research scientist at NRCan, CFS, GLFC in Sault Ste. Marie, Ontario. Her research focuses on (1) how biodiversity responds to natural and forest harvest disturbance and (2) developing approaches for incorporating indicators into forest management. She is a member of the federal-provincial Forest Bioeconomy Technical Working Group and is beginning a field project this summer in Chapleau to examine the impacts of forest biomass removal on invertebrate biodiversity. She is also on the organizing committee for the Biomass/ Biodiversity Workshop.

Lisa.Venier@NRCan-RNCan.gc.ca, 705-541-5605

Kara Webster

Kara Webster is a research scientist in forest soil ecology at NRCan, CFS, GLFC in Sault Ste. Marie. She is interested in understanding how soil works to support natural forests, and how forest management and climate change impact key ecosystem services, such as water storage and carbon sequestration, they provide. She does this by combining field monitoring, empirical and ecosystem modelling, and GIS mapping to investigate soil processes across various spatial scales. This research will provide knowledge to better understand the role of soils as an ecological indicator of productive forests, knowledge that will be used to improve policies for forest sustainability and carbon management in a changing climate. Her current research projects include: Mapping critical source areas in forests on complex terrain; the impact of silviculture methods such as biomass removal for bioenergy production on soil microbial function and nutrient cycling; and, carbon dynamics and greenhouse gas production of boreal wetland and permafrost peatlands.

Kara.Webster@NRCan-RNCan.gc.ca, 705-541-5520

APPENDIX 3: Workshop Structure

A3.1 Structure of the Workshop

The workshop format was designed to facilitate the expression of the different perspectives (industry, forest community, First Nations, policy and research) involved around the question of the impact of biomass harvesting for bioenergy on biodiversity as well as the different science disciplines (from microbial ecology to theoretical ecology) required to help answer these research questions. The approach was to use a variety of facilitation activities to generate discussion and consensus around the prioritisation of research activities.

The overall agenda outlining the workshop process can be found in Appendix 7.
Prior to the workshop, questions were sent to the participants (Appendix 8) to ensure their adequate preparation for the workshop. During the workshop, presentations were given by the organizational team and invited speakers to provide context and background information. At the start, to get familiarized with the different perspectives, participants were invited to provide examples of where their work has changed due to considerations of biomass harvesting for bioenergy:

Participants were asked the following questions:
What form does harvesting biomass for bioenergy currently take?
How might that change as biomass becomes more valuable in the future?
What are the main concerns about biomass harvesting?
What are the recent research questions resulting from bioenergy demands?

A3.2 Day 1

The first day of the workshop was dedicated to (1) the development of a conceptual model of impacts of biomass removal on biodiversity to act as a framework for the following activities and (2) the identification of research approaches that would determine the amount of biomass removal that is sustainable from a biodiversity perspective. The day was separated into two main break-out sessions.

A3.2.1 Conceptual Model: Day 1 break-out session 1

The objective of the first break-out session was to identify underlying linkages and causes between increased biomass removal and potential impacts on biodiversity. The participants were first separated into 10 small groups of similar expertise to develop a consensus within a given discipline. The researchers were requested to identify the elements and processes sensitive to biomass harvesting within their discipline. At the same time, the policy, industry and forest community participants were requested to list important questions that research should address. This was done to ensure that proposed research was addressing the questions relevant to the other groups. In the second part of the exercise, the participants were redistributed into one of four larger multidisciplinary groups each given the task of developing an effects pathways conceptual model linking the harvest activities to the likely effects on biodiversity and ecosystem processes. These models, and the identified critical pathways, helped to guide the research prioritization activities.

A3.2.2 Research Approaches: Day 1 break-out session 2

After a presentation on a field study example given by Jay Malcolm (University of Toronto), the second break-out session was dedicated to the identification and prioritization of research approaches that could efficiently determine the amount of biomass removal that is sustainable from a biodiversity perspective. Participants were invited to develop a research proposal for manipulative research that could capture the response of the elements and processes identified in the conceptual model designed in the first activity based on different theoretical levels of funding.

A3.3 Day 2

The second day of the workshop focused on developing effectiveness monitoring hypotheses and prioritizing these hypotheses.

A.3.3.1 Effectiveness Monitoring: Day 2 break-out session 1

After a presentation on the Effectiveness Monitoring Framework in Ontario (Robert Rempel, Research Scientist, Centre for Northern Forest Ecosystem Research) , the first break-out session of Day 2, involved two stages. First, individuals were asked to formulate one or more effectiveness monitoring hypotheses that would help to address the overarching objective of the workshop. Then, within groups, each individual presented their hypothesis to the group for discussion and critique. Hypotheses were then revised according to comments. Each participant was then asked to rate their hypotheses in terms of its feasibility, sensitivity, connectivity, and degree of integration. Hypotheses were then voted on by all participants.

A3.3.2 Effectiveness Monitoring Priorities: Day 2 break-out session 2

We chose the top 3 hypotheses for effectiveness monitoring based on votes and assigned each one to a break-out group. The group was asked to develop an effectiveness monitoring plan to address the hypothesis.

APPENDIX 4: Effects Pathway Conceptual Models

A4.1 Importance of a conceptual framework

At the beginning of the workshop we spent some time developing conceptual models of the impacts of biomass removal on biodiversity to frame the subsequent discussions on research priorities and effectiveness monitoring. A conceptual model is a simplified representation of a complex system that illustrates both the component parts and their interactions. It is a framework for how we think a system works. A good conceptual model is an important tool in all stages of developing a monitoring or adaptive management program (Gross 2003).

At the beginning of the planning process a conceptual model is a framework to drape ideas, discussions and relevant literature around to provide a broader context. It provides the context for organizing information and knowledge. The conceptual model is formulated by different experts contributing their shared understanding of system dynamics. Developing a good conceptual model at the start of the process helps to: (1) formalize current understanding of system processes and dynamics; (2) identify the bounds and scope of the system of interest, and; (3) identify linkages of processes across disciplinary boundaries (Gross 2003).

Once the basic framework has been determined, the conceptual model allows examination of the important components, process and their functional roles, interconnections and linkages. Thus at this stage, the model provides a means to highlight key linkages that have been poorly studied, thus setting priorities for future study, as well as identifying elements that would be effective indicators for monitoring impacts.

As the research and monitoring program progress, new information is gained and indicators monitored. This updated knowledge allows us to quantify and create a more thorough understanding of the components and linkages that lead to adaptive changes in the conceptual model.

Throughout this process, communication of the adaptive management program among scientists, policy analysts, forest managers, stakeholders and the public is essential. The conceptual model provides a common framework to communicate knowledge, gaps, results and impacts.

A4.2.What is an effects pathway model?

An effects pathway model is a decision-making assistance tool that supports managers, researchers and practitioners involved in different levels of planning for ecosystem, and in this case, forest management. In our context here, the model provides a framework to identify the effects of forest management practices on elements of the system, both direct and indirect as well as on ecosystem processes. The intent is to summarize all of the predicted effects of an intensification of biomass removal compared to natural disturbance on components and processes within the forest ecosystem. The model is scale independent both in terms of time and space so that effects may be immediate or long term, local or at landscape scales.

A4.3 Steps in constructing the effects pathway model

During the workshop the participants were asked to contribute to the development of the conceptual model. Initially, groups of experts from the same field met to highlight key components and processes related to their area of expertise (soil micro-organisms, fungi, non-timber vegetation, abiotic factors, insects and spiders, mammals and birds, trees) and then larger groups were formed containing individuals with different expertise to construct a model. A flow chart of the process was as follows (Figure 2):

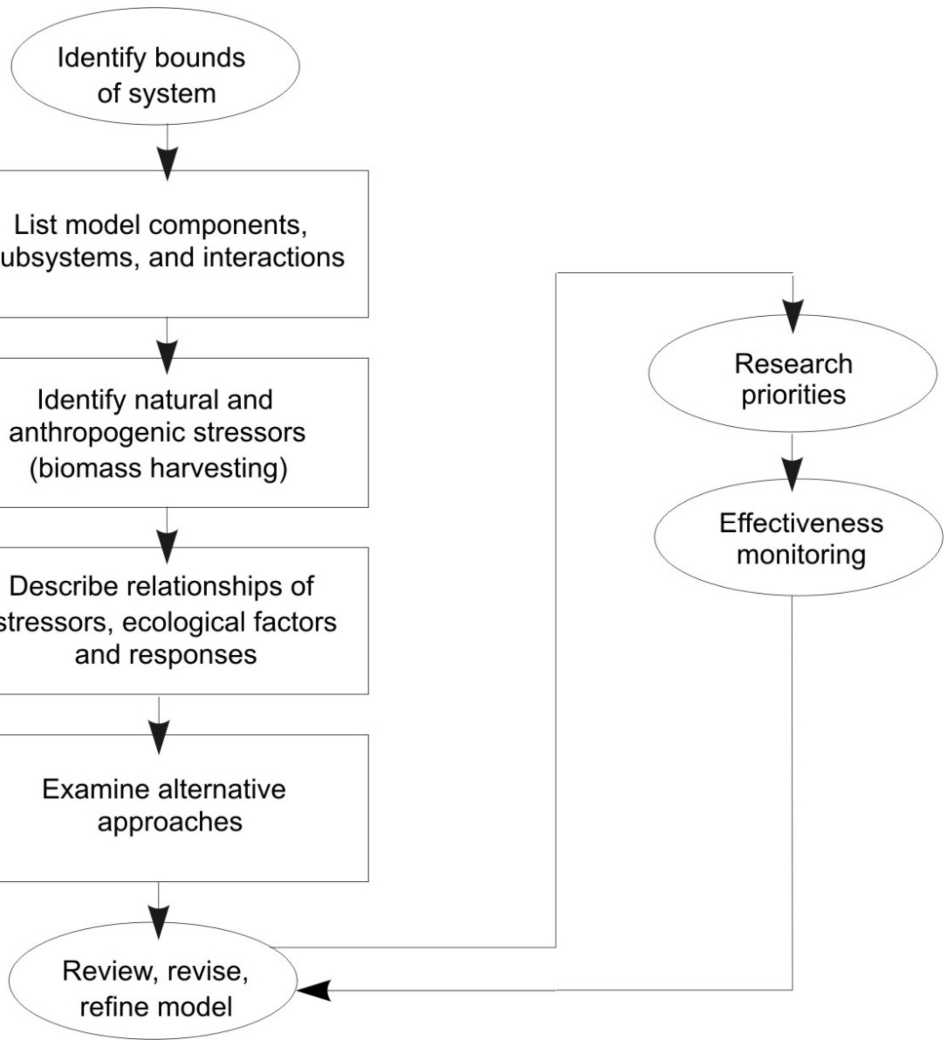

Figure 2. Flow chart of steps taken to develop the conceptual model.

A4.4 Understanding impacts of biomass removal intensification

Impacts of biomass removal intensification can have first and second order impacts on the ecosystem. The first order impacts are the components directly impacted by intensification of biomass removal and include loss of dead wood, changes in climate/microclimate, changes in soils and residual vegetation structure and physical damage (Figure 3). The second order impacts are on the biota mediated by changes incurred by direct impacts, recognizing that there are feedbacks among trophic levels, so impacts on one trophic level can be "felt" at other levels (Figures 4 - 6).

Although the effects pathway model is scale independent it is important to acknowledge the potential different temporal and spatial scales of impacts of different effects. Most of the changes indicated in Figures 3-6 have a strong temporal component that could not be captured in the model. For instance, the temporal sequence of changes in the dead wood profile is not captured in the model but has been generally noted as an expected loss of CWD. Temporal and spatial scale issues will be dealt with as key issues in the Priority for Research and Monitoring Design sections. The ultimate design of research questions will have to incorporate the expected temporal trajectory of these changes.

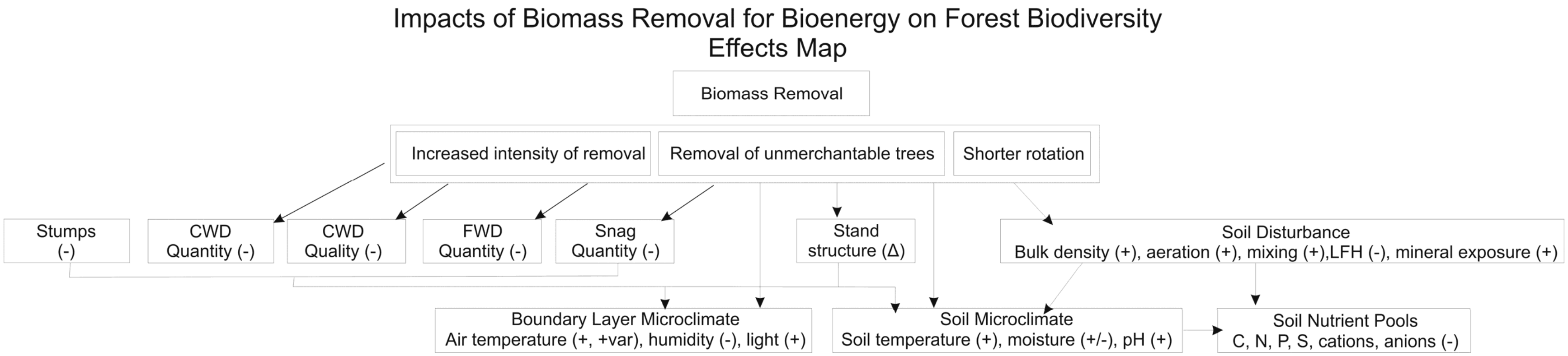

Figure 3. High level effects map of the impacts of biomass removal for bioenergy on ecosystem properties. Effects may be increasing (+), decreasing (-), both (+/-), unknown (?), reflect change (Δ) where direction is not known, or increasing variability (+var)

In the following sections we describe the impacts on the 3 main groups: Soil microbes (decomposers and pathogens) (Figure 4), vegetation (primary producers) (Figure 5), and animals (consumers and predators) (Figure 6).

A4.5 Soil microbe model (Figure 4)

The key ecosystem services that soil microbes provide include decomposition and nutrient cycling, mutualism and parasitism. Soil microbes are essential in the breakdown of litter, mineralization of essential plant nutrients, and conservation of these nutrients within the soil system. Saprophytic fungi are the dominant decomposer in forest ecosystems involved in initial carbon (C) breakdown of lignified tissues. Mycorrhizal fungi are important in nutrient cycling, particularly of phosphorus (P). Bacteria are important in nutrient cycling, particularly of nitrogen (N), but also for C and sulphur (S). These microbes may be heterotrophs (e.g., methanogens from acetate, methanotrophs), dependent on organic substrate, or they may be chemoautotrophs, dependent on inorganic substrates (e.g., ammonifiers, nitrifiers, denitrifiers, methanogens from CO_2, N fixers).

Harvesting directly affects these processes through the reduction and redistribution of organic matter, compaction, changes in plant cover, and modification of microclimate, all of which affect the distribution, composition and activity of the soil biological communities. Northern forests have evolved with major disturbances and are very resilient. The present set of biota in these forests provides useful redundancy and a simplified soil biological system is likely to adversely affect nutrient cycling, tree growth, and forest health and can potentially lead to pest problems (Marshall 2000).

While there are few studies examining the impacts of intensive biomass harvesting for bioenergy on soil microbes, there have been studies examining short term effects of clear cut harvesting. Clear cut harvesting generally leads to declines in microbial biomass (Schilling et al. 1999) and extracellular enzyme activity (Hassett and Zak 2005) in the second year following harvest, although the first year response may initially be an increase or no trend, depending on the soil microbial composition prior to harvesting (Siira-Pietikäinen et al. 2001). Respiration follows the biomass response, initially enhanced following harvest (Schilling et al. 1999; Walmsley and Godbold 2009), due to depletion of easily decomposable substrate from logging slash and dead root biomass, and then declining (Siira-Pietikäinen et al. 2001). Bacteria may show no effect, decline (in particular N fixers), or increase (Siira-Pietikäinen et al. 2001). Effects on fungi include changes in species composition and diversity (Sayer 2006) and declines in fungal biomass (Siira-Pietikäinen et al. 2001; Forge and Simard 2000). Fungi are generally negatively impacted, particularly the mycorrhizae, likely related to a decrease in number of mycorrhizal root tips (Siira-Pietikäinen et al. 2001), and impacts for non-mycorrhizal fungi are generally poorly known (Marshall 2000). Recovery in microbial functioning generally occurs after 10 years (e.g., Houston et al. 1998) although some longer term changes in community composition have been observed (Hartmann et al. 2009). Changes over the longer-term are less apparent because of gradual recovery of most biological components with canopy closure (Marshall 2000).

The key factors affecting soil microbes associated with biomass harvesting are changes to the physical and chemical environment and the metabolic substrates (i.e., organic material for heterotrophs and inorganic molecules for chemoautotrophs). Soilmicroclimate affects rates of enzymatic reactions (temperature), solubilisation of substrate (soil moisture, pH) and ionization (pH). Soil disturbance impacts soil microclimate but also impacts soil horizons (bulk density, aeration, mixing), determining the amount of oxygen in the soil, which influences oxidation-reduction reactions in the soil. Litter, CWD, FWD, and stumps and organic matter in soil provide carbon substrate that fuels heterotrophic metabolism. The quantity determines the gross amount of substrate available, influencing the number of microbes, but quality of substrate determines which organisms are decomposing that material (e.g., fungi with higher C:N can break down organic matter with higher C:N) and the rate at which the material is broken down.

Reduced organic matter and nutrient inputs are perhaps the most obvious impact of intensified biomass removal (Hagerberg and Wallander 2002). In terms of corollaries, long-term agricultural field experiments may be the best proxy for the impacts of more intensive forestry. One of the key findings from the long-term agricultural research is the importance of returning “crop” residues to the soil (Vance 2000). In addition to residues as a source of C and nutrients for microbes, leaving debris on the harvested site: provides soluble tannins that inhibit nitrifying bacteria; reduces nitrate and cation leaching (Powers 1989); provides material that mitigates the adverse effects of harvesting machinery on logging trails (Addison and Barber 1997); enhances moisture retention; reduces erosion, and; provide sites for asymbiotic N-fixing bacteria (Amaranthus et al. 1989; Powers 1989).

The indirect effects of intensified biomass removals are the impacts of changes in the soil microbial community that filter up to other trophic levels. Decomposers have a strong “bottom-up” control on higher trophic levels, providing an ecosystem service of recycling nutrients required at higher trophic levels. In addition pathogens affect community size and composition of higher trophic levels. Mutualistic interactions, such as through N fixation or mycorrhizal associations, affect vegetation composition and vigour.

Conversely, soil microbes in turn are affected by changes in higher trophic levels that create “top-down” controls. In particular microbes are impacted by the amount of carbon substrate, from vegetation litter (leaves, branches, root exudates, etc.) and dead animal biomass, that is available for decomposition.

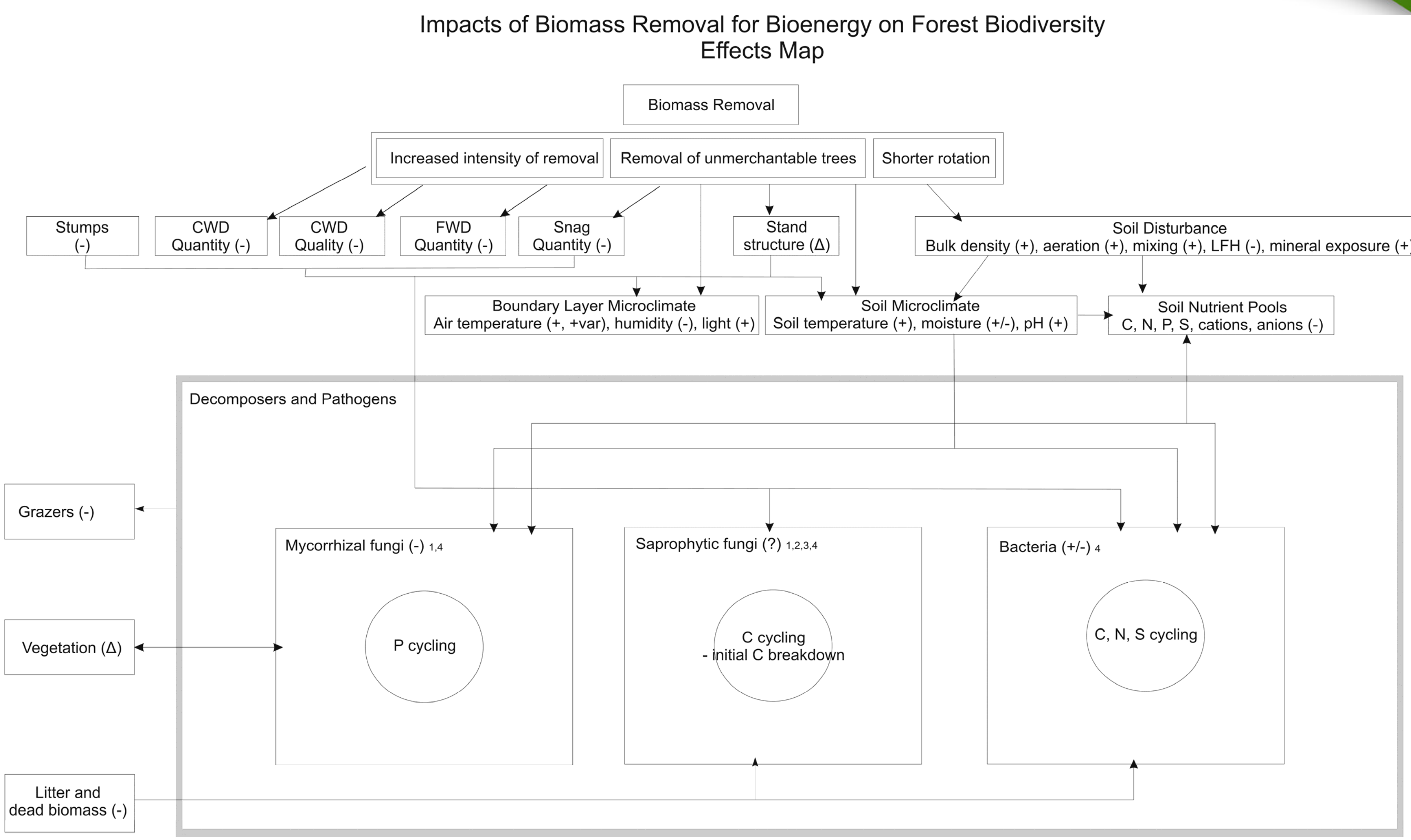

Figure 4. Effects map for impacts of biomass removal for bioenergy on soil microbes. Effects may be increasing (+), decreasing (-), both (+/-), unknown (?) or reflect change (Δ).References: [1]Forge and Simard 2000, [2]Marshall 2000, [3]Sayer 2006, [4]Siira-Pietikäinen et al. 2001.

A4.6 Vegetation model (Figure 5)

Vegetation is likely to be affected directly and indirectly by biomass removal, through damage and competition, respectively (Roberts 2004). An increased intensity of removal is likely to influence vegetation response in terms of regeneration strategy and competitiveness (Haeussler et al. 2004; Roberts 2004).

Changes in the deadwood profile are likely to impact the vegetation community. While the loss of snags directly affects epiphytes and lichens, the loss or modification of the characteristics of the down woody debris may affect vegetation recruitment and survival via modification of soil microclimate, loss of nurse logs and reduction of habitat diversity (Lee and Sturgess 2001; Crites and Dale 1998; Cole et al. 2008; Newmaster et al. 2007). Vegetation community composition and structure may also be affected by the loss of dead wood via a potential modification of decomposition and soil nutrition following a reduction in abundance of saproxylic fungi. Changes in decomposition that impact soil nutrition may lead to changes in species composition, some species being more sensitive to limitation of particular nutrients.

An increase in forest floor disturbance may also affect vegetation community (Nguyen-Xuan et al. 2000; Haeussler et al. 2002; Newmaster et al. 2007). Shorter rotation length may also impact vegetation, notably if it does not allow sufficient time for the vegetation community to converge toward mature community assemblage before the next rotation. Short rotations have been shown to favour the development of a dense understory layer that can delay tree recruitment (Royo and Carson 2006).

Vegetation has an immediate, filter and founder effect on ecosystem processes, through dominant species, subordinate species that influence the recruitment of dominants, and transient species, respectively (Grime 1998). Changes in vegetation community are likely to have a synergic feedback effect, resulting in further impact. For instance, modification of the understory vegetation composition and structure may affect propagule, seed and seed bank availability and composition, resulting in further modification of understory community over the longer term. Changes in vegetation community may also affect other trophic groups. Vegetation influences higher trophic groups via modification of animal habitat and resources. Vegetation response may also affect lower trophic groups for instance, soil fauna and fungi associated to a particular vegetation composition or structure (De Bellis et al. 2007). Changes in vegetation community may also affect ecosystem processes such as soil productivity (e.g., Wookey et al. 2009). However, lack of information on key effect traits such as the foliar and root nutrients, lignin and phenolic content for many key understory species reduce our capacity to predict how a modified vegetation community following harvesting for biomass could affect soil productivity.

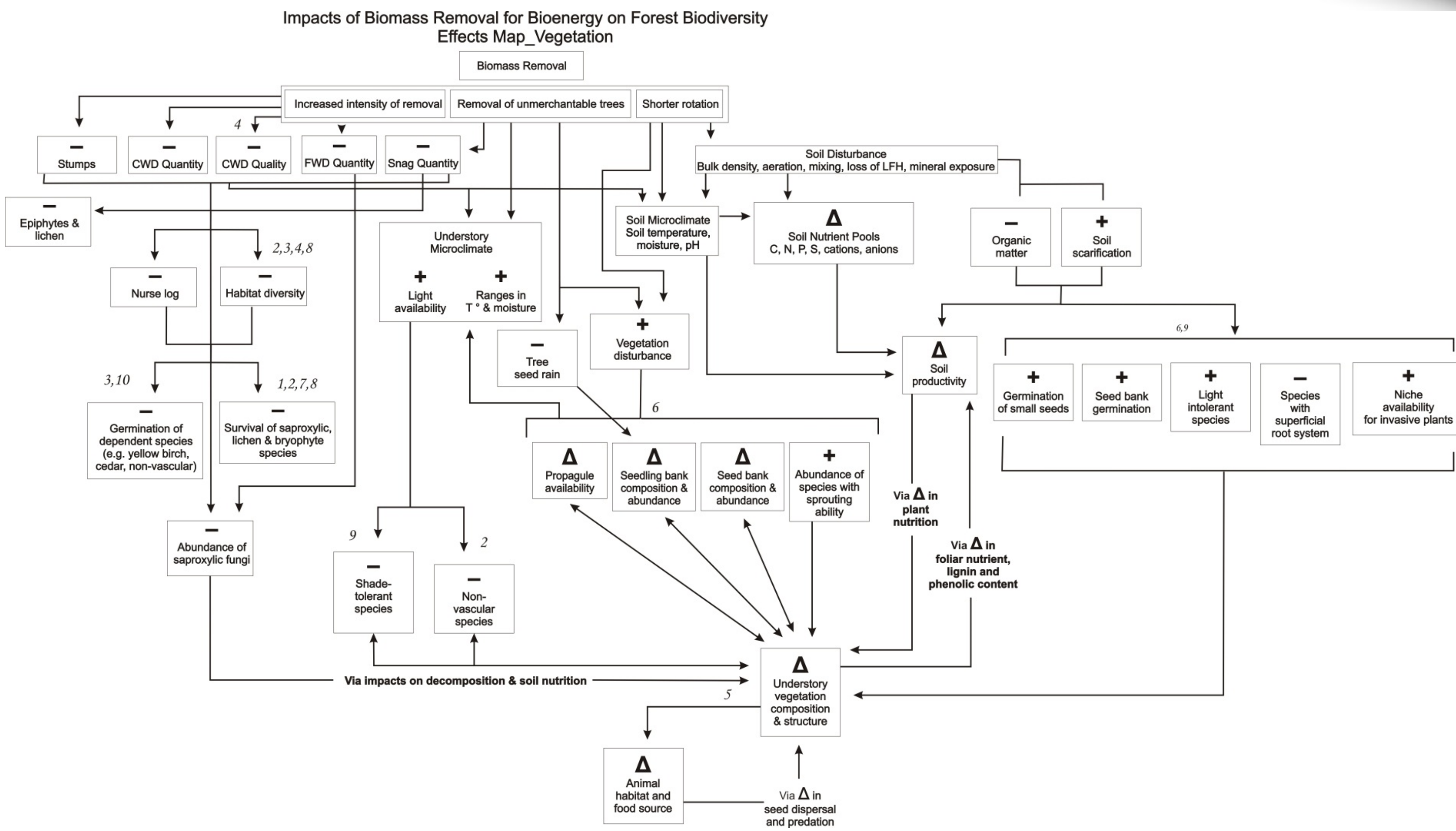

Figure 5. Vegetation effects pathways conceptual model. References: [1]Caners et al. 2009, [2]Cole et al. 2008, [3]Cornett et al. 2000, [4]Crites and Dale 1998, [5]DeBellis et al.2007, [6]Haeussler et al. 2002, [7]Jonsson et al. 2005, [8]Mills and MacDonald 2005, [9]Newmaster et al. 2007, [10]Simard et al. 2003.

A4.7 Invertebrate and Vertebrate Model (Figure 6)

Given the scope of this model we generated a fairly simple representation of the potential components and interactions for these groups. It is important to note that many of the relationships in this model are based on physical habitat requirements and are not necessarily trophic in nature. Of note, are the many saproxylic organisms (those that are directly or indirectly dependent on dead wood). The saprotrophic fungi provide a basis for a large contingent of fungivores including collembola (Hopkin 1997), dipterans (Grove 2002), coleopterans (Grove 2002) and mites (Johnston and Crossley 1993). These, along with the saprotrophic invertebrates, provide the trophic foundation for a wide variety of invertebrate predators, insectivorous mammals (Maser et al. 1979), and ground and bark foraging birds (Imbeau et al. 2001, Johnston and Holberton 2009). These in turn are preyed upon by a variety of top predators including owls (Mazur and James 2000), marten (Jensen et al. 2012) and foxes (Jones and Theberge 1983).

In terms of physical habitat and environment, stand structure is expected to have a significant effect on bird community composition (Venier and Pearce 2007). Snags are a necessary component for a variety of cavity nesting birds (Martin and Eadie 1999) and mammals (Martin et al. 2004) and the removal of unmerchantable trees is expected to reduce the future recruitment of snags. The boundary layer microclimate that is affected by stand structure and down wood quantity and structure is also expected to influence amphibians, small mammals (Maser et al. 1979) and epigaeic invertebrates (Pearce et al. 2003). The biomass removal effects on soil animals largely resembles the effects on soil microbes. As outlined in the soil microbe section, the reduction and redistribution of organic matter and associated effects (e.g., soil compaction, changes in plant community, changes in microclimate), will have a large impact on soil animal communities. Although we have not documented all of the possible components and connections in Figure 6, it is clear that biomass removal has the potential to impact a large proportion of the trophic web as well as having impacts directly through changes in habitat structure and microclimate. It seems likely that the more direct impacts (those effects that are more directly connected to the loss of biomass) will be better targets for initial research as their effects are less likely to be confounded by additional unrelated stressors and interactions.

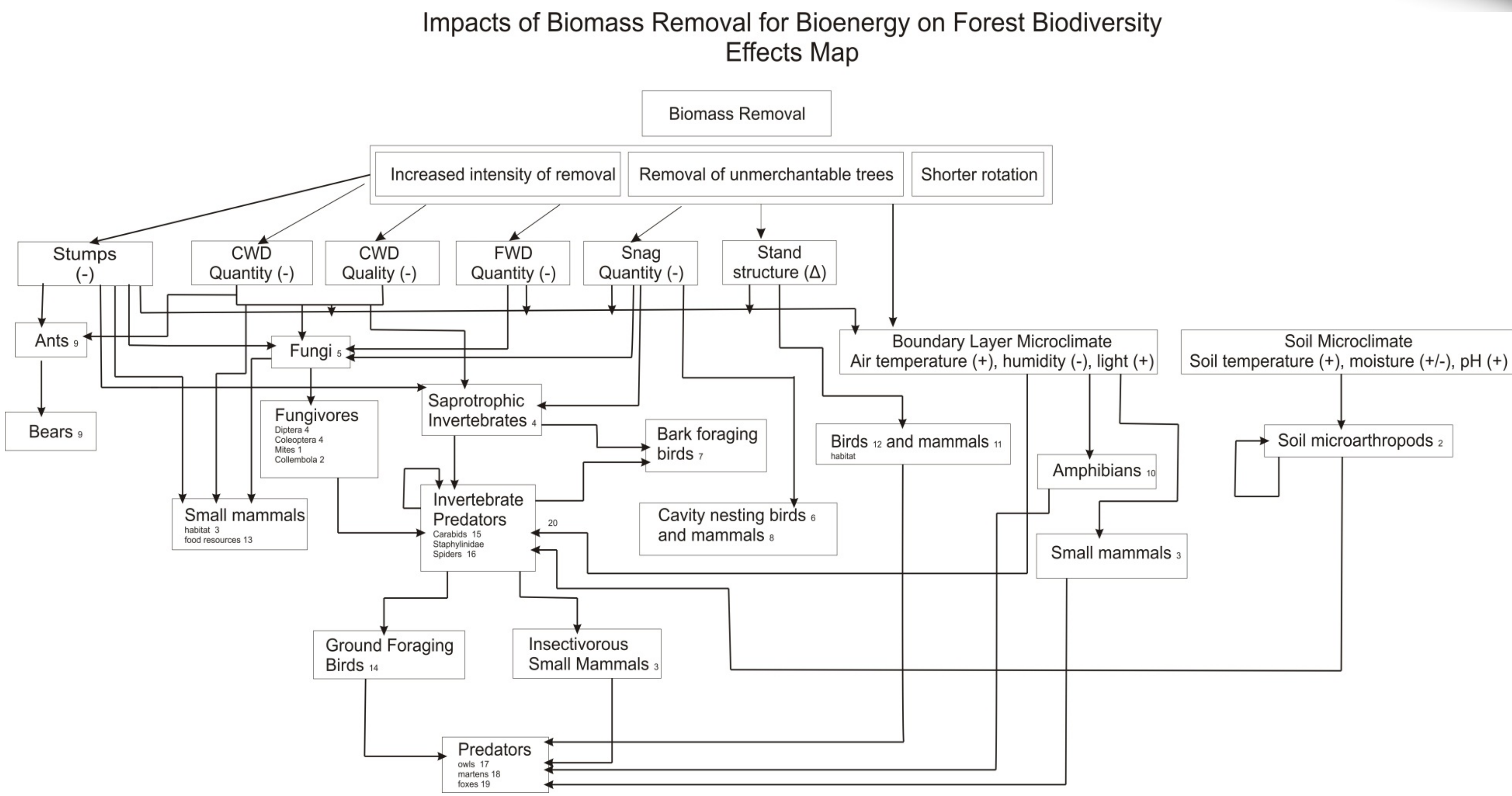

Figure 6. Effects pathways conceptual model for invertebrates and vertebrates. References: [1]Johnston and Crossley 1993, [2]Hopkin 1997, [3]Maser et al. 1979, [4]Grove 2002, [5]Boddy et al. 2008, [6]Martin and Eadie 1999, [7]Imbeau et al. 2001, [8]Martin et al. 2004, [9]Noyce et al. 1997, [10]Homyack et al. 2011, [11]St-Laurent et al. 2007, [12]Venier and Pearce 2007, [13]Orrock and Pagels 2002, [14]Johnston and Holberton 2009, [15]Lovei and Sunderland 1996, [16]Wise 1993, [17]Mazur and James 2000, [18]Jensen et al. 2012, [19]Jones and Theberge 1983, [20]Pearce et al. 2003.

A4.8 Key messages and common themes from the conceptual model

- The effects of biomass removal are primarily mediated through the loss of woody debris in all of its forms, changes in microclimate due to loss of cover, and increase in soil disturbance mainly through compaction.
- There is an array of physical, chemical and biotic impacts of biomass harvesting.
- Physical impacts involve alteration of habitat and changes in microclimate.
- Chemical impacts relate to soil pH and carbon and nutrient availability.
- Biotic impacts are mostly related to food web interactions (trophic effects).
- In addition to direct effects, there are indirect cascading effects up and down the food web.
- There is not always a clear positive or negative effect, particularly where there is a community of organisms (e.g., bacteria and fungi) that are composed of different species that perform different or redundant roles.
- Linkages among trophic levels have generally been poorly studied, and strength of connection and feedback among levels have not been not quantified.
- We expect that many effects will be specific to forest type such as coniferous vs deciduous.

APPENDIX 5: Research Priorities

During the workshop, the participants were separated into four multidisciplinary groups and were invited to identify the research questions and underlying hypotheses that need to be addressed to develop policy to ensure the sustainability of harvest for bioenergy. Further, they were asked to share their thoughts on the design of a manipulative research experiment that could effectively test the proposed hypotheses. The conceptual models developed in the first activity provided a framework from which to develop priority hypotheses. Each group was given a different fictive funding level (i.e., amount of money to run the research project: 50k, 100k, 500k and 1 million per year). The different funding levels were expected to result in different imperatives for priority setting. Each group was requested to identify:

- the elements to be measured to assess the impacts of biomass removal on biodiversity
- the approach taken to measure those elements
- specific statements of the hypotheses that need to be tested
- details of the study design to be implemented.

In this section, we first present highlights of the research proposals developed by each group, then we provide a summary of the key messages and common ground in study design among groups and then outline concerns and questions that were raised among groups.

A5.1 Group Highlights

<u>A5.1.1 Group A</u>
Funding level: $50,000/ year

<u>A5.1.1.1 Focus taken by the group</u>:
This group focused on the problem of guiding policy with limited resources. They summarized the research question as follows: In a harvesting for bioenergy context, how much slash should be left on site and how does that vary with site type?

This group emphasized the fact that beyond the research component, this question included a strong social and community component. Therefore, critical thinking and decision analysis in an adaptive management context including the values of multiple stakeholders should be used at the start to orient the objectives and research questions. Following this line of thought, projects that can accommodate values of more than one stakeholder should be prioritized.

Under a scenario of limited resources, they felt that the priority should be on the development of good/up-to-date knowledge based on a literature review/synthesis and theoretical models. A circumboreal retrospective of studies was suggested as a good learning tool (e.g., in this case, the effects of multi-rotational intense management taken from Nordic areas like Fennoscandia). Then, a modest long term trial with key treatments and monitoring key elements could be developed. The trial should focus on what might happen in the future in a scenario of a higher value for biomass and potential pressure to increase levels of biomass removal beyond current practices.

A5.1.1.2 Study design:
The trial design should be based on the results and methodology applied successfully somewhere else for a similar research question. The trial should include a contrasted range of biomass removal (i.e., 100% slash left on site, an intermediary level and 0% left on site) to help determine a threshold. A natural disturbance treatment (e.g., fire in the case of boreal forest) should be considered as the benchmark (control). To reduce the resources required, a critical time in the succession could be chosen for example when deadwood is at its lowest level and therefore most limiting.

A5.1.1.3 Response variable to be measured:
With limited resources, one key trophic or functional group should be chosen as the element to monitor. Saproxylic species and those that are known to have a strong linkage with stand productivity (e.g., driving nutrient cycling) were suggested. In addition, reduced tree growth as a surrogate of a change in site productivity has also been suggested as a potential indicator.

With limited resources, the choice of elements to be measured should be done with multiple stakeholder perspectives in mind. For instance, the response variable chosen to be measured may also be the one that has the most value for the First Nations, be known as sensitive in a biodiversity perspective, as well as the one that could more easily guide policy development.

A5.1.2. Group B
Funding level: $100,000/year

A5.1.2.1 Focus taken by the group:
This group focused their discussion on whether or not a threshold response to biomass removal exists. They provided specific questions derived from different perspectives: From an industrial perspective: How much can we take out from a site without any significant impact? If a threshold exists then that would be the operational target for slash retention. From a research perspective: What is the shape of the biodiversity response curve to increasing biomass removal? Is there a threshold? Will thresholds be different among taxa? Does it vary with time since disturbance?

A5.1.2.2 Study design:
The experimental design was focused on manipulating different characteristics of the wood profile, principally on two main axes:
a) Quantity of biomass. An experimental design including a full range of biomass removal
b) Quality of woody debris. This should include different species composition (i.e., hardwood and softwood), but also different size classes and level of decomposition. This would address the question: do we need big wood or does lots of little wood suffice?
With limited resources, it was recognized that a full suite of biomass removals (in terms of quantity and quality – driven by species composition – building on Jay Malcolm's talk) was not possible. In this case, the group suggested a simplified study design, keeping only two levels of biomass removal treatments. They felt the best approach would be to have a paired set of removals that bracketed the current level of acceptance (one higher and one lower), but where still operationally and economically feasible. If possible, this should be stratified by high hardwood vs high conifer retention. If the number of site types

is limited due to budget limitation, they suggest using the literature to identify those deemed most sensitive to biomass removals.

For the selection of the response variables/indicators, the group talked about looking at the case of regions with similar forest ecosystems (e.g., Europe) where they have a longer history of intensification of biomass removal and identify what they have lost with this intensification and with time (i.e., sensitive taxa in Europe). They suggest using the European literature and the European red-listed species to identify species sensitive to intensive removals. "Sister" species for North America, i.e., possessing similar characteristics or requirements could then be identified as potentially sensitive species.

A 3-taxa node approach was suggested by this group as response variables to be measured:

- bird communities (require vertical complexity),
- small mammals (require horizontal complexity),
- fungal communities (some species-specific DWD responses).

An additional fourth node, the insects, was also suggested. To obtain an ecosystem level assessment without having to measure everything, it was suggested to make a detailed analysis of few key selected groups that are good links among these nodes.
This group hypothesized that lower trophic levels are going to be more affected by an increasing intensity of biomass removal.

<u>A5.1.3 Group C</u>
Funding level: $500,000/ year

<u>A5.1.3.1 Focus taken by the group</u>:
The group summarized the research question as follows: How does diversity change with intensity of biomass harvesting? The group felt that an equally important but less tractable question was how biomass harvesting affects ecosystem services. Currently, we don't know enough about the response of the different components of the ecosystem or the relationship between biodiversity and ecosystem processes and services to get to this question but the group felt that it will be an important one in the future. For instance, if the underlying goal of biomass harvesting is to displace systems that use fossil fuels and ameliorate global warming then it should be recognized that forest ecosystems play a big role in composition of the atmosphere by exchanging carbon dioxide, methane, and nitrous oxide. We should be looking at the impact of biomass harvest on the microbes that are producing these gases to confirm that this form of forest management is not exacerbating the greenhouse gas emission problem.

<u>A5.1.3.2 Study design</u>:
This group highlighted that not only does deadwood abundance and distribution change over time, but also the state of decomposition of deadwood changes over time. Therefore appropriate controls must consider both time since disturbance and time since death of the tree. They argued for using 2 nested chronosequences as controls: stands that correspond to different loads of deadwood at different stages of succession and inside of that, chronosequences of logs ranging from fresh deadwood to well decomposed deadwood. These two chronosequences would provide the full range of natural variability in the deadwood profile.

Two simultaneous approaches could be used to examine the impact of biomass removal on biodiversity. First, sites with previous biomass removal disturbances could be searched out to use in a retrospective study. This approach would be limited by the availability of stands with the appropriate treatment at the appropriate successional stage. The advantage of this retrospective approach would be the ability to examine a complete chronosequence immediately rather than needing to wait for succession. The second approach would be to put treatments into place that examined the full range of biomass removal. The group recommended that sites should be included with the following levels of woody biomass left on site (80, 40, 20, 10, 0 $m^3 \cdot ha^{-1}$). This range of retention would bracket the 40 $m^3 \cdot ha^{-1}$, suggested as a threshold value based on the research lead by T. Work on invertebrates.

If resources are limited, the experiment should be conducted in the most sensitive ecosystem. For instance, select a recently disturbed stand and manipulate wood biomass into a gradient of CWD retention. An additional set of treatments could also include a gradient of fine woody debris.

A5.1.3.3 Response variables to be measured:

- Focus on the groups of organisms that have been shown to respond to losses of dead wood.
- The group highlighted vascular and non-vascular plants, and insect groups (e.g., leaf litter invertebrates).
- Groups that use dead wood as a resource, such as fungi and saprotrophic insects (more likely to be sensitive to decompositional state of deadwood).
- A potentially useful metric to relate biodiversity changes to key ecological services would be the biomass within each trophic level. By tracking biomass increment, you can, in turn, follow the flow of energy (carbon) between each trophic level.

A.5.1.4 Group D
Funding level $1,000,000 / year

A5.1.4.1 Focus taken by the group**:**
The group summarized the research questions as follows: Will intensification of biomass removal lead to a decrease in biodiversity? When does biomass removal become detrimental to ecosystem resilience? What is the minimum manipulation (biomass removal) to get a signal? Is there a linear response or threshold level that triggers a negative response? How does this ecological threshold compare to a socially-acceptable threshold?

A5.1.4.2 Study Design:
Under sufficient resources, the group suggested increasing spatial distribution and resolution, increasing the number of replicates, including the social aspect and including a larger number of trophic levels. The main challenge identified by this group was to find a design that can incorporate the landscape perspective, with modeling suggested as a helpful tool to do so. They suggest working both at the landscape and stand level to maximize the application of the results at broader regional/national scales. They identified the value in the development of a network of studies across Canada. The research project could be designed with subgroups of the research team, one looking at physical, and the others at specific

biological aspects. The EMEND (Ecosystem-based Management Emulating Natural Disturbance) project was presented as an example of this.

The experimental design should include a strategy to link the response of the different groups of elements that composed the trophic web with the abiotic component. Time and space were identified as critical elements to consider in the design of the experiment. Natural spatial variability should be taken into account. A dynamic system modeling approach was identified as being a potentially useful tool for scaling information over both time and space. Such an approach would be well suited for making future predictions, and for identifying sensitive variables. A range of removal intensity (it has been suggested to bracket the suggested minimal retention of CWD of 40 $m^3 \cdot ha^{-1}$).

This group suggested a nested design stratified by ecoregion including 6 landscapes of 500km x 500 km and 6 sites of 100m x 100m). Plots of 70 x 70m to 100 x 100 m were suggested as a minimum scale for the sampling units.

They suggest using different “natural disturbance” controls according to the treatment intensity and match a management type (e.g., shelterwood, clearcut) to a specific disturbance type of similar intensity (wind disturbance, insects, fire).

A5.1.4.3 Response variables to be measured:
They suggested a nested multiscaled evaluation of response variables. More specifically, they suggest measuring a range of taxa. The selected taxa should be identified according to their sensitivity, with priority given to the one with the most cross-taxa linkages. Structural attributes (e.g., volume of coarse wood) and abiotic variables (e.g., soil nutrients) should also be measured.

APPENDIX 6: Effectiveness Monitoring

We asked workshop participants to identify priority hypotheses that should be addressed using effectiveness monitoring to ensure the maintenance of ecological integrity in the context of biomass harvesting. Table 2 lists all of the hypotheses that were suggested. It was our hope that hypotheses would be specific enough to test without much additional discussion, for example, that hypotheses would specify species or groups of species to examine, and that temporal and spatial scale would be specified, etc. However, for the most part participants were reluctant to get too specific and generated very broad and general hypotheses that will require much more discussion to become testable. We then asked participants to vote for hypotheses that were felt to be the highest priority.

Table 2. Hypotheses suggested by individual participants to be considered as part of an effectiveness monitoring framework

1. Characterization of stand structure and DWD (size, class, volume) are suitable proxies for determining acceptable levels of biodiversity (microbial, plant, fauna).
2. Across spatial scales and over time, intensification of biomass harvest (relative to current guidelines) to a level of X $m^3 \cdot ha^{-1}$ will not lead to 1. Extirpation or long-term decline of key wildlife species (plant or animal) that is directly dependent on forest biomass 2. Degradation of key ecological processes associated with creating DW.
3. Niche diversity is reduced by forest management activities compared to natural disturbance.
4. Rates of community recovery will not differ between biomass harvest stands and naturally disturbed stands. At the stand scale, trophic community profile (richness and evenness), vascular plants, ground arthropods, small mammals at 0, 5, 25 years, are appropriate post-treatment temporal benchmarks of stand recovery.
5. Biomass harvesting may alter the understory structure relative to traditional harvesting and natural disturbance.
6. Biomass harvest does not affect microbial biomass or composition at either the molecular or functional level.
7. The monitoring program will have the necessary adaptive management tools and flexibility to be able to respond properly to stakeholder evolution.
8. From a social perspective, a more intensive harvest level (beyond current practices) will be acceptable or palatable to the public.
9. In time (10-20 years) variability in decay stages of downed logs will decline as a result of biomass removal.
10. Annual monitoring of biodiversity, as specified by a keystone species (i.e., species responsive to retained wood-standing and downed-patches) at the stand level is sufficient to track response to forest management impacts from biomass removal.
11. Mycorrhizal fungi will be reduced with intensive harvesting, with direct links to nutrient cycling, tree growth, and food supply for small mammals.
12. By site type: maintaining the complete (or 50%) range of pre-harvest downed wood (quantity, quality of both FWD and CWD) and current requirements for standing tree retention will maintain the full range of dead-wood dependent species over time (bryophytes, lichens, cavity nesters).
13. At the cut block scale, recovery of plant species composition and litterfall N rates following biomass harvesting will vary depending on site type, intensity of removal and time since harvest

14. Increased biomass harvesting will result in higher levels of non-native plant species establishing at a given site, indicating forest community alteration. Biomass harvesting will result in a loss of bryophytes, site disturbance, niche openings, forest community destabilizaton, and microsite alteration.
15. Biomass removal will not affect the distribution and abundance of calicioid lichens and hepatics over either the short-term (0-10 years) or long-term (70 years).
16. Reductions in tree recruitment and regeneration, resulting from changes in microclimate and microtopography, will result from more intensive harvest operations.
17. Resilience will increase with the number of "keystone" nodes that are preserved in the foodweb network.
18. Increased removal of biomass will negatively impact abiotic factors and reduce quantity, quality of the habitat which, in turn, will decrease mature forest macroarthropod diversity, and increase opportunistic macroarthropod diversity. Changes in the relative abundance will occur over time.
19. The level of CWD/FWD retention associated with biomass harvesting does not impact ecological integrity when compared to natural disturbance over the course of a full rotation.
20. Current guidelines for biomass harvest do not reduce the landscape level available CWD and FWD below ecologically sustainable levels over the long-term (1 rotation).
21. Ontario's policy framework for forest management provides for sustainability. The amount and kinds of biomass indicated in FMPs can be achieved without significant or irreversible change in inherent structure or ecosystem function.
22. Our current guidelines emulate natural disturbance processes and landscape disturbances while minimizing adverse effects on plant life, animal life, water, soil, air.
23. Increased biofibre removal relative to current full-tree harvesting will increase soil nitrogen availability immediately post-harvest but decrease over time.
24. Biomass harvesting as proposed in current guidelines, will emulate natural disturbance regimes (notwithstanding the effects of post-harvest silviculture) and will not contribute to the loss of fungi, plant or animal diversity, will not cause irreparable damage to ecosystem function or processes, will be economically viable and will be socially acceptable.
25. Uncertainty of biomonitoring is greatest when CWD is lowest along a chronosequence of stand types (time since fire).

Participants scored hypotheses based on *feasibility, sensitivity, connectivity* and *degree of integration*. Feasibility was the likelihood that the hypothesis could be successfully tested. Sensitivity was the likelihood that the response would be sensitive to biomass removal or that a lack of response would indicate that the ecological integrity was not compromised. Connectivity was measured as the number of nodes in the effects pathway that were connected to the response. The degree of integration was estimated by how well the various components of the hypothesis were integrated into a synthetic understanding of the system. All participants were then asked to vote on the highest priority hypotheses. Each participant was given 5 votes and could vote for one hypothesis more than once. The top three hypotheses are listed as the first three hypotheses in Table 2. Each of these hypotheses was then given to a break out group to design a monitoring project that could address the hypothesis.

A.6.1 Group 1. Characterization of stand structure and CWD (size, decay class, volume) are suitable proxies for determining acceptable levels of biodiversity (microbial, plant, fauna).

The discussion centered around a 2-tiered approach that would include extensive monitoring of woody debris (size, decay class, volume). This, in essence, would be compliance monitoring in that it monitors the forestry activity for meeting the woody debris objectives that are predicted to meet the biodiversity objectives. The second tier would involve intensive monitoring of biodiversity in sites with a gradient of woody debris retention, assuming that current practices would leave some variation in woody debris amounts on sites. Considerable discussion centered around which taxa would be most appropriate for intensive monitoring. It was recognized that species that are directly dependent on dead wood (i.e., saproxylics) would be a good focus, in part, because the Scandinavian example suggests that saproxylics will be significantly impacted. There was no general consensus on other groups to monitor although the issue of appropriate spatial scale came up in that many species require relatively large spatial scales to monitor effectively (e.g., birds, mammals, monitoring saproxylics with flight intercept traps). Other variables that will affect the outcome were identified: site region, site type, age at time of harvest, harvest system, disturbance type and time since disturbance. Sampling would need to be stratified over these variables to fully understand the woody debris dynamics in relation to forestry operations. The inclusion of disturbance type here implies that natural disturbance could act as a reference condition for measurements although this was not stated explicitly. Some suggested that current practices are successful at maintaining ecological integrity. However, to the best of our knowledge this has not been demonstrated from a woody debris perspective. The age at time of harvest is an interesting variable in that it recognizes that wood debris content changes over time in forest stands. At later stages, woody debris is recruited with time so older forests that are harvested have the potential to have more woody debris than younger forests. It was suggested that effectiveness monitoring be linked to ongoing programs including Silviculture Effectiveness Monitoring (SEM), Growth and Yield program (G&Y), the National Forest Inventory Program (NFI), and Enhanced Forest Resource Inventory (EFRI).

A6.2 Group 2. Across spatial scales and over time, intensification of biomass harvest (relative to current guidelines) to a level of X $m^3 \cdot ha^{-1}$ will not lead to (1) extirpation or long-term decline of key species (plant or animal) that are directly dependent on forest biomass (2) loss of key ecological processes associated with creating deadwood.

This group emphasized an ecological stratification approach with samples stratified by cover type (hardwood, conifer, mixedwood), age (early, mid, late seral stages) and natural disturbance types (fire, insect outbreak, gap phase dynamics). Sampling design would be nested with a primary sampling node being landscape defined ecoregionally, and secondary sampling sites within nodes. Focal species selection would be guided by research and current knowledge, with floral, faunal and fungal diversity being pushed through an ‘indicator selection filter’. Selection criteria would include sensitivity to management, ability to detect an effect, dependency/association. The metric for focal species would likely be occupancy or probability of occupancy. Deadwood characteristics and dynamics would be measured including quantity, quality, dispersion and distribution. Deadwood dynamics and supply would be modelled to support the monitoring program.

A6.3 Group 3. Niche diversity is reduced by forest management activities compared to natural disturbance.

Examples of niche diversity were given as stand structure and composition, coarse and fine woody debris, light availability, substrate and soil properties. There is a need to link niche diversity with species occurrence to more directly address the issue of biodiversity. The idea of using the Scandinavian evidence for sensitive species to identify species to monitor was supported. As with the first hypothesis, the idea of using both an extensive and intensive approach was suggested. This group was particularly interested in using a multi-scale approach including the landscape scale because of the scale of the disturbances. As stated in the hypothesis, natural disturbance was recommended as the reference condition. The importance of examining the difference between different forest types was emphasized. Gradient of removal could be examined from light disturbance to intense disturbance. It was suggested that there may be existing sources of data available to address this hypothesis and that modelling should be used to understand dynamics. Plots should be measured every 5 years to capture the temporal dynamics of changing niche diversity and biodiversity response through time.

APPENDIX 7: Workshop Agenda

Day One: Wednesday, February 22, 2012

	8:30	**Greetings and workshop process** Lisa Venier and Isabelle Aubin CFS-GLFC, Sault Ste Marie	
Moderator for the day: Isabelle Aubin			
Block One	9:40	**Overview talk** "A short review of studies on biomass harvesting impacts on biodiversity" Lisa Venier CFS-GLFC, Sault Ste Marie	
	10:00	*Coffee and Tea Break*	
Block two	10:15	**Break-Away Group Session #1** "A closer look at effects of biomass removal on taxa and Identifying research priorities"	
Block two	11:00	**Interactive Session** "Developing a conceptual model of biomass removal effects on ecosystem components and functions"	
	12:00	*Lunch in the GLFC*	

Block three	**13:00**	Round table synthesis on the conceptual model
	13:30	**Presentation: A field study example** "Boreal small mammal, fungi, and insect communities as a function of variation in downed woody debris quantity and quality" Jay Malcolm University of Toronto
	13:50	Break-Away Group Session #2 "A closer look at research priorities" 
	15:00	*Break*
Block four	**15:15**	**Group Reports and Round Table Synthesis**
	16:15	Review of the day: Look at the challenges ahead
	16:30	***Finish***
	18:30	***Supper at Dock's Restaurant***

Day Two: Thursday February 23, 2012

8:30 **Recap from Day 1**
Isabelle Aubin
CFS-GLFC, Sault Ste Marie

Moderator for the day:* *Lisa Venier and Kara Webster

8:45 **Introduction to workshop process for Day 2**
Lisa Venier
CFS-GLFC, Sault Ste Marie

Block	Time	Session
Block One	**8:55**	**Overview talk** "Hypothesis-driven forestry guidelines and effectiveness monitoring" **Rob Rempel, OMNR**
	9:15	**Talk** "The bioeconomy as it pertains to the forest industry - past, present and future" Joe Maure MNR, Industry Relations Branch, Sault Ste Marie
	9:35	**Break-Away Group Session #1** "Identifying key hypotheses for effectiveness monitoring" 
	10:35	*Coffee and Tea Break*
Block two	**10:50**	Round table synthesis "Prioritizing hypotheses"
	11:50	*Lunch in the GLFC*

Block three	12:50	**Break-Away Group Session #2** "Developing a monitoring design to test hypotheses"	
	14:20	**Round table synthesis**	
	15:00	*Break*	
Block four	15:15	**Plenary discussions on key points and questions**	
	16:30	*Finish*	

APPENDIX 8: Preparatory material

Preparatory material for POLICY MAKERS and FOREST MANAGERS

For the workshop to run efficiently, we would appreciate that you take some time to think about a few questions we've outlined below.
This preparation is important as we will base the success of the workshop on the quality of the 'content' and conversations derived from the group exercises and discussions.

Preparatory Question No.1:

With the growing interests in bioenergy how will the current harvesting practices and operations change?

Preparatory Question No.2:

What are the current knowledge gaps? What are the research priorities that need to be addressed to inform biomass harvesting policy?

Preparatory Question No.3:

Participants will be invited to develop a conceptual model on the effects of biomass removal on abiotic and biotic elements.

Please take a few moments to think of which elements you would include in a conceptual model. How are some elements interrelated? Which elements or interactions are particularly more sensitive to biomass removal?

Preparatory Exercise No.4

Food for thought: we invite you to watch a 3 minute TED TALK on the simplification of complex conceptual models at the following link:

http://www.ted.com/talks/eric_berlow_how_complexity_leads_to_simplicity.html

And lastly, below are few questions which will be discussed at the workshop that you may want to think about ahead of time:

- What are the elements that should be measured in priority to assess the impacts of biomass removal on biodiversity, and how?

- What are the elements that should be prioritized in a monitoring program that measures the impacts of biomass removal on biodiversity? At what intensity, frequency, etc?

Merci et au plaisir de discuter de tout cela prochainement!

Preparatory material for Researchers

For the workshop to run efficiently, we would appreciate that you take some time to think about a few questions we've outlined below (*especially the first question*).
This preparation is important as we will base the success of the workshop on the quality of the 'content' and conversations derived from the group exercises and discussions.

Preparatory Question No.1:

Based on your expertise, what are the direct and indirect impacts of biomass removal on the taxon or taxa you are familiar with in your own research? Provide references and specifics (scientific papers but also ongoing research).

Preparatory Question No.2:

At least three main aspects of the intensification of biomass removal in the context of bioenergy are:

- Higher quantity of biomass removed
- Removal of non-commercial woody species
- Shorter rotation

Please add additional aspects, detailing their primary impacts (e.g. loss of CWD, decreases in soil moisture) and provide specifics on how they could influence the taxa you are familiar with.

Preparatory Question No.3:

Based on the impacts and linkages derived from question 1, participants will be invited to develop a conceptual model on the effects of biomass removal on abiotic and biotic elements.

Please take a few moments to think of which elements you would include in a conceptual model. How are some elements interrelated? Which elements or interactions are particularly more sensitive to biomass removal?

Preparatory Exercise No.4

Food for thought: we invite you to watch a 3 minute TED TALK on the simplification of complex conceptual models at the following link:

http://www.ted.com/talks/eric_berlow_how_complexity_leads_to_simplicity.html

And lastly, below are few questions which will be discussed at the workshop that you may want to think about ahead of time:

- What are the new research priorities emerging from the growing interest in bioenergy which need to be explored to inform biomass harvesting policy?

- What are the most important questions that need to be addressed?

- What are the elements that should be measured in priority to assess the impacts of biomass removal on biodiversity, and how?

- What are the elements that should be prioritized in a monitoring program that measures the impacts of biomass removal on biodiversity? At what intensity, frequency, etc?

Merci et au plaisir de discuter de tout cela prochainement!

Preparatory material for the INDUSTRY

For the workshop to run efficiently, we would appreciate that you take some time to think about a few questions we've outlined below.
This preparation is important as we will base the success of the workshop on the quality of the 'content' and conversations derived from the group exercises and discussions.

Preparatory Question No.1:

With the growing interests in bioenergy how will your current harvesting practices and operations change?

Preparatory Question No.2:

What are the important questions for researchers to focus on answering in order to properly and efficiently evaluate the impacts of intensive biomass harvesting?

Preparatory Question No.3:

Participants will be invited to develop a conceptual model on the effects of biomass removal on abiotic and biotic elements.

Please take a few moments to think of which elements you would include in a conceptual model. How are some elements interrelated? Which elements or interactions are particularly more sensitive to biomass removal?

Preparatory Exercise No.4

Food for thought: we invite you to watch a 3 minute TED TALK on the simplification of complex conceptual models at the following link:

http://www.ted.com/talks/eric_berlow_how_complexity_leads_to_simplicity.html

And lastly, below are few questions which will be discussed at the workshop that you may want to think about ahead of time:

- What are the new research priorities emerging from the growing interest in bioenergy which need to be explored to inform biomass harvesting policy?
- What are the most important questions that need to be addressed?

- What are the elements that should be measured in priority to assess the impacts of biomass removal on biodiversity, and how?

- What are the elements that should be prioritized in a monitoring program that measures the impacts of biomass removal on biodiversity? At what intensity, frequency, etc?

Merci et au plaisir de discuter de tout cela prochainement!

Preparatory material for the Forest communities and First Nation

For the workshop to run efficiently, we would appreciate that you take some time to think about a few questions we've outlined below.
This preparation is important as we will base the success of the workshop on the quality of the 'content' and conversations derived from the group exercises and discussions.

Preparatory Question No.1:

With the growing interests in bioenergy how will forest communities be affected?

Preparatory Question No.2:

What are the important questions for researchers to focus on answering in order to properly and efficiently evaluate the impacts of intensive biomass harvesting?

Preparatory Question No.3:

Participants will be invited to develop a conceptual model on the effects of biomass removal on abiotic and biotic elements.

Please take a few moments to think of which elements you would include in a conceptual model. How are some elements interrelated? Which elements or interactions are particularly more sensitive to biomass removal?

Preparatory Exercise No.4

Food for thought: we invite you to watch a 3 minute TED TALK on the simplification of complex conceptual models at the following link:

http://www.ted.com/talks/eric_berlow_how_complexity_leads_to_simplicity.html

And lastly, below are few questions which will be discussed at the workshop that you may want to think about ahead of time:

- What are the new research priorities emerging from the growing interest in bioenergy which need to be explored to inform biomass harvesting policy?

- What are the most important questions that need to be addressed?

- What are the elements that should be measured in priority to assess the impacts of biomass removal on biodiversity, and how?

- What are the elements that should be prioritized in a monitoring program that measures the impacts of biomass removal on biodiversity? At what intensity, frequency, etc?

Merci et au plaisir de discuter de tout cela prochainement!