Living Legacy Trust Proposal - Stage 3 - Detailed Proposal (Second Submission)
Title: An Operational Methodology for Measuring and Analyzing Bioindicators to Support Sustainable Forest Management.
Proponents: Dr. Lisa Venier, Dr. Jennie Pearce, Dr. Dan McKenney, Great Lakes Forest Research Centre, Canadian Forest Service, Sault Ste. Marie, Ontario, P6A 5M7
Partners: Chris Grant, Domtar; Keith Wade, Pukaskwa National Park; Scott Jones & Dean Phoenix, Wildlife Assessment Program, Ontario Ministry of Natural Resources

1. STATEMENT OF OBJECTIVES

Introduction and Background

What we plan to do

- Our **general objective** is to **empirically** evaluate a specific set of ecological bioindicators of Ontario boreal forest sustainability. We define bioindicators as species or assemblages that can indicate a disruption in ecosystem processes due to timber harvesting activities.
- **The major outcome of this study** will be an operational field methodology to measure and evaluate bioindicators for sustainable forest management in Ontario.
- Thus, this **report** will
    1. identify specific monitoring questions and needs with partners,
    2. recommend which data to collect, how best to collect it, how much it will cost to collect and analyse,
    3. recommend how to analyse the data to extract the necessary information
    4. discuss how models may be employed in bioindicator monitoring programs.
- These methods for analysis and interpretation of bioindicator data will be **focused on meeting planning, reporting, regulation and management objectives**.
- We will develop this operational methodology using the Pukaskwa / White River area as a case study. This area is ideal as it contains a large National Park with minimal anthropogenic disturbance history as a control, and a heavily managed forest.
- We will **collect field data** to
    1. assess the sensitivity of the proposed bioindicators and data collection methods to detect differences in population levels and species assemblage composition within mature forest in disturbed versus undisturbed landscapes
    2. assess bioindicator response to succession (using space as a substitute for time)
    3. assess methods to develop and quantitatively evaluate habitat models developed using monitoring data, local vegetation data and large-scale land cover data including FRI and Landsat TM.
- The **methods** that we identify will be applicable across the boreal. Specific results are applicable within the study region.
- **Our intent is to provide a model** for how to obtain meaningful answers from bioindicator data, not to identify bioindicators applicable for the entire boreal. The species and groups of species we examine will be specific to this geographic area.
- We have provided a detailed justification for the **species** that we have selected (see Taxa Selection below) but one of the main criteria is that the species have been identified in Ontario as potential indicators through other processes conducted by the Ontario Ministry of Natural Resources.

Policy context

The World Commission on Environment and Development (WCED 1987) proposed that criteria and indicators could be used to examine the sustainability of renewable resource management by periodically monitoring certain indicators within the managed environment. Subsequent to this, agreements among nations that export forest products (Montreal Process, 1995) proposed to use criteria and indicators for assessing forest management and to certify that fibre products were produced sustainably. These agreements resulted in the publication of a list of criteria and their associated indicators for Canada by the Canadian Council of Forest Ministers (CCFM 1995, 1997).

In Ontario, the "Class Environmental Assessment for Timber Management on Crown Land" (Timber EA) (Ontario Ministry of Environment 1994) and the Crown Forest Sustainability Act (CFSA), passed in 1995, provide a legal framework requiring Ontario to demonstrate that forest harvesting is conducted in a manner not detrimental to the sustainability of forest ecosystems. Therefore, in Ontario there is a legal imperative to demonstrate that timber harvesting is undertaken sustainably, and CCFM provides a framework and broad list of indicators to achieve this. An operational methodology to implement this objective has not be established.

Bioindicator framework

McGeoch (1998) provides a very good framework for the testing and application of bioindicators which is comprised of nine steps (see Table 1). We use this framework to review the work on bioindicators in Canada to date, and to place the proposed project into context. **Step 1**: Broad objectives to assess the sustainability of forests have been determined through international, national and provincial level processes. **Step 2**: The refinement of objectives and definition of a clear endpoint. These have not been well developed in Canada (Lautenschlager 2000). There are examples of operational level use of surrogates of bioindicators, such as habitat, in forest planning (e.g. Duinker et al. 2000, Biodiversity Assessment Program BAP). However these projects rely on hypotheses of how the bioindicator responds to management actions, rather than directly testing this relationship. There are no operational level discussions directly relating the bioindicators to sustainable forestry.

Step 3: Selection of bioindicators: Numerous authors have discussed biological and practical criteria for the selection of bioindicators (e.g. Landres et al. 1988, Noss 1990, Spellerberg 1991, Kremen et al. 1992, Hammond 1994, Pearson 1994, Niemi et al. 1997, McGeoch 1998, McLaren et al. 1998, Simberloff 1998, Wedeles and Willams 1999). McLaren et al. (1998) report on the ongoing process in Ontario to select vertebrate wildlife species as indicators under two of the CCFM (1995) criteria: criterion 1, "Conservation of Biological Diveristy," indicator 1.2.2, "Population levels and changes over time of selected species and species guilds;" and Criterion 5, "Multiple Benefits to Society," indicator 5.1.3 "Animal population trends for selected wildlife species of economic importance." They developed a set of criteria to *a priori* select potential vertebrate indicator species, and from this, suggested 49 species as indicators within the boreal forest region (selected mammals, birds, and amphibians). This is an important step forward, as it reduces effort from being directed to species unlikely to be good indicators. Work has also been undertaken at the model forests in Canada to refine the use of criteria and indicators as part of their Local Level Indicators (LLI) program (Canadian Model Forest Network 2000). In particular, the Lake Abitibi model forest has undertaken to screen and test a wide range of indicators relevant to CCFM and to test the indicators using existing data for test areas (Wedeles and Williams 1999). They provide recommendations regarding the specific indicators to be used for meeting each of the criteria listed in the CCFM. **However, they do not provide information on the species to be chosen, or the process through which they may be chosen, and tested as indicators of sustainability. These studies only identify potential indicators. There have been no direct empirical tests as to the effectiveness of these species as indicators. Although standard survey techniques are available for most of the species listed, no details on how to effectively monitor these species in the context of forest sustainability have been proposed.**

Detailed information on how to monitor these species to be able to detect a significant impact of forest harvesting on species populations is imperative to meeting Ontario's legal obligations. At present, the Wildlife Assessment Program of the Ontario Ministry of Natural Resources is establishing a monitoring network across the productive Ontario forest to monitor small mammals, songbirds and salamanders. Detailed data on the occurrence and abundance of all species present within an area (not just the suggested bioindicator species) is being collected at these monitoring sites. This data may be used to examine the feasibility of these suggested indicators over a wide area. However, this monitoring network has been rapidly established to meet a variety of needs, with little emphasis placed on the needs of bioindicator monitoring and evaluation. **There has been no assessment of the design, and intensity of sampling required to adequately sample the local population at each of the relevant spatial scales (stand, forest, landscape), and over what time scale a trend is likely to be detected.**

Steps 4-7: The next 4 steps of McGeoch's (1998) framework include the accumulation of data on the indicator, collection of relational data, and statistically establishing the relationship between the indicator and the relational data. Based on these results the indicator can be rejected or accepted (preliminarily). **It is these 4 steps that we**

consider in this proposal and which we and our partners believe have not been addressed in other indicator work in Ontario. This will involve an explicit operational definition of the problem, intensive data collection, and comprehensive statistical analysis. The result will be an assessment of the ability of the potential indicators to meet the specific and broad objectives of bioindicators in Canada. McGeoch (1998) included two more steps in her framework, **Step 8** an examination of the robustness of the indicator by developing and testing appropriate hypotheses under different conditions, and **Step 9** to make specific recommendations based on the original objectives. **To examine the robustness of these indicators (step 8) we will conduct numerical simulation experiments, parameterized by the empirical work, to assess the amount of change that the data could detect at varying sample sizes. In step 9 we will make recommendations for some of the bioindicators that have been proposed by OMNR (1999) and MacLaren et al. (1998), and several others proposed by us.** The development and use of bioindicators is an ongoing process. There is no reason to expect that a preliminary selection of indicators using expert knowledge and a scientific literature search will identify a final set of useful indicators.

To inform our general objective, we have **3 specific objectives** as follows:

Objective (i) **We will evaluate the sensitivity of the proposed bioindicators and data collection methods** to detect differences in population levels and species assemblage composition within mature forest in disturbed versus undisturbed landscapes (**Steps 4-8** in McGeoch 1998). The sensitivity of indicators is related to statistical power in that it assesses the ability of the data or test to identify an effect or a change when a change has actually occurred (Rotenberry and Wiens 1985). **We will analyse the statistical power of current methods** of biodiversity data collection, **and compare population level and species assemblage level indicators**, including invertebrate indicators that have been proposed (Churchhill 1997, Beaudry et al 1997, Atlegrim et al 1997), but not included in the current Ontario Ministry of Natural Resources monitoring program. **We will also explore the potential of groups of species (species assemblages) as bioindicators**. These will be selected on either a taxonomic or functional basis, or on some combination of both. Hammond (1994) advocates the use of 'shopping baskets' of suitable taxa when, as may often be true, it is difficult to identify a single taxon that fulfils all the criteria necessary for the required bioindicator. The advantages of using groups of species rather than single species have been stated as 'providing improved resolution and scale of inventory and monitoring' (Kremen et al. 1994). Groups of taxa represent a wider array of taxonomic, functional and habitat diversity and increase the number and types of environmental responses that are perceived (Kremen et al. 1994). **We will evaluate the cost of directly monitoring** bioindicator species or assemblages.

Objective (ii) Forecasts of habitat supply or predictions of bioindiator population levels require knowledge of bioindicator response to succession. **We will examine the species assemblage composition and population levels of selected species in disturbed and regenerating stands to assess when these stands begin to function as mature forest from an organism perspective**. Without an understanding of the relationship between forest succession and habitat suitability the effects of aggregated disturbances across the landscape cannot be evaluated. This objective recognizes the need for a criteria and indicators protocol to consider the aggregation of localized catastrophic events (such as fire or clear-cut logging) across temporal and spatial scales. The relationship of forest age and bioindicators is a key input to the development of habitat models (see Objective (iii).

Objective (iii) Existing biodiversity reporting protocols rely on describing the impact of forest management on habitat. The CCFM identifies many habitat features to consider as indicators of sustainable forest management. In addition, the cost of monitoring individual species or assemblages across the landscape in a rigorous and effective manner may be prohibitively expensive. It is therefore important to define a relationship between bioindicators and habitat attributes that may be readily and cost-effectively included in existing monitoring and reporting activities. For selected species, we will develop and quantitatively assess the quality of habitat models developed using monitoring data, local vegetation data and large-scale land cover data including FRI and Landsat TM. In particular **we will prepare a strategy on how bioindicator models may be effectively developed and implemented at the operational level**. This exercise will **include a thorough examination of prediction error** using independent validation data (Pearce et al. 1999, Pearce and Ferrier 2000) **and the implications of this error** in large-scale habitat assessments. Both the relationships themselves, and the error in these relationships, are critical inputs to large-scale models of species distribution, relative abundance (Norton and Williams 1992), and forecasts of habitat supply.

Living Legacy Trust Priorities

These objectives address 4 of the Living Legacy Trust Priorities: *Priority #10; Biodiversity of terrestrial ecosystems*: We are proposing to assess the potential of vertebrate and invertebrate indicators to demonstrate change in forested ecosystems. We will be developing protocols for measuring bioindicators and assessing the costs of these protocols. We will also be evaluating the usefulness of these data for creating models and maps of species distribution. *Priority #11 : Understanding the impact of management in terrestrial ecosystems*: We will be conducting these studies in an area of active forestry and in a neighbouring reserve area to look at impact of logging disturbance on population levels, variability and community composition within forested areas. *Priority # 12: Understanding Ecosystems*: One of the principal objectives of this project is to examine methods of assessing population and community composition at the landscape level. We will be evaluating the effectiveness of several survey and monitoring techniques including playbacks for birds (potentially useful when target species are identified). *Priority #13: Protection of species and wildlife communities:* As part of our study design we will attempt to assess the scale at which disturbance influences local populations by examining population levels and community composition in forested areas with varying degrees of logging disturbance in the landscape.

2. DETAILED DESCRIPTION OF THE PROJECT WITH SPECIFIC TIME LINES

Scale of study

We will investigate these objectives at a number of scales. We will conduct detailed surveys for bioindicators to address all three objectives at the local scale within a single landscape in northcentral Ontario. This landscape contains a spatial control (Pukaskwa National Park) and a range of disturbance levels (Domtar management area). Detailed investigations at this level will provide specific information to inform the preparation of a monitoring strategy in Ontario. At the regional scale, we will be investigating the ability of models to relate the vertebrate and invertebrate bioindicators to landscape characteristics to reduce the need for expensive population monitoring over large spatial and temporal scales. Temporal relationships between the bioindicator and habitat will be investigated by sampling across multiple age classes within the local study area. This study is designed to answer specific questions required to develop an operational and effective monitoring strategy.

Taxa Selection

We have selected taxa to conform to vertebrate species and sampling methods already being undertaken in Ontario by the Wildlife Assessment Program OMNR (point counts for songbirds, live mammal traps for small mammals and cover boards for salamanders), and invertebrate taxa that are readily sampled through pitfall trapping (carabids, spiders). Within the vertebrate groups we will pay special attention to species that were identified as potential bioindicators by McLaren et al. (1998). Pitfall trapping provides a cost effective, widely accepted and efficient means of sampling carabids, spiders and ants. Carabids in particular have been suggested as indicators of habitat change by several authors (eg. Duchesne and McAlpine (1993), Spence *et al*. (1996), Beaudry *et al*. (1997)) due to their stable and well-known taxonomy, the availability of keys (ie Lindroth 1961-1969) and taxonomic expertise. Spiders too have a stable taxonomy for most families, and keys for Canadian families are published (Dondale and Redner 1978, 1982, 1990, Platnick and Dondale 1992), although taxonomic expertise is less readily available. Ants will not be considered here due to the difficulty of their identification (keys to North American ant species are available, although no comprehensive revision of Canadian ant species has been conducted), scarcity of taxonomic expertise and assumed lack of bioindicator potential in the Ontario boreal forest (Gary Umphrey pers. comm.). Carabids in particular, show affinities with structural characteristics of the forest, many of which are important for higher taxa, such as coarse woody debris. They also show a well-defined response in the composition of assemblages to anthropogenic disturbance such as logging (eg Niemelä *et al*. (1993), Addison and Barber (1997)) and silvicultural treatments (eg Duchesne and McAlpine (1993), Beaudry *et al*. (1997)). Invertebrate groups may be more valuable indicators of anthropogenic disturbance than many vertebrate groups because they have shorter life histories, and therefore an impact on populations can be detected earlier than that for vertebrates, they represent both predator and prey guilds, and they may demonstrate stand level and regional level effects. We are currently completing a review of this information and the role that these invertebrate groups might play as bioindicators of anthropogenic disturbance in Canadian forests.

Study Area

The study area consists of the north end of Pukaskwa Park (approximately 600km^2) and part of the adjacent White River Sustainable Forest License of Domtar (also approximately 600km^2). The interior is well forested with mostly mixed forest (20%-80% coniferous or deciduous trees). The topography is rugged. The SFL area is being actively logged, including the area adjacent to the Park. The north end of the Park is accessible through the SFL area. The roads end near the Park boundary and access to the interior is by ATV and helicopter.

Sampling design

We will establish approximately 150 bird and invertebrate survey plots within mixed forest. These sites will be distributed within mature mixed forest (ranging from 60-80 years post fire) both within the park and the adjacent SFL, and within regenerating forest (0 – 30 years post clear cut harvest) within the SFL. The exact location of these sites will be finalized in the first field season, in conjunction with advice from Keith Wade (Pukaskwa) and Chris Grant (Domtar). A subset of these sites will be surveyed for small mammals and salamanders. Pukaskwa Park and OMNR are currently finalizing the selection of survey sites for two small mammal trapping programs (and salamander surveys for OMNR) to be conducted within these two landscapes in 2001. This study will establish 20-50 plots at which small mammals and salamanders will be surveyed and will be augmented by sites surveyed by OMNR and Pukaskwa Park where applicable.

Time line

Feb-April 2001. Refine specific monitoring questions in consultation with partners, and commence operational monitoring document.
Hire field crew.
Organize and establish field camp.
Acquire and prepare GIS database of digital spatial layers including Landsat TM, FRI, Ecosite, Roads, Cut overs, Forest Management Plans
Finalize the location of field plots in consultation with partners.
Work prior to April 1, 2002 will be conducted through 'in kind' support from the Canadian Forest Service, Domtar, Pukaskwa Park and the Wildlife Assessment Program.

May – Aug. 2001. 1st year of field work (Objectives 1–2): establish plots, install invertebrate pitfall traps and salamander cover boards, conduct small mammal trapping, songbird censuses. Empty pitfall traps fortnightly, sort and prepare invertebrate samples. Check salamander boards. Record habitat characteristics at the trap level (micro site) and the site level (transects). Enter data.

Sept – April 2002. Assess error description and visualization techniques for statistical models. Identify carabid and spider samples to species level. Preliminary investigations into bioindicator relationships.

May – Aug 2002. 2nd year of field work (Objectives 1-2): Continue songbird, small mammal, salamander and pitfall trapping. Sort and prepare invertebrate samples. Enter data.

Sept – April 2003. Conduct computer intensive simulation to examine issues of bioindicator sensitivity, monitoring study design and sample size. Identify invertebrate samples from 2nd field season to species level. Develop modeling techniques using 2 years of data, and continue exploring bioindicator relationships.

May – Aug 2003. 3rd year of field work (Objectives 1–2): Continue songbird, small mammal, salamander and pitfall trapping. Sort and prepare invertebrate samples. Enter data.

Sept – April 2004. Completion of data analysis incorporating third year field data and bioindicator models. Completion of reports.

3. IDENTIFICATION OF INTERIM MILESTONES

Year 1, March 2002

1. Completion of web page to include all reports and data produced by the project.
2. Annual report including complete summary of field work, costs, and data summaries, and cumulative inventory of species. To be published on web site.
3. Completion of first stage of monitoring report identifying monitoring questions (hypotheses), prioritising those questions and developing an operational monitoring framework to address those questions. Document prepared for peer reviewed journal and to be included on the web.
4. Review paper of carabids as indicators in Canada for peer reviewed publication.
5. Review paper of ground spiders as indicators in Canada for peer reviewed publication.

Year 2, March 2003

1. Annual report including complete summary of field work, costs, data summaries, and cumulative inventory of species. To be published on web site.
2. Completion of second stage of monitoring report, reviewing existing data sources and the suitability of existing regional monitoring studies to answer monitoring questions.
3. Discussion paper for peer reviewed publication on the description and visualisation of model error and how information on model error may inform a monitoring program.

Year 3, March 2004

1. Completion of third stage of monitoring report outlining the operational methodology required to measure and evaluate bioindicators for sustainable forest management. This report will include recommendations for which data to collect, how best to collect it, how much to collect, how much it will cost to collect, how to analyze the data to extract the necessary information and how models may be employed in bioindicator monitoring programs.
2. Preparation for peer reviewed publication of a manuscript on bioindicator sensitivity and monitoring design.
3. Preparation of manuscript for peer reviewed publication on modeling bioindicator relationships.

4. PLAN FOR HUMAN RESOURCES:

(a) Qualifications of Project Staff and Partners (see Appendix 2)

(b) Role/responsibilities for each team member.

The responsibilities of Project Leader will be shared between Dr. Lisa Venier and Dr. Jennie Pearce. Geographic Information System support will be provided by Kevin Lawrence (GIS Specialist, Great Lakes Forest Research Centre) and Janice McKee (GIS and Database Technician, GLFC) of the Landscape Analysis and Applications Section. Mr. Lawrence's expertise is provided as 'in kind' support. Ms. McKee will be paid from salary dollars in the financial plan. Kathy Campbell (Landscape Analysis Technician) will be providing both GIS and administrative support. Her support is provided as 'in kind.' Dr. Dan McKenney will be providing advice on all aspects of the project, but especially in the context of economic and trade-off analysis. His support is provided 'in kind'.

Keith Wade, Resource Management Specialist, Pukaskwa National Park. Mr. Wade will be providing expert advice on site location within and outside the Park as well as logistic support for the field component of the study, accommodation for field crews, and some helicopter transportation within the Park. His mammal and herptile study will provide data to the project.

Chris Grant, Forester, Domtar. Mr. Grant will be providing logistic support in the form of data (maps), road access information, site selection expertise and GIS analysis.

Dean Phoenix, Scott Jones, Wildlife Assessment Program, OMNR. Mr. Phoenix will be providing support in the form of sampling design advice, and data from the Wildlife Assessment Program as well as field support and field supplies for salamander and small mammal sampling. As head of the OMNR Wildlife Assessment Program, Mr. Jones will be providing intellectual input into study design, and refinement of questions.

5. FINANCIAL PLAN

Not included: Available from proponents

Table 1: McGeoch (1998) framework for testing bioindicators

McGeoch step	Notes	Progress to date
Step 1. Determine broad objective	To not have a significant impact on biota through anthropogenic activities in forests.	WCED 1987, Montreal Process 1995, CFSA
Step 2. Refine objectives and clarify endpoint	To determine and be able to predict the impact of disturbance on biota using an indicator. Determine attributes of forest ecosystems potentially impacted by disturbance, and define criteria for choosing indicators.	CCFM 1995, 1997, Model forest activities: eg. Wendeles and Williams 1999, McLaren et al 1999.
Step 3. Select potential indicator based on accepted a priori suitability criteria	Select species, higher level taxon, assemblage or community that may be indicators of anthropogenic disturbance.	McLaren et al. 1998
Step 4. Accumulate data on indicator	Establish species presence/absence, abundance, richness, interactions or temporal changes according to criteria for impact. Collate existing empirical studies testing the disturbance hypothesis. Collate existing survey data Conduct power analysis to determine sample size required to detect hypothesised relationship. Undertake additional surveys.	WAP
Step 5. Collect quantitative relational data	Measure levels of disturbance	
Step 6. Establish statistically the relationship between the indicator and the relational data.	Establish the relationship between the disturbance and the composition, structure or function of the indicator.	
Step 7. Based on the nature of the relationship, either accept or reject the species, taxon or assemblage as an indicator.	Are there significant strong correlations between the disturbance and measured qualities of the indicator? YES continue to step 8. NO either conclude that the disturbance has no impact on the biota or repeat procedure from step 3.	
Step 8. Establish the robustness of the indicator by developing and testing appropriate hypothesis under	Is the significant relationship detected between the disturbance and measured qualities of the indicator	

different conditions.	applicable in other areas or at different times? Is the relationship between the disturbance and other taxa different to the relationship discovered in step 7.
Step 9. Make specific recommendations based on the original objectives for the use of the indicator.	Use the indicator to monitor and predict the impact of disturbance on communities, habitats and ecosystems.

List of Appendices

Appendix 1: Qualifications of the Proponents (short biographies and a selected list of publications)

Appendix 2: Letters of Commitment from Partners

(i) Keith Wade, Pukaskwa National Park

(ii) Scott Jones, Dean Pheonix, Wildlife Assessment Program, Ontario Ministry of Natural Resources

(iii) Chris Grant, Forestry Services Manager, Domtar

Appendix 3: Responses to scientific reviews from first submission

Appendix 4: Copy of the scientific reviews from first submission

Appendix 5: Literature cited

Appendix 1: Qualifications of Proponents

Dr. Lisa Venier completed her PhD in Landscape Ecology at the Ottawa- Carleton Institute of Biology in 1996. In this project she worked in collaboration with Dr. Dan Welsh of the Canadian Wildlife Service- Ontario Region to examine the effects of scale, habitat specificity and landscape level habitat availability on the relationship between abundance and distribution of boreal forest songbirds. This work involved stochastic individual-based simulation modeling to generate testable hypotheses about the influence of landscape level characteristics on local abundance and distribution (Venier and Fahrig 1996). She tested these hypotheses using empirical data collected in Northwestern Ontario boreal forest (Venier et al. submitted, Venier and Fahrig 1998, Venier and Welsh 1997, Venier 1996). Since completing her PhD, Dr. Venier has been a Research Scientist with the Canadian Forest Service, Great Lakes Research Center in Sault Ste. Marie since 1997 as a member of the Landscape Analysis and Applications Section headed by Dr. Dan McKenney. Dr. Venier's current research centers around predicting the abundance and distribution of organisms at a variety of scales. She has been examining techniques for the development of predictive models of species abundance and distribution as a function of climate and vegetation at a variety of scales (Venier et al. 1999,Venier et al. 1998, McKenney et al. 1999). Dr. Venier brought the experience of this work into an international collaboration with the University of Minnesota as part of a project funded by the Great Lakes Protection Fund. As part of this collaboration, Dr. Venier co-authored a review paper on the ecological sustainability of birds in boreal systems (Niemi et al. 1998) to identify knowledge gaps in our understanding of sustainability. This project is also examining the use of these large scale databases for setting priorities in species conservation, identifying gaps in conservation of species (Niemi et al. submitted) and using satellite imagery to improve and refine large-scales models of forest biodiversity distribution. Dr. Venier was also project leader on the development of a digital database of range maps of birds breeding in Canada (Welsh et al. 1999). She is a member of the Technical Committee of the new Breeding Bird Atlas for Ontario and is conducting analysis on the pilot season data as part of the sampling subcommittee. At landscape and local scales, Dr. Venier has been conducting studies to examine the influence of local and landscape forest characteristics on local population levels of boreal forest songbirds and invertebrates on a three year field project in Northwestern Ontario. Dr. Venier has also been involved with work examining predictive accuracy of biodiversity models (Pearce et al. In Press, McKenney et al. In Press).

<u>Selected Publications</u>

McKenney, D.W., Kesteven, J.L. Hutchinson, M.F. and **Venier, L.A.** *In Press.* Canada's Plant Hardiness zones revisited. Canadian Journal of Plant Science.

Pearce, J.L., **Venier, L.A.**, Ferrier, S. and McKenney, D.W..In press. Measuring prediction uncertainty in models of species distribution *In:* Predicting plant and animal occurrences: issues of scale and accuracy, edited by J.M. Scott, P.J. Heglund, M. Morrison, M. Raphael, J. Haufler, and B. Wall. Covello, CA : Island Press.

McKenney, D.W., **Venier, L.A.**, Heerdegen, A., McCarthy, M.A., A Monte Carlo experiment for species mapping problems. In press *In:* Predicting plant and animal occurrences: issues of scale and accuracy, edited by J.M. Scott, P.J. Heglund, M. Morrison, M. Raphael, J. Haufler, and B. Wall. Covello, CA : Island Press.

Venier, L.A., McKenney, D.W., Wang, Y., and McKee, J. 1999. Models of large-scale breeding bird distribution as a function of macroclimate in Ontario Canada. Journal of Biogeography 26:315-328.

Welsh, D.A., **Venier**, L.A., Fillman, D.R., McKee, J., Phillips, D., Lawrence, K., Gillespie, I. And McKenney, D.W. 1999. Development and Analysis of Digital Range Maps of Birds Breeding in Canada. Information Report ST-X-17. Science Branch, Canadian Forest Service, Natural Resources CanadaNiemi, G., Hanowski, J., Howe, R., McKenney, D., Mladenoff, D., Smith, C., **Venier, L**. and Welsh, D. 1998. Forest Bird Biodiversity: Indicators of Environmental Condition and Change in the Great Lakes Watershed. A Final Report to Great Lakes Protection Fund/ STE 1880.

Niemi, G., Hanowski, J., Helle, P., Howe, R., Monkkonen, M., **Venier, L.** and Welsh, D. 1998 Ecological sustainability of birds in boreal systems. Conservation Ecology 2 (2):17

Niemi, G., Hanowski, J., Howe, R., Jones, M., Lima, A., McKenney, D., Mladenoff, D., Sales, J., Smith, C., **Venier, L.**, Welsh, D. and Wolter, P. Submitted. Prioritization of extinction risk and shared management responsibility for breeding birds in the Great Lakes Watershed. Submitted

McKenney,D.A., Rempell, R., **Venier, L.A.**,Wang, Y. and Bissett, G. 1998. Development and application of a spatially-explicit moose population model. Canadian Journal of Zoology 76: 1922-1931.

Venier, L.A., Hopkin, A.A., McKenney, D.W. and Wang, Y. 1998. A spatial, climate-determined hazard rating for scleroderris disease of pines in Ontario. Canadian Journal of Forest Research 28: 1398-1404.
Venier, L.A. & Fahrig, L. 1998. Intra-specific abundance-distribution relationship. Oikos 82:483-490.
Venier, L.A. & Mackey, B. G. 1997. A method for rapid, spatially-explicit habitat assessment for forest songbirds. Journal of Sustainable Forestry 4: 99-118.
McKenney, D.W., **Venier, L.A.**, Ball, I. McKee, J., Possingham, H. and Mackey, B. 1997. A Gap analysis of bird distributions in southern Ontario. Proceedings of the Symposium on Systems Analysis in Forest Resources. May 28-31, 1997, Traverse City, Michigan.
Venier, L.A. & Welsh, D.A. 1997. An experimental decision support tool for boreal forest songbirds. In: The status of forestry/wildlife decision support systems in Canada. Proceedings of a symposium Toronto Ontario, 1994 I.D. Thompson (editor). Natural Resources Canada, Canadian Forest Service, Sault Ste. Marie, Ontario.
Venier, L.A. & Fahrig, L. 1996. Habitat availability causes the species abundance - distribution relationship. Oikos 76:564-570.
Welsh, D.A. & **Venier, L.A.** 1996. Binoculars and Satellites: Developing a conservation framework for boreal forest wildlife at varying scales. Forest Ecology and Management: 85: 53-65.
Venier, L.A. 1996. The effects of amount of available habitat in the landscape on relationsh bewteen abundance and distribution of boreal forest songbirds. Ottawa-Carleton Institute of Biology, PhD. Thesis. Ottawa, Ontario, Canada.
Venier, L.A., Fahrig, L. and Welsh, D.A. Submitted to Landscape Ecology. The influence of landscape composition on local abundance and occupancy of boreal songbirds**.**
Venier, L.A., Dunn, P.O., Lifjeld, J.T. & Robertson, R.J. 1993. Behavioural patterns of extra-pair copulation in tree swallows. Animal Behaviour 45: 412-415.
Venier, L.A. , Mather, M.H. & Welsh, D.A. 1993. Density and productivity measures for evaluating habitat quality: Implications for wildlife management. 7th Annual Symposium on Geographic Information Systems in forestry, environment and natural resources management Symposium Proceedings, Vancouver.
Venier, L.A. & Robertson, R.J. 1991. Copulation behaviour of tree swallows, *Tachycineta bicolor* : paternity assurance in the presence of sperm competition. Animal Behaviour 42: 939-948.

Dr. Jennie Pearce: Since January 1999, Dr. Pearce has been working with the Landscape Analysis and Applications section of the Canadian Forest Service as a Visiting Fellow. Her research has focused on the role of invertebrates, especially carabid beetles, as bioindicators in the boreal forest of Canada, and the role that modeling can play in regional planning activities. Journal papers currently being prepared from this work include three papers on the habitat relationships of carabids, spiders and other invertebrates within north-western Ontario, a paper evaluating pitfall trap designs to minimise small mammal bicatch, a paper evaluating the feasibility of modeling avian relative abundance using Breeding Bird Survey data, and a paper evaluating the influence of sample size, occupancy rate and spatial autocorrelation of the performance of logistic regression models. This furthers work that Dr. Pearce was undertaking whilst employed as a Research Scientist with the New South Wales National Parks and Wildlife Service in Australia, where she was primarily concerned with developing statistical and spatial mapping techniques to aid regional conservation planning activities. Specific projects undertaken there include: developing statistical techniques to evaluate the accuracy and reliability of regional flora and fauna distribution models; investigating innovative methods of incorporating expert knowledge, qualitative mapped information and context information directly into predictive habitat models; evaluating different abundance modeling regression techniques and the usefulness of regional scale models of relative abundance; investigating the impact of various logistic regression modeling strategies on the predictive accuracy of habitat models; planning and research into species community modeling techniques, such as modeling species dissimilarity as a function of environmental and geographic distance, and developing new indices of species dissimilarity that give greater emphasis to the presence and abundance of rare species.

From 1994-1995 Dr. Pearce was employed as Scientific Coordinator and Biometrician on a special project on identifying old growth forest jointly managed by the NSW National Parks and Wildlife Service and State Forests of NSW. Her responsibilities included maintenance of the scientific rigour and accountability of the technical component of the project, data analysis, management of technical staff, project team representation at workshops, community seminars and project management meetings, and the day to day coordination of the technical component of the project.

Other research activities have focused on studying the habitat relationships of individual species in Australia, in order to develop specific habitat management strategies for the maintenance of these (usually endangered) populations. This research is described by over ten journal articles that concentrate on linking point-based information with spatial and temporal information in mathematical and statistical models.

<u>Selected papers</u>

Pedlar, JH, **Pearce, JL**, Venier, LA & McKenney, DW. in press. Coarse woody debris in the boreal forests of northwestern Ontario. *Forest ecology and Management*.

Pearce, JL., Ferrier, S & Scotts, D. in review. Validating and refining fauna and flora regional predictive models developed for north-east NSW. *Ecological Management*.

Pearce, JL & Ferrier, S. 2000. Modelling the relative abundance of flora and fauna species at a regional scale. *Biological Conservation*.

Pearce, JL, Cherry, K, Drielsma, M, Ferrier, S & Whish, G. 2000. Incorporation of expert knowledge into quantitative models of species distribution. *Journal of Applied Ecology*.

Pearce, JL & Ferrier, S. 2000. Assessing the predictive performance of wildlife-habitat models developed using logistic regression. *Ecological Modeling* 133, 225-245.

Pearce, JL & Ferrier, S. 2000. An evaluation of alternative algorithms for fitting species distribution models using logistic regression. *Ecological Modelling* 128, 127-147.

Pearce, JL, Venier, L, Ferrier, S. & McKenney, D. 1999. Measuring prediction uncertainty in models of species distribution. In "Proceedings of the Conference on Predicting species occurrences: Issues of scale and accuracy, Snowbird, Utah, October 18-22.

Pearce, JL & Ferrier, S. 1996. Evaluating and refining models of flora and fauna species distribution developed for north-east New South Wales. Consultancy report by the NSW National Parks and Wildlife Service to the Australian Nature Conservation Agency, Canberra.

McCarthy, MA, **Pearce, JL** & Burgman, MA. 1994. Use and abuse of wildlife models for determining habitat requirements of forest fauna. *Australian Forestry* 57, 82-85.

Pearce, JL & McCarthy, M. 1994. Linking statistical habitat models with population viability analysis. In "Proceedings of the Resource Technology Conference, Melbourne, Australia, Sept. 26 - 30, 1994.

Akçakaya, HR, McCarthy, MA & **Pearce, JL** 1993. RAMAS/GIS: Linking landscape data with population viability analysis. Pp. 627-632, in '*Proceedings, International Congress on modelling and simulation*', Volume 2. (Eds. M. McAleer and A. Jakeman). Dec. 6-10, 1993. Uni. West. Aust., Perth.

Dr. Dan McKenney is the Chief of the Landscape Analysis and Applications Section (formerly the Forest Resource Economics Section), Canadian Forest Service, Sault Ste. Marie. Dr. McKenney's expertise is in the area of resource economics and spatial modeling. The Landscape Analysis and Applications Section has 10 scientific and support staff from a variety of disciplines and undertakes modeling and field-based studies at a variety of scales. Dr McKenney has been involved in and managed large studies both nationally and internationally. He has attracted over $2,500,000 in research funding in the last 6 years and has over 30 scientific publications and 50 other technical reports, conference proceedings and other manuscripts. A full CV is available upon request.

<u>Selected publications</u>

McKenney, D. 2000. What's the economics of intensive silviculture? Forestry Chronicle 76(2):275-281.

Price, D., **D.W. McKenney**, I. Nalder, M.F. Hutchinson and J Kestevan. 2000. A comparison of two statistical methods for interpolating monthly mean climate. Ag. And Forest. Met. 101:81-94.

McKenney, D.W., Mackey, B.G. and H. Macdonald. 1999. Biodiversity conservation and economic preferences. In Modelling Change in Integrated Economic and Environmental Systems. Eds. S. Mahendrarajah, A.J. Jakeman and M. McAleer. John Wiley and Sons Ltd. p. 215-239.

McKenney, D.W., Mackey, B.G., Joyce, D. 1999. Seedwhere: a computer tool to support seed transfer and ecological restoration decisions. Environmental Modelling and Software. 14:589-595.

McKenney, D.W., Zavitz, B., Mackey, B.G. 1999. Calibration and sensitivity analysis of solar radiation model (SRAD) . Int. J. of Geographical Information Systems.13: 49-65.
McKenney, D.W. 1998 Resource economists should do more cost analysis and less benefit analysis. Australian National University, Centre for Resource and Environmental Studies Ecological Economics Working Paper 9801. See http://cres.anu.edu.au/~dstern/anzsee/EEP.html
McKenney, D.W., Mackey, B.G., Bogart, J., McKee, J., and M. Oldham. 1998. Bioclimatic and spatial analysis of Ontario reptile and amphibians. Ecoscience, 5(1): 18-30.
McKenney, D.W., Nippers, B., Racey, G., and R. Davis. 1997. An analysis of wood supply, caribou habitat trade-offs in Northwestern Ontario. Rangifer, Special Issue 10: 1-8
McKenney, D.W., Beke, N., Fox, G. and A. Groot. 1997. Does it pay to do silviculture research on slow growing species? For. Ecology & Mgmt. 95: 141-152.
Mackey, B.G., **McKenney, D.W**., Yin-Qian Yang, McMahon, J.P. and M.F. Hutchinson 1996. Site regions revisted: a climatic analysis of Hill's site regions for the province of Ontario. Can. J. For. Res. 26:333-354.
Sarker, R. **McKenney, D.W**., Nippers, B. and D. Joyce. 1996 Seedcost: the cost of seed for artificial regeneration in Ontario. Ontario Ministry of Natural Resources., Sault Ste. Marie.
McKenney, D.W. and D.B. Lindenmayer 1994. An economic assessment of a nest-box strategy for the conservation of an endangered species. Can J. For. Res. 24:2012-2019.

Appendix 2: Letters of support from partners.

Not included: Available from proponents

Appendix 3: Detailed Response to Peer Reviews Provided.

Not included: Available from proponents

Appendix 4: Reviewers Comments.

Not included: Available from proponents

Appendix 5: Literature Cited

Addison, J. A. and Barber, K. N. 1997, Natural Resources Canada, Canadian Forest Service No. Information report GLC-X-1.

Atlegrim, O. Sjoberg, K. and Ball, J.P. 1997. Forestry effects on a boreal ground beetle community in spring: selective logging and clear-cutting compared. Entomologica Fennica 8: 20-26.

Duinker, P.D., Doyon, F., Morash, R., Van Damme, L., MacLeod, H.L., Rudy, A. 2000. BAP (Biodiversity Assessment Program) Report #1. Background and Structure.

Beaudry, S., Duchesne, L.C., and Côté, B., 1997. Short-term effects of three forestry practices on carabid assemblages in a jack pine forest. Canadian Journal of Forest Research **27**: 2065-2071.

Bellhouse, T.J., Phoenix, R.D., Richard, B. and Postma, J. 2000. Ontario Wildlife Assessment Program. Field Manual for Establishing and Measuring Permanent Sample Sites for Monitoring Forest Wildlife. Version 0.52.

Canadian Council of Forest Ministers. 1995. Defining sustainable forest management: A Canadian approach to criteria and indicators. Natural Resources Canada. Ottawa, ON. 22p

Canadian Council of Forest Ministers. 1997. Criteria and indicators of sustainable forest management in Canada: Technical report. Natural Resources Canada. Ottawa, ON. 137p

Canadian Council of Forest Ministers. 2000. Criteria and indicators of sustainable forest management in Canada: National Status 2000 Natural Resources Canada. Ottawa, ON. 122p.

Canadian Model Forest Network 2000. A User's Guide to Local Level Indicators of Sustainable Forest Management. Draft report prepared for the CMFN LLI Workshop: Local Level Indicators for Sustainable Forest Management - Putting Knowledge into Practice. Moncton, NB June 26-27, 2000.

Churchill, I.C. 1997. Spiders as ecological indicators: an overview for Australia. Mem. Mus. Vict. 56:331-337.

Dondale, C.D. and Redner, J.H. 1978. The insects and arachnids of Canada. Part 5. The crab spiders of Canada and Alaska (Araneae: Philodromidae and Thomisidae). Agric. Can. Publ. 1663. 255 pp.

Dondale, C.D. and Redner, J.H. 1982. The insects and arachnids of Canada. Part 9. The sac spiders of Canada and Alaska (Araneae: Clubionidae and Anyphaenidae). Agric. Can. Publ. 1724. 194 pp.

Dondale, C.D. and Redner, J.H. 1990. The insects and arachnids of Canada. Part 17. The wolf spiders, nurseryweb spiders, and lynx spiders of Canada and Alaska (Araneae: Lycosidae, Pisauridae, and Oxyopidae). Agric. Can. Publ. 1856. 383 pp.

Duchesne, Luc C. and McAlpine, Robert S. 1993, Forestry Canada Petawawa National Forestry Institute No. Report No. 16.

Furness, R.W., and Greenwood, J.J.D. 1993. Birds as Monitors of Environmental Change. Chapman & Hall, London.

Hammond, P.M. 1994. Practical approaches to the estimation of the extent of biodiversity in speciose groups. Philosophical Transactions of the Royal Society of London B 345: 119-136.

Howe, R.W., Niemi, G.J., Lewis, S.J. and Welsh, D.A. 1997. A standard method for monitoring songbird populations in the Great Lakes region. The Passenger Pigeon 59: 183-194.

Kimmins, J.P. 1990. Monitoring the condition of the Canadian forest environment: the relevance of the concept of 'ecological indicators'. Environmental Monitoring and Assessment 15: 231-240.

Kremen, C. 1992. Assessing the indicator properties of species assemblages for natural area monitoring. Ecological Applications 2: 203-217.

Kremen, C., Merenlander, A.M. and Murphy, D.D. 1994. Ecological monitoring: a vital need for integrated conservation and development programs in the tropics. Conservation Biology 8: 388-397.

Landres, P.B., Verner, J. and Thomas, J.W. 1988. Ecological uses of vertebrate indicator species: a critique. Conservation Biology 2: 316-328.

Lautenschlager, R.A., MacLeod, H., Hollstedt, C. and Balsillie, D. 2000. Examining the Specifics approach to identifying indicators of sustainable natural resource management in Ontario, Saskatchewan, and British Columbia. The Forestry Chronicle 76: 725-738.

Lindroth, C.H., 1961-1969. The ground-beetles (Carabidae, excl. Cicindelinae) of Canada and Alaska. (Suppl.) 20 (1961), 24 (1963), 29 (1966), 33 (1968), 34 (1969), & 35 (1969). Opuscula Entomologica, Lund University, Sweden.

Manly, B.F.J. 1997. Randomization, Bootstrap and Monte Carlo Methods in Biology. 2nd Edition. Chapman & Hall, London.

McGeoch, M.A., 1998. The selection, testing and application of terrestrial insects as bioindicators. Biological reviews of the Cambridge Philosophical Society **73**: 181-201.

McLaren, M.A., Thompson, I.D., and Baker J.A. 1998. Selection of vertebrate wildlife indicators for monitoring sustainable forest management in Ontario. The Forestry Chronicle 74: 241-248.

Montreal Process. 1995. Criteria and indicators for the conservation and sustainable management of temperate and boreal forests: the Montreal Process. Can. For. Serv., Hull, QC. 27p.

Niemelä, J., Langor, D., and Spence, J.R., 1993. Effects of clear-cut harvesting on boreal ground-beetle assemblages (Coleoptera: Carabidae) in western Canada. Conservation Biology **7**: 551-561.

Niemi, G.J., Hanowski, J.H., Lima, A.R., Nicholls, T. and Weiland, N. 1997. A critical analysis of the use of indicator species in management. Journal of Wildlife Management 61: 1240-1252.

Norton, T.W., and Williams, J.E. 1992. Habitat modeling and simulation for nature conservation: a need to deal systematically with uncertainty. Mathematics and computers in simulation 33, 379-384.

Noss, R.F. 1990. Indicators for monitoring biodiversity: a hierarchical approach. Conservation Biology 4: 355-364.

Ontario Ministry of the Environment. 1994. Class environmental assessment by the Ministry of natural resources for timber management of Crown lands in Ontario. Toronto. 561 pp.

Pearce, JL & Ferrier, S. 2000. Assessing the predictive performance of wildlife-habitat models developed using logistic regression. Ecological Modeling 133: 225-245.

Pearce, JL, Venier, L, Ferrier, S. & McKenney, D. 1999. Measuring prediction uncertainty in models of species distribution. In "Proceedings of the Conference on Predicting species occurrences: Issues of scale and accuracy, Snowbird, Utah, October 18-22.

Pearson, D.L. 1994. Selecting indicator taxa for the quantitative assessment of biodiversity. Philosophical Transactions of the Royal Society of London B: 75-79.

Platnick, N.I. and Dondale, C.D. 1992. The insects and arachnids of Canada. Part 19. The ground spiders of Canada and Alaska (Araneae: Gnaphosidae). Agric. Can. Publ. 1875. 297 pp.

Rotenberry, J.T.and Wiens, J.A. 1985. Statisical power analysis and community-wide patterns. American Naturalist 125: 164-168.

Simberloff, D. 1998. Flagships, umbrellas, and keystones: is single-species management passe in the landscape era? Biological Conservation 83: 247-257.

Spence, J.R., Langor, D.W., Niemelä, J., Cárcamo, H.A., and Currie, C.R., 1996. Northern forestry and carabids: the case for concern about old-growth species. Annales Zoologici Fennici **33**: 173-184.

Spellerberg, I.F. 1991. Monitoring Ecological Change. Cambridge University Press, Cambridge.

Venier, L.A., McKenney, D.W., Wang, Y., and McKee, J. 1999. Models of large-scale breeding bird distribution as a function of macroclimate in Ontario Canada. Journal of Biogeography 26:315-328.

Wedeles, C. and Williams, J. 1999. Assessment of indicators of sustainable forest management. Summary Report. Submitted to : The Forest Ecosystem Science Co-operative. ArborVitae Environmental Services.

World Commision on Environment and Development (WCED). 1987. Our Common Future. Oxford University Press, New York, NY.