# Using Expert Opinion And Perceptual Mapping: To Develop Biodiversity Indicators For Ecosite Classification And Decision Support

By

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A Thesis submitted in partial fulfillment
of the requirements for the degree of
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# Using Expert Opinion And Perceptual Mapping: To Develop Biodiversity Indicators For Ecosite Classification And Decision Support

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## ABSTRACT

The Criteria & Indicators (C&I) hierarchical framework forms the crucial link to the reporting on biodiversity, at international, national, provincial and local levels. Conservation and monitoring of biodiversity has been implemented by establishing criteria and indicators (C&I) for sustainable forest management in Canada. The incorporation of indicators is the interface between research and policy. Determination of the indicators are based on an extensive review of literature on application of indicators in forest management, with emphasis on the boreal forest ecosystems around the world, and expert opinion through the Delphi approach. The indicators obtained were incorporated into a matrix according to scaling criteria. Incorporating biodiversity indicators in forest management, however, is constrained by a number of factors such as cost, certification requirements, and feasibility of use in the field.

I used expert perception of biodiversity indicators to help understand underlying constraints and reduce conflicts among stakeholders in monitoring indicators. Perception mapping provided a rapid way to assess expert opinion with respect to the development and monitoring of biodiversity indicators, as well as to gauge progress toward achieving sustainable forest management goals. My research focused on the various groups of biodiversity indicators classified according to scale and expert perceptions of the relative importance of each group. In this study, experts were asked to rank biodiversity indicators in order to address the current situation, likely future scenarios, and where forest managers could be without cost constraints while monitoring these indicators. The landscape-based groups of indicators were the most feasible for forest managers. Experts had diverse opinions regarding species-based indicators. Experts also thought the least developed were the gene-based indicator group. Perception maps were generated to visually represent how experts perceived these indicator groups and supporting literature was assessed to develop best practices for future indicators. This mapping approach helps us in making informed policy decisions and streamlines our focus on incorporating indicators for monitoring sustainable forest management and conservation of biodiversity.

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## 1.0.0. Introduction

### 1.1.0. What is Biodiversity?

Biodiversity, an enigmatic aphorism, is the "variety of life and its processes on which all flora and fauna depend" (U.S Forest Service 1990; Baydack et al. 1999). Life as we see and know today is due to biological diversity, and our continued existence depends on conservation of this diversity (Baydack et al. 1999). The term biodiversity is a recently coined terminology arising about two decades ago (Hawksworth 1995), but diversity has been in existence since the very beginning of life. Biodiversity has been the awakening or clarion call that has swept across the world, especially for those examining and establishing conditions for the sustainability of future generations. Biodiversity has single-handedly shaped the conservation biology paradigm (Farnham 2002) leading to a tremendous shift in policy implications, land use, resource management and decision-making throughout the world.

### 1.2.0. The emergence of Biodiversity

Biological diversity has brought about wide ramifications in all fields since its original definition (Norse & McManus 1980) indicated by far reaching implications to policy and general approaches to conservation. Biodiversity, a shortened terminology for biological diversity was first coined by Walter G. Rosen in 1985 (Hawksworth 1995) for the national forum on "BioDiversity". Wilson (1988) later edited the proceedings of that conference (Hawksworth 1995). Lovejoy (1980) is said to have also described it with respect to the number of species, mentioning that rapid species decline was occurring without permitting time for evolution. However, he provided no specific definition. Norse

and McManus (1980) described the other two levels of what is now perceived in the definition of biodiversity i.e. the ecosystem and genetic levels. Conservation of biological diversity in U.S. National forests expanded the terminology to refer to community or ecosystem, species and genetic level diversity issues (Norse et al. 1986). Definitions have evolved to take into account all three levels of diversity namely ecosystem, species and genetic components of biodiversity (Norse et al.1986). Many researchers (Hawksworth 1995; Norse 1996; Baydack et al. 1999; Farnham 2002) have traced the history and evolution of the biodiversity terminology in the scientific literature. Mosquin et al. (1995) defined five components of biodiversity, suggesting genetic, taxonomic, ecosystem variations, their functions and the abiotic matrix enveloping them as how biodiversity should be addressed. Biodiversity has changed conservation policy worldwide and appears on more websites than scientific concepts like relativity and sciences like molecular biology (Norse and Carlton 2003)

### 1.3.0. Biodiversity Conservation Paradigm in Sustainable Forest Management:

### 1.3.1. The Canadian Biodiversity Strategy (CBS) definition of Biodiversity

The CBS definition of biodiversity is "The variability among living organisms from all sources including, interalia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems." (Biodiversity Convention Office 1995)

For biodiversity conservation to succeed in a forestry setting, the focus should be on ecologically sustainable forestry that aims at the ecological integrity of the forest and sustain other functional benefits (Mosquin et al. 1995). The difficulty of conserving

biodiversity arises from lack of knowledge on the exact number of species in Canada. Of the estimated 140, 000 species only half have been described (Mosquin et al. 1995).

### 1.3.2. Evolution of Canada's Forest Strategy:

In Canada development of a National Forest Strategy took place over approximately 25 years (Figure1).

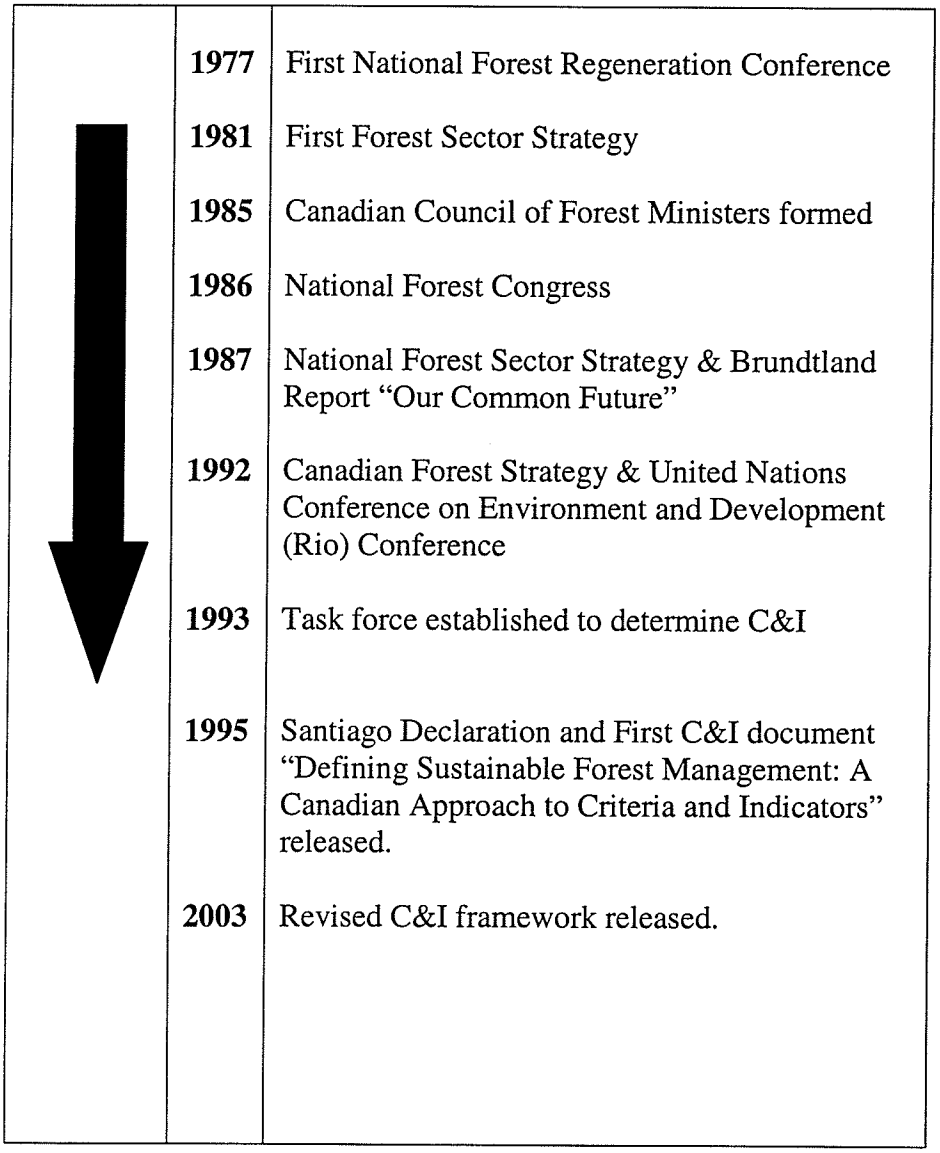


**Figure 1. Evolution of Canada's Forest Strategy** (Source Canadian Council of Forest Ministers. 1997).

The year 1977 marked the first National Forest Regeneration Conference sponsored by the Canadian Forestry Association. This led to the first Forest Sector Strategy for Canada in 1981. The Canadian Council of Forest Ministers (CCFM) was formed in 1985 to bring about a consensus among the 14 federal, provincial and territorial ministers to work together on national and international issues regarding sustainable forest management. This subsequently led to the National Forest Congress in 1986. The proceedings from the congress led to the National Forest Sector Strategy in 1987 (National Forest Strategy 1998). By 1990, changes in the perception of society's views towards the environment led CCFM to focus on much wider areas in forest management, primarily social, economic, and cultural values (Brundtland 1987). The Brundtland report and extensive consultations with Canadians from all walks of life led to the formation of the National Forest Strategy (1992). The Forest Strategy was instrumental in showing Canada's commitment to sustainable development at the United Nations Conference on Environment and Development (UNCED) in1992.

One of the 96 commitments of the Canadian Forest Strategy was to develop criteria and indicators (C&I) to monitor and measure Canada's progress towards sustainable forest management and conservation of biodiversity. The criteria and indicators document was released in 1995, *Defining Sustainable Forest Management: A Canadian Approach to Criteria and Indicators.* Progress has been made date on the reporting and implementation of the indicators within the criteria and indicator framework (Canadian Council of Forest Ministers 2000).

### 1.3.3. Criteria and Indicators at the Global level in Forestry:

Canada's C&I have subsequently been used in various forest industries worldwide. At present seven major criteria and indicator processes and initiatives exist globally, they are the International Tropical Timber Organization (ITTO), Pan-European, Montreal, Tarapoto, Dry Zone Africa, Near East, Central American and African Timber Organization (ATO) processes (Castañeda 1999). All of these processes are conceptually similar in their objectives and approach.

Apart from forestry, the C&I initiative is being implemented in various other ecosystems (Castañeda 1999), especially in rangelands (Flather and Sieg 2000), where the applicability of the Montreal process C&I has been evaluated. The C&I concept has been applied in other disciplines and areas such as rural sustainability (Gupta 2001).

## 1.4.0. The Issue:

### 1.4.1. Determining and Evaluating Biodiversity Indicators

Various approaches have been taken to incorporate biodiversity into sustainable management of forests. The Canadian Biodiversity Strategy and the criteria and indicators approach to Sustainable Forest Management work towards national and international commitments of Canada to monitor and measure the state of Canadian biodiversity status. However, there is a need to develop measures to conserve biodiversity at all scales. This is especially true at scales where on-site forest management activities take place, for the importance of conserving biodiversity can never be overstated, and conservation of biodiversity in all aspects and at all levels is important (Baydack et al. 1999).

The criteria and indicators developed by the Canadian Council of Forest Ministers (CCFM) lend the framework required to develop biodiversity indicators at all levels. Incorporating biodiversity indicators into a level of ecological classification, where management activities take place, will help to attain the goal of conserving and measuring biodiversity at all levels. In Manitoba, an ecological land classification at the ecosite level is being developed to assist with management activities and decision-making. Ensuring compatibility of the biodiversity indicators with the ecological land classification at the ecosite level will ultimately lead towards better management of forests. The development of biodiversity indicators and their compatibility between the various levels of ecological classification will provide linkages to the policy of incorporating indicators in international, national, and sub-national levels.

The criteria and indicator approach will also give an opportunity to apply this over different scales and create uniformity in application. The criteria and indicator approach is recognized and adopted worldwide. It is also essential to determine the perception of experts regarding these indicators in forest management. However, incorporating biodiversity indicators is constrained by a number of factors such as cost, certification requirements, and feasibility of use in the field.

Based on the above facts, I proposed that determining expert perception of these indicators would help to understand possible constraints in applying these indicators to sustainable forest management.

### 1.4.2. From the National level to Sub-national, provincial or?

The Forest Biodiversity Indicators Workshop (McKenney 1994) held in Sault Ste Marie, Ontario brought out information relevant to scale, and described the need for

indicators to provide information and to operate across various spatial scales such as, the national, regional and local levels. McKenney (1994) notes that an indicator should focus on societal values and what is feasible to conserve, and biodiversity indicators should provide feedback to decision makers on land use and resource utilization (Mackay et al. 1994).

The emerging issue is the need for provincial indicators or sub-national indicators especially with respect to the various land classification scales (Working Group 2001). Mosquin et al.(1995) identified this issue and suggested the need for involvement of provincial strategies for conserving biodiversity. The need to link datasets from local to national levels has been highlighted (Canadian Council of Forest Ministers 2000).

Quebec and Ontario have already developed approaches and provincial level indicator frameworks, in their jurisdictions (Canadian Council of Forest Ministers 2000 and Working Group 2001). Newfoundland and Saskatchewan are in the process of developing provincial indicators (Working Group 2001). New Brunswick has produced a vision document for managing its forests (Canadian Council of Forest Ministers 2000). In Manitoba, the forestlands inventory technical advisory committee (FLITAC 2000) has also suggested expanding the scope of inventories by incorporating non-timber features, biodiversity and recreational values. It also recommends that ecological classifications of forestlands, which are functionally operational, be completed to lead into the complete ecological land classification (Ecological Stratification Working Group, 1996) of Canadian forests.

### 1.4.3. Manitoba Ecosite Project and ELC

Research on ecosite classification at the University of Manitoba is being undertaken in partnership with the three forest industries in Manitoba (Tembec, Tolko, and Louisiana Pacific) the Province of Manitoba, Manitoba Hydro, Ducks Unlimited and Geospatial International. Federal granting agencies NSERC, and SSHRC, and the Canadian Forest Service, are also involved in developing this ecosite level of classification and decision support system for the boreal shield and boreal plains ecozones of Canada in Manitoba.

### 1.4.4. Ecosite

Ecosite are at a scale, which are mappable, and forest management activities are carried out (Racey et al. 1996). In Manitoba, work has been carried out on sustainability indicators (Manitoba Round Table 2001). However, the scale issue has to be reviewed in their application to sustainable forest management and at the ecosite level of classification. The various Model forests around the country have developed local level biodiversity indicators (Model Forests 2000). Again the need is to determine if these indicators are compatible to the ecosite level of classification that is being developed for Manitoba. It is important to find out if these are applicable through out the province or if they are more specific to the region they were developed. Canada is covered by about 418 million hectares of forests(Canadian Council of Forest Ministers 2000). Dealing with such a huge area makes it necessary to look at surrogates to assess and measure the overall health of the region. About 8.5% of the province is under protected areas (Parks Canada 2000) while this effort is commendable, protected areas alone will not solve the

need to conserve and maintain biodiversity; there is a need to develop pro-active measures.

Pearson (1995) suggested measures and criteria for the development and selection of indicator taxa; Noss (1990) suggested a hierarchical approach focusing on the three attributes of biodiversity; composition, structure and function proposed by Franklin (1981). For conservation of biodiversity to be possible, the indicator approach was suggested as being the most plausible because, "Indicators are measurable surrogates for environmental end points such as biodiversity" (Noss 1990). Development of biodiversity indicators and their compatibility between the various levels of ecological classification will provide linkages to the policy of incorporating indicators in international, national, and sub-national levels. The CCFM felt the criteria and indicator approach would also give an opportunity to apply biodiversity indicators over different scales and create uniformity in application.

### 1.4.5. Ecological Land Classification and Criteria & Indicators Hierarchy Comparison:

The Canadian Committee on Ecological Land Classification (Canada Committee on Ecological Land Classification 1977) was instrumental in incorporating ecological land classifications as part of the inventory within forest management (Wiken and Ironside 1977). Sims et al. (1996) define Ecological Land Classification (ELC) as a scientific endeavor that attempts to organize, stratify and evaluate ecosystems (and complexes of ecosystem) for the purpose of land resource management.

The ELC is an entity within a nested hierarchy of spatially definable polygons (Rowe 1961; Urban et al. 1987). In Canada the CCELC hierarchy of land classification

was established to aid in various natural resource management issues (Ecological Stratification Working Group 1996). In a similar fashion the C&I initiative began to evolve as it became apparent that no single national set of C&I will be able to cover the regional and local requirements at all scales, subsequently provinces and model forests across the country have begun developing their own C&I (Working Group 2001) and a C&I hierarchy has been established.

An ecological land classification is useful in conservation of biodiversity as a land area, and all that resides on it first needs to be spatially specified, assigned and described, before proper management activities are carried out (Sims et al 1996). Further, to fulfill this common goal of conservation of biodiversity, there is a need for synergy and synthesis between and among the hierarchies. It is essential that scalability and compatibility between these various levels of organization, especially the C&I hierarchy and CCELC hierarchy, be made. Linkages between the C&I hierarchy and the CCELC hierarchy is necessary for better management decisions.

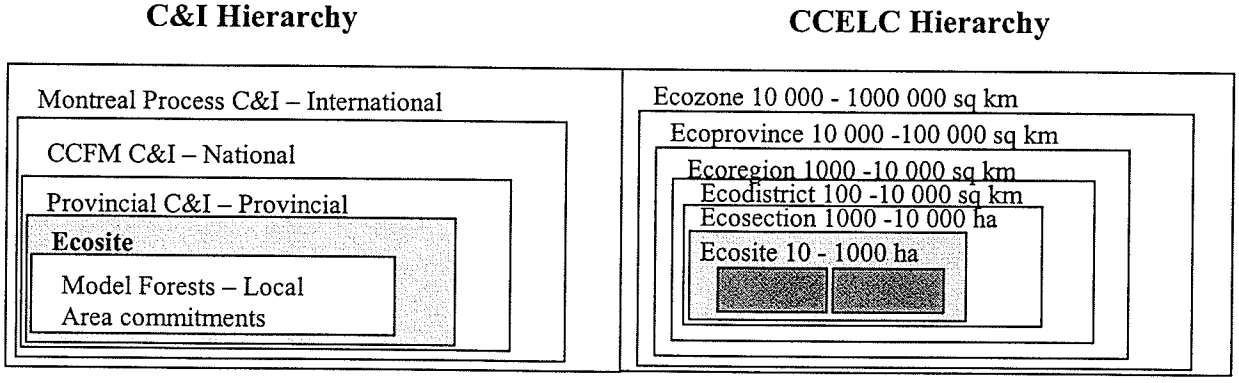


**Figure 2. C&I and CCELC Hierarchy Comparison.**

### 1.4.6. Expert Input and Perception utilization:

Biological diversity has far-reaching implications in a wide array of policy areas. A solution to address the issue of monitoring biodiversity in differing management

decisions is to understand the perception of the experts as to why they believe it is important for monitoring these indicators. This research focuses on the various groups of biodiversity indicators classified according to scale and expert perceptions on the relative importance of each group. Understanding the perceptions of the concerned experts will aid us in making informed policy decisions and streamline our focus on developing indicators for implementation in sustainable forestry and managing protected areas for the future.

### 1.5.0. Perceptual Mapping

Perceptual mapping is a graphics technique used by marketers and researchers (Bigne et al. 2002; Diamantopoulos et al. 2003; Kuhfeld 2004) that attempts to visually display the perceptions of customers or potential customers, perceptual mapping procedure utilizes readily available ratings data, which are used to satisfy management's need for a competitive comparison (Wittenschlaeger and Fiedler 1997). Perceptual maps are a tool to simplify many complex relationships and plot the interrelationships of consumer products, industrial goods, institutions, populations and individual opinions (Wittenschlaeger and Fiedler 1997; Pan and Baker 1998). Any subject or individual that can be rated on a range of attributes can be mapped to show their relative positions in relation to other subjects or individuals as well as to the attributes they were rated on, this mapped output is known as a perceptual map (Wittenschlaeger and Fiedler 1997; Kuhfeld 2004).

Perceptual mapping provides a rapid way to assess expert opinion with respect to the development and application of indicators and how to assess their progress in monitoring. In this current study, I address current expert perceptions, and identify expert

perceptions with and without cost constraints for biodiversity indicators. This approach is relatively less expensive, compared to collecting years of relevant data to understand change in perceptions, and has the ability to repeat iterations with regards to changes in perception. Currently this perceptual mapping approach is being used extensively in marketing research (Bigne et al. 2002; Diamantopoulos et al. 2003). Perception mapping has been used to study athlete opinions regarding banned substance use in sports (Pan and Baker 1998) and it has also been used in education to understand student instructor relationships (Williams and Lawson 2001). It is hoped that applying this methodology with respect to expert opinions on biodiversity indicators will help in understanding significant issues in sustainable forestry.

My research, in essence, compares and contrasts how and why experts in the field view biodiversity indicators grouped by scale.

### 1.6.0. Research Objective:

The purpose of this research is to assess expert perceptions on how to address the conservation of biodiversity in sustainable forest management. Specific objectives of the study are:

- To identify possible biodiversity indicators for the conservation of biodiversity in Manitoba through a literature review and expert opinion.
- To decipher what experts perceive these indicators are achieving or not achieving.
- To highlight the underlying relationships that exists between these various indicator groups and relate them to the ecosite level of ecological classification.

- To apply perception mapping as a tool for analyzing expert opinion with regards to biodiversity indicators in sustainable forest management and protected areas management.
- To recommend best practices for the development of future indicators in sustainable forest management.

## 2.0.0 Methodology

### 2.1.0. Introduction:

The criteria and indicators, though well established and implemented at the national level, however, need to also be considered at the local level. Developing these indicators at the ecosite level in Manitoba is connected to forest management activities occurring on the ecosite land classification unit. The research was carried out in three phases Figure 3 explains the methodology adopted for this study.

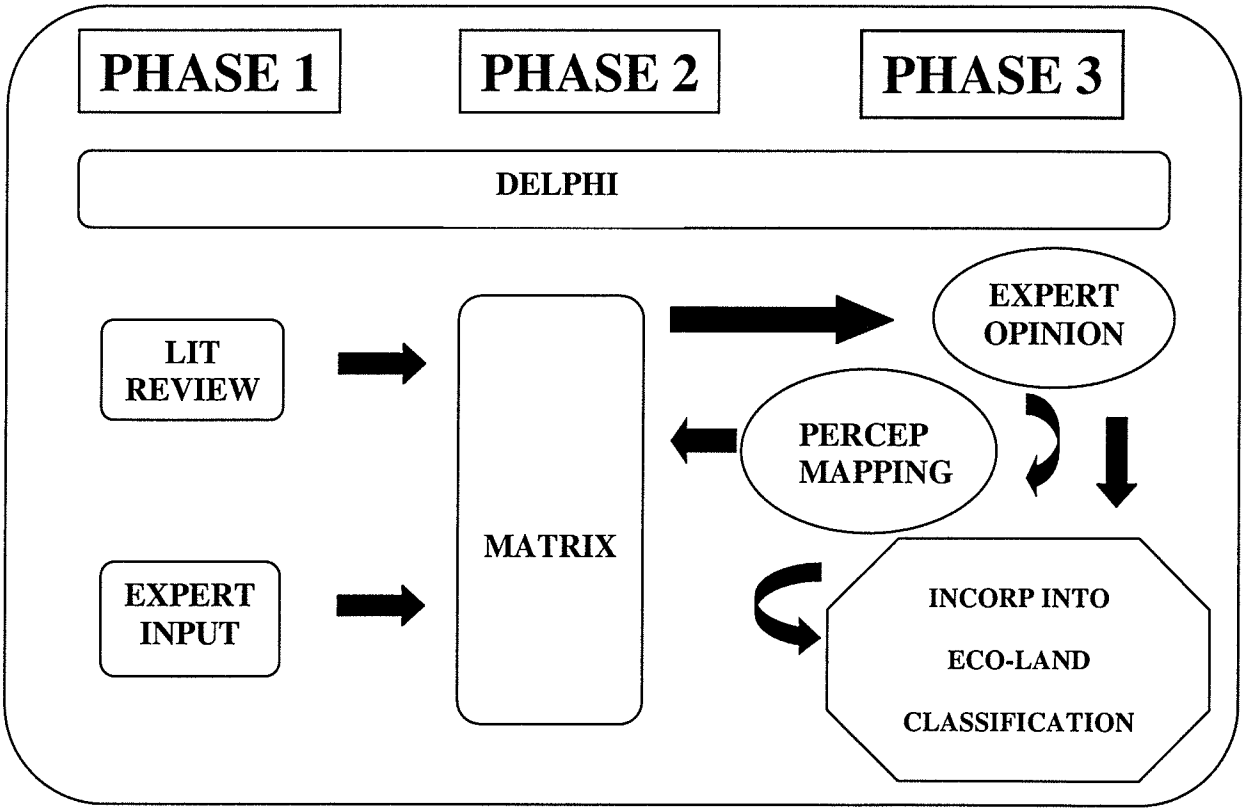


**Figure 3: Schematic representation of the methodology adopted.**

### 2.2.0. Literature Review:

Gathering information about indicators was accomplished by reviewing the application of indicators over various other jurisdictions in Canada, application of these indicators in Model forests across the country was also reviewed. A literature review of available indicators was carried out to develop a matrix of 101 indicators, which is discussed in the next chapter on indicator literature. The indicator matrix was developed primarily from:

- The Montreal Process indicators on monitoring biodiversity.
- Canadian Council of Forest Ministers (CCFM) indicators on biodiversity
- Provincial indicators developed across Canada
- Model forests indicators across Canada with special emphasis on Manitoba Model forest indicators and,
- Indicators from global boreal forest regions especially, Scandinavia.

### 2.3.0. Expert Input:

However, information gathered regarding the relevant criteria and indicators need to be validated by local experts and expert knowledge input is essential. Review of scientific literature led to information, which needed to be scientifically credible and verifiable (Schuster et al. 1985). This can be achieved by employing different methods of expert opinion gathering. Hence, different expert opinion collecting techniques were explored, the Delphi Method and Nominal Group Technique (NGT) have been used alternately for amassing group opinion (Delbecq et al. 1975). Although both approaches are very similar in collection of information, the two methodologies differ in their group processes and by the way data is collected (Delbecq et al. 1975).

### 2.4.0. Nominal Group Technique (NGT):

Nominal group technique developed by Andre L. Delbecq and Andrew H. Van de Ven in 1968 (Delbecq et al. 1975) is a structured group meeting, which requires the physical presence of the experts around a table (Delbecq et al. 1975). Silent generation of ideas in writing takes place followed by round-robin recording of ideas on flip charts, with discussions of each recorded idea for clarification and evaluation (Delbecq et al. 1975). To complete the process individual voting on important ideas through rank ordering or rating is accomplished (Delbecq et al. 1975).

### 2.4.1. Drawbacks of the Nominal Group Technique:

Anonymity is compromised because experts need to be present (Delbecq et al. 1975). Physical presence of experts is necessary and requesting all the experts to be present at the same time could lead to inconvenience. Group discussions that are interactive tend to have "process loss" (Steiner 1972). These may be due to mismatch among experts, caused by status, influence of personality, social pressure on competent experts by incompetent experts, and also by the quality of the contributions (Steiner 1972; Delbecq et al. 1975; Schuster et al. 1985).

### 2.5.0. The Delphi Process:

The RAND Corporation initially developed the Delphi technique during the 1950s primarily to "obtain the most reliable consensus of opinion of a group of experts by a series of questionnaires interspersed with controlled opinion feedback"(Dalkey and Helmer 1963).

This tool can be used for condensing expert group knowledge (Dalkey et al.1969) and typically was developed as a forecasting tool; it can also be used in decision-making (Fusfeld and Foster 1971 and Crance 1987). The subjective aspect of Delphi allows linkages to quantitative data as well (Fusfeld and Foster 1971). The Delphi Method has been accepted and applied in the fields of defense (Dalkey and Helmer 1963), corporate planning (Fusfeld and Foster 1971), renewable resource management, medicine (Zuboy 1981) and education (Uhl 1983). In wildlife management, it has been widely used with respect to habitat suitability assessments and index curves (Schuster et al. 1985, Crance 1987, Mollohan et al. 1995 and Uhmann 2001).

Data gathering methods associated with expert opinions involving interactive discussions have not only shown limitations in accuracy but also biases (Dalkey 1969 and Delbecq et al. 1975). The major premise of the Delphi process is to gather an unbiased synthesis of expert opinion (Delbecq et al. 1975). The Delphi approach leads to a consensus of experts, where collation of expert judgement obtained is greater than opinion obtained from a single expert (Dalkey 1969; Fusfeld and Foster 1971; Uhl 1983 and Crance 1987).

An aspect of the Delphi Method is anonymity of the experts during the information-gathering phase (Dalkey 1969; Delbecq et al.1975; Coughlan and Amour 1992). " Delphi aims to make use of the positive attributes of interacting groups" (Rowe et al. 1991) and the social pressure to conform is removed by anonymity (Delbecq et al.1975; Schuster et al. 1985). The essentials that characterize a Delphi technique are anonymity, iteration, controlled feedback, and statistical aggregation of group response (Rowe et al. 1991).

Three separate groups of individuals were needed to carry out the Delphi process for this study (Turoff 1970; Delbecq et al.1975).

1. The decision-makers, and the group that receives and implements the recommendations of the Delphi.
2. A group or person, who sends out the initial questionnaire, summarizes and carries out the Delphi.
3. A group of experts that answers the questions.

### 2.5.1. Why use the Delphi process in determination of Biodiversity Indicators:

Although information exists on biodiversity indicators in Manitoba, the development of specific indicators needs refinement. Because, there are a whole array of possible indicators that can be used, which would be best for Manitoba at the ecosite level of land classification needs to be determined. The Delphi process can be employed as a useful communication tool in planning (Uhl 1983) and decision-making (Coughlan and Armour 1992). The method has been used for gathering information in various fields, but has not been applied on expert opinion of biodiversity indicators and perceptions. The Delphi method also allows for current exchange of scientific and technical information that cannot be accomplished by the traditional literature search (Crance 1987). The method can also evaluate the applicability of biodiversity indicators in Manitoba.

### 2.5.2.0.Guidelines for the Delphi Method:

#### 2.5.2.1. Number of experts:

The ideal number of experts is yet to be determined for the Delphi method (Crance 1987). The number of respondents needed to constitute a respective sampling

pool determines the number of participants. The "information processing capabilities of the design and monitoring team" (Crance 1987) will determine the number of participants. Care was taken to prevent overrepresentation by stakeholders or individuals (Crance 1987) from a single group or geographical area. In this study, experts were determined from three major groups, government, industry, and university researchers.

**2.5.2.2. Selection of experts:**

Traditionally, the experts for the Delphi process will be selected by a method commonly known as the snow- ball sampling method (Babbie 1998). One or more identified experts in a field will be interviewed and asked to suggest whom they think are experts in the area of the study being undertaken. The process will continue until a substantial list of experts and no new names of experts arise (Crance 1987). However, in some cases the need to obtain representative experts from different areas of expertise will also be needed to address a particular concern.

In a traditional Delphi approach, once the experts have been finalized, each expert is mailed an information package with a broad question on the topic to be addressed (Delbecq et al. 1975 and Crance 1987), typically rank ordering questions to prioritize them (Delbecq et al. 1975). Space is provided in the questionnaire for the participants to suggest information to be included in the next round of questions. The first round of questions usually consists of unstructured questions (Uhl 1983) with instructions to return the completed questionnaire (Dalkey 1969; Delbecq et al. 1975; Crance 1987).

The summary of the responses is carried out and the second iteration begins by forwarding the summary to the experts (Dalkey 1969; Delbecq et al.1975; Uhl 1983 and Crance 1987). The summary is accompanied with a second set of questions highlighting

the responses obtained from the first round (Delbecq et al. 1975; Uhl 1983 and Schuster et al. 1985). The participants are requested to respond to the second questionnaire and the highlighted agreements /disagreements arising from the first round (Crance 1987; Coughlan and Armour 1992). The responses of the completed second questionnaires, on return, are summarized (Dalkey 1969; Delbecq et al. 1975; Uhl 1983 and Crance 1987). The Delphi process is completed after a consensus is reached or an agreeable level of uniformity is reached among the experts (Delbecq et al 1975; Uhl 1983; Schuster et al. 1985; Crance 1987 and Uhmann 2001).

### 2.6.0. Modified Delphi approach:

### 2.6.1. Workshop Process:

Alternatively a modified Delphi with a workshop process may also be implemented (Uhmann 2001), where the initial information gathering will be carried out during a daylong workshop. Subsequently, the detailed summary and the second iteration questionnaires are sent to the participants (Uhmann 2001).

### 2.6.2. Structured Questionnaires:

The Delphi approach can be modified and a change warranted by the situation is also acceptable, if there is enough information available to produce a focused and structured questionnaire (Uhl 1983). The Delphi may also be used by skipping the first round (Uhl 1983). One of the advantages of a structured questionnaire is its timesaving and a straightforward approach (Uhl 1983).

For the purpose of this research, I adopted the structured questionnaire approach, since there is a lot of information available for the various indicators in sustainable forest

management, such as the CCFM, Model Forest, and Provincial C&I. The need is to determine what would be feasible for Manitoba, what indicators are already being monitored, what needs to be monitored or implemented, and also what will most likely be implemented as an ideal indicator. This process is essential for criteria and indicators since decision-makers will be in a better position to make informed policy recommendations.

### 2.7.0. Drawbacks of the Delphi process:

The Delphi process may be used in various expert opinion gathering exercises (Uhmann 2001) however, certain disadvantages do exist must be taken into account before proceeding with Delphi process.

1. Time (Delbecq et al. 1975)

The time taken by experts to answer is considerably less compared to the time taken to summarize and develop the subsequent set of questionnaires during each iteration (Delbecq et al. 1975). Hence, time could be a limiting factor.

2. Motivation (Delbecq et al. 1975)

Data collection is carried out in isolation. This could lead to decrease in the quality of information obtained, as group motivation is not a part of the Delphi method (Uhmann 2001)

3. Written skill (Delbecq et al. 1975)

The written skill of the experts could also be a limiting factor in the Delphi process as misinterpretation could occur and "verbal clarification"(Uhmann 2001) will not be possible because of the anonymity factor among experts (Delbecq et al. 1975). Since

differences cannot be discussed and are just counted as ratings, the accuracy of information could be reduced (Delbecq et al. 1975).

### 2.8.0. Indicator Matrix Development:

The indicators were collated into a matrix based on ecosystem, species, and genetic diversity, which are termed as elements in the CCFM C&I hierarchy. However, some of the indicators, though related to the boreal forest were not present in Manitoba; especially species-based indicators relating to large carnivores (Model Forest 2000) such as *Ursus arctos* (Grizzly bear) and therefore these were removed from the Indicator Matrix.

With the large number of indicators that were identified, it was necessary to further refine the matrix of indicators to arrive at a more feasible number of indicators.

### 2.8.1. Matrix Refinement:

A matrix of 101 biodiversity indicators was obtained from the extensive literature review. However, the feasibility of implementing all of the indicators was limited. Hence, it was necessary to further refine the matrix; expert opinion from Academic, Provincial and Industry personnel was gathered through snowball sampling (Babbie 1998).

### 2.8.2. Snowball Sampling:

In snowball sampling a primary contact is identified and used to identify additional experts and continued until the contact names are repeated or the required sample size is reached and the process is deemed complete. During the first iteration of this study sampling consisted mainly of University researchers. The second iteration was

more expansive with 13 experts selected equally from each of the three important areas Academia, Provincial Government, and the Forest Industry.

The experts determined by snowball sampling suggested the refinement of the matrix. The matrix was refined and divided into three elements (i.e. Ecosystem, Species and Genetic diversity indicators) based on scale according to the CCFM C&I (Canadian Council of Forest Ministers 1995).

Since the Ecosystem indicators were relatively large in number, it was further refined into three sub-groups based on their function. The ecosystem based subgroups were: a) Structure and Pattern, b) Protected Areas and c) Disturbance and Fragmentation. The total number of indicators was reduced to half its original size by the process of consensus elimination, where an indicator was eliminated if experts consistently ranked an indicator poorly. The final matrix yielded approximately fifty indicators, with approximately ten indicators in each of the five groups.

### 2.8.3. Questionnaires:

Four sets of questionnaires to assess expert perceptions were developed (Appendix 1A-1D). Questionnaire A: Landscape based indicators were divided into three subgroups, Questionnaire B: Species based indicators, Questionnaire C: Gene based indicators, and Questionnaire D: To understand which among the five scaling groups the experts considered most important to fulfill their area of expertise or interest.
Experts were asked to rank indicators given in each of the questionnaires A, B, and C, (the refined indicator matrices) in three categories: 1) best measure irrespective of cost, 2) best for current implementation, and, 3) critical for future operational use within 5 years.

Experts were also asked to rank questionnaire D according to their perception of each scaling group based on its importance to their area.

### 2.9.0. Ranking:

In 1932, Renis Likert developed a measurement method, called the Likert Scales, which has been used in attitude surveys. The system ranked answers that ranged from "strongly disagree" to "strongly agree." The ranking in this study was implemented following Likert (1932) type scale ranging from: 1 very poor, to 10 very good. Traditionally, Likert type scales range from 1 very poor to 5 very good or 1 very poor to 7 very good (Likert 1932; Clason and Dormody 1994). In this study initially a scale of 1 to 5 was used in the first iteration, however, a scale of 1 to 10 was adopted in the second iteration. A 10-point scale has been employed in similar situations (Nass et al. 2001; Berrenberg et al. 2002) to enable better dispersion of data.

### 2.10.0. Iteration:

The Delphi method and the perception mapping were both implemented in an iterative process, and the iterations were carried out to further refine the relationships among and between the indicators and indicator groups. In this study, two sets of iterations were carried out, the first consisted of a limited group of biologists, and the second iteration consisted of a wider circle of experts from industry, provincial government and researchers. Repeated iterations over a period of time will help decision makers to assess changes in perceptions and attitudes, as experts assimilate more information.

### 2.11.0. Analysis:

Spearman Rank Correlations, Correspondence Analysis and Multiple Discriminant Analysis were the techniques used in development of perceptual maps since these techniques were better suited for analyzing rank ordered data and are discussed below.

### 2.12.0. Perceptual Mapping:

Any subject or individual that can be rated on a range of attributes can be mapped to show their relative positions in relation to other subjects or individuals as well as to the attributes they were rated on, this mapped output is known as a perceptual map (Wittenschlaeger and Fiedler 1997; Kuhfeld 2004). Perceptual maps are a tool to simplify many complex relationships and plot the interrelationships of consumer products, industrial goods, institutions, populations and individual opinions (Wittenschlaeger and Fiedler 1997; Pan and Baker 1998).

Perceptual mapping has been used extensively in marketing research to answer questions such as identifying customers, where a particular product is positioned, what new products need to be created, where can new products be positioned (Kuhfeld 2004).

Perceptual mapping is important to this study because of a need for visually representing complex information on biodiversity indicators for forest managers to determine and understand what indicators are important at present, as well as feasible for the future. Therefore, perceptual mapping was used in this research to produce maps and plots that displayed where a particular indicator was positioned in monitoring, what new indicators will be needed, and whether there was a preference for a particular indicator

group? In addition it enabled analysis of whether experts differ in preference for certain indicators.

Kuhfeld (2004) suggests perceptual mapping can be implemented using an array of methods such as correspondence analysis (CA) (Hoffman and Franke 1986; Malhotra and Bartels 2002), multiple correspondence analysis (MCA), analysis of covariance (ANCOVA) (Diamantopoulos et al. 2003), preference mapping (PREFMAP), multidimensional preference analysis (MDPREF) (Pan and Baker 1998), and multidimensional scaling (Williams and Lawson 2001).

### 2.12.1. Spearman Rank Correlation:

Spearman rank correlation (Spearman 1904) was used in the first iteration, since the data being dealt with consisted of ranked data, as a preliminary analysis of perception mapping a Spearman rank correlation (Table 6, 7 & 8) was carried out to understand the relationships among the experts and between the scaling groups.

In the second iteration there was also a need to understand what would be the best group from the present to the future. Spearman rank correlation was carried out to understand and better portray the relationships among the experts and between the scaling groups over time. This is a coefficient based on calculating the differences in rankings for an individual on the two variables to be correlated.

Kendall's (1938) tau coefficient was not used because it requires an assumption that the ranks are continuously distributed (Hays and Winkler 1975).

Spearman rank is useful as a measure of strength of the relationship between two variables. Spearman rank is also better suited for non-parametric data (Hays and Winkler 1975). A weakness of Spearman rank is the inability of the correlation between two

variables to not imply or describe the cause (Crichton 1999) (i.e. one causing the other) since both variables may be related to a third underlying variable.

### 2.12.2. Multiple Discriminant Analysis:

MDA is similar to the multivariate analysis of variance (Legendre & Legendre 1998) and is also known as canonical variates analysis. The objective of MDA is to maximally distinguish two or more natural groups of individuals in a multivariate space. This method can be used as a formal statistical approach to determine the significance of group separation as well as provide a " Descriptive" ordination of group relationships on a scatterplot. Discrimination is accomplished by finding a series of axes (similar to ordination axes) that maximize the between-groups variance relative to the variance within groups. The method also determines which of the $p$ variables (CA axis 1) are most useful in discriminating the $g$ (expert) groups.

In this study, MDA was used to explore whether occupation influenced expert perceptions of biodiversity indicators. MDA was also used descriptively to better understand perceptual mapping results.

### 2.12.3. Correspondence Analysis:

For the mapping approach, Correspondence Analysis (CA) (Greenacre 1984) was used. CA is a technique that graphically displays scaled response and can be implemented in almost all rectangular matrices (Higgs 1990). CA best describes two-way associations (Malhotra and Bartels 2002) or two-way dual scaling (Walker pers.com 2004). The CA positioned experts based on how they ranked the indicators and indicators based on how they were ranked by experts. The CA also reduced the dimensionality of the data and

makes the data easily interpretable (Greenacre 1984; Hoffman and Franke 1986; Higgs 1990). CA would also help in the interpretation of motivation (Higgs 1990), about why experts want to measure certain groups and indicators over other indicators, since requesting a direct response could possibly bias opinions (Rice 1989; Higgs 1990) here bias implies the experts changing their normal response because they think the answer should be different. CA also gives an opportunity to track changes over time (Higgs 1990), hence perceptual maps could be ideal for incorporating within Decision Support Systems (DSS) with regards to tracking expert perceptions of these indicators and give forest resource managers insights into making policy decisions such as focusing on what group of indicators needs more data to begin monitoring, and for what group of indicators more data is likely to become available in the near future.

Questionnaire D was used to develop a perceptual map of expert opinion for the question, which among the five groups, was most likely to fulfill their area of expertise. Also, which of the indicator sub-groups they thought would be most useful irrespective of cost, for current implementation as well as being important for monitoring in the next five years.

Expert opinion was analyzed with respect to each of the sub-groups and a perceptual map of the five groups was developed. Expert perceptions of feasibility for current indicator implementation, and possibility of implementation in five years were mapped.

**2.12.3.1. Biplot:**

The Biplot technique (Bradu and Gabriel 1978; Gabriel 1981) is used for a number of methods like MDPREF, PREFMAP, CA and MCA (Kuhfeld 2004). The

Biplot at the same time displays the row and column tables of a data matrix in a two-dimensional plot (Higgs 1990; Kuhfeld 2004). The CA 1st axis and CA 2nd axis scores are usually utilized to plot the Biplots. The mapping approach in this study also incorporated the Biplot technique.

**2.13.0. Conclusion:**

To summarize the methodology, the mapping of expert perceptions concerning the various indicator-scaling groups lead to proper understanding of relationships between these groups by:

1) Visually representing how experts perceive these indicator groups.
2) Spatially surmising expert perceptions with respect to the capability of implementing these indicators.
3) Understanding, where the focus should be in developing and monitoring each of these indicator-scaling groups and indicators, and
4) Inferring what the best indicators could be regardless of cost constraints.

## 3.0.0. Indicator Literature Review:

### 3.1.0. Introduction:

Indicators and forestry practices from various parts of the world were reviewed. Since forestry in Canada and Scandinavia both deal with similar ecosystems (Henry 2002), Scandinavian examples are discussed in detail. Comparing and contrasting similarities in the forestry practices and indicators monitored assisted in understanding the similarities between the two continents and their respective forest industries.

The review of Canada's Biodiversity Conservation Strategy and Canadian indicator literature consisted of an extensive amount of indicators in place across the country at all levels from the International (MP C&I), National (CCFM), Provincial (Ontario), Local level (Model Forests) indicators across the country.

The indicator matrix obtained from the review of indicators was incorporated in questionnaires given to experts from the forest industry, provincial decision makers, biologists and university researchers.

### 3.2.0 Biodiversity Monitoring in Scandinavian Boreal Forests:

#### 3.2.1. Boreal Forest Circumpolar Distribution:

Boreal forests are circumpolar in distribution, occurring between 50 and 60 degrees North latitudes (www.ucmp.berkeley.edu 2003). Boreal forests constitute one of the largest terrestrial biomes in the world, accounting for more than 13 million square kilometers (Henry 2002). Boreal forests in Scandinavian countries and Eurasia support similar assemblage of species and characteristics (Henry 2002). The influences of

humans and forest management on these forests have also existed for centuries (Henry 2002).

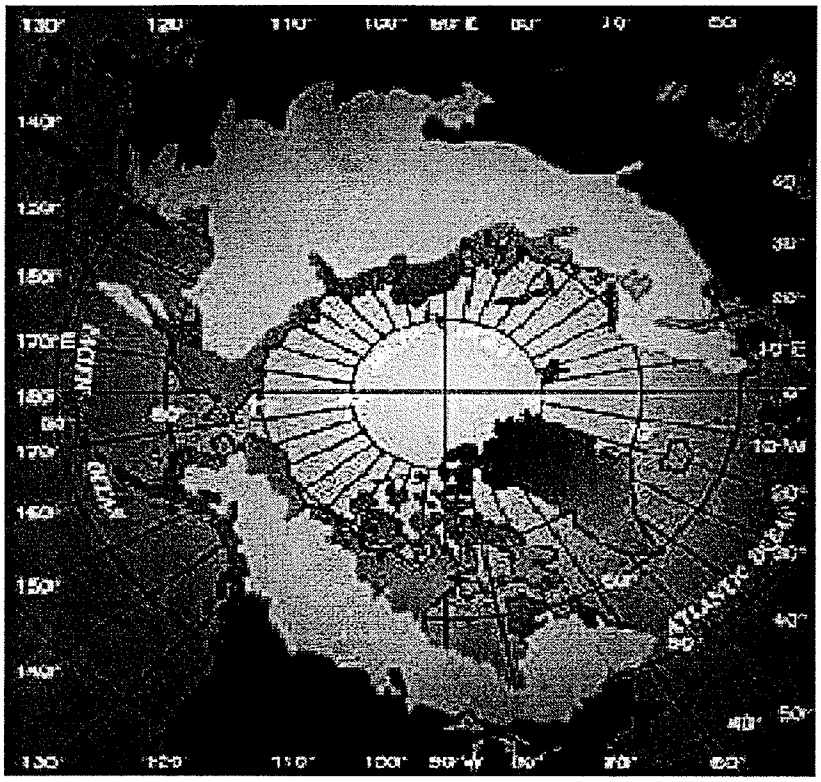

**Figure 4: Circumpolar distribution of the Boreal Forest.** Map source (Hare and Ritchie 1972)

This literature review focused on Scandinavian Boreal forests and was carried out to determine and identify indicators that can be applied to sustainable forest management activities in Canada. Summarizing the various approaches taken for measuring and monitoring Biodiversity in Scandinavian Boreal forests and contrasting those with approaches in Canada, increases the knowledge for achieving sustainable forest management.

Efforts to compare and contrast certain bird species between Eastern Canadian Boreal forests and Fennoscandia have been attempted (Louis et al. 2000), and efforts are

underway in a limited scale to apply certain bird species like woodpeckers as indicators of forest bird diversity (Mikusinski et al. 2001) in Canada. To give further background into forestry practices and the extent of forestry, the Nordic countries account for 2 percent of the forest areas in the world compared to 7 percent of Canada (www.borealforest.org 2003). Historically, forestry practices and anthropogenic influences have been more pronounced and intense in Scandinavia, having been carried out over centuries (Larsson and Danell 2001) compared to Canada, where forestry practices began to occur in earnest from the beginning of this century (www.canadianforestry.com 2001). However, exploitation of resources in other areas like fur trade have been taking place for some centuries.

The awareness of biodiversity as a major management issue in Fennoscandia occurred after the Rio Conference in 1992 (Larsson and Danell 2001). Threats faced by Fennoscandia forests include loss of habitat and monocultured forests leading to loss of diversity in structure (Larsson and Danell 2001). Global warming, air pollutants and introduced species management, especially species for commercial forestry (Sjoberg and Danell 2001) constitute other major threats (Larsson and Danell 2001). Management for biodiversity focuses on three major paradigms: forest reserves, modified silvicultural methods, and habitat restoration (Fig .5)

Angelstam and Andersson (2001) have discussed developing guidelines for forested reserves in Sweden. Similarly, in Manitoba, the province is in the process of establishing protected areas under the protected areas initiative (PAI) in partnership with World Wildlife Fund Canada's Endangered Spaces Campaign. The protected areas initiative, is however, more expansive, with involvement from other resource sectors as well.

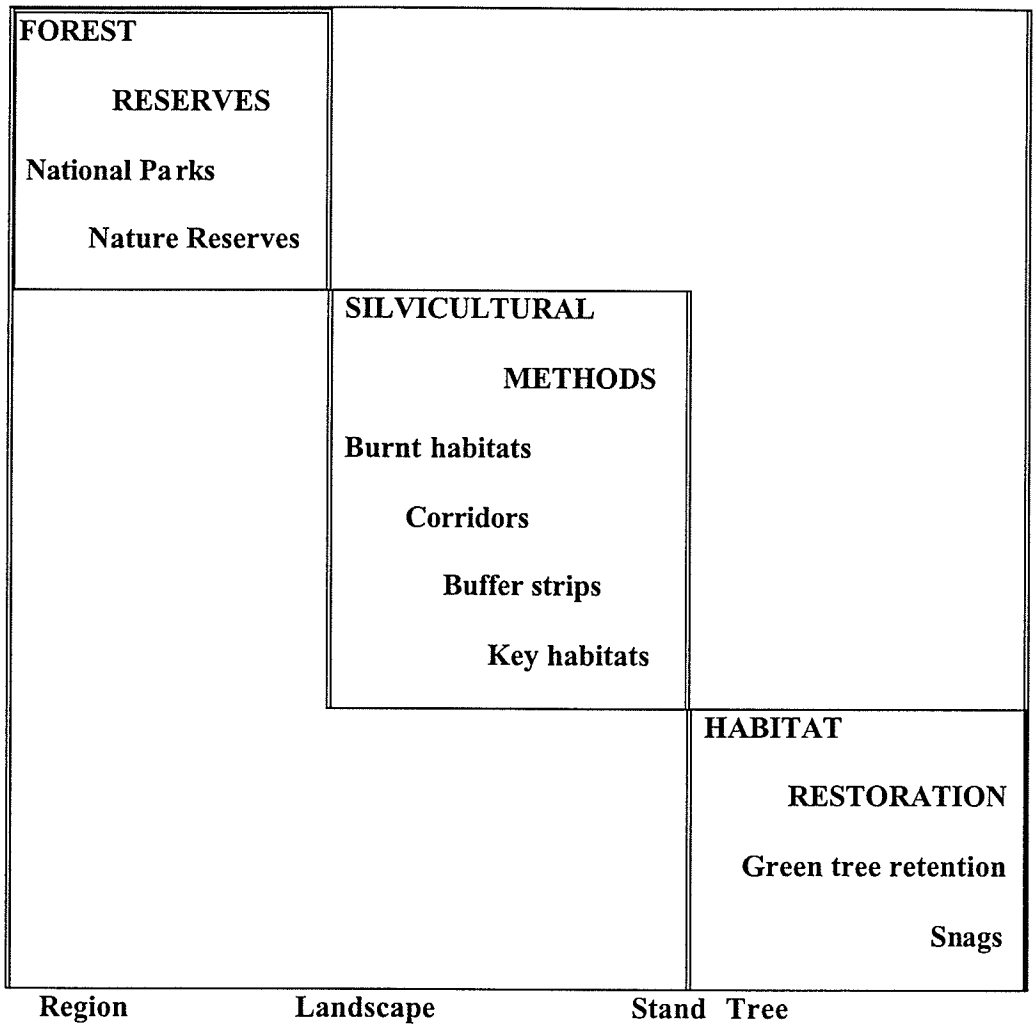


**Figure 5: Methods to conserve Biodiversity in Fennoscandia. Source: Modified from (Larsson and Danell 2001).**

Complementing the forested reserve concept is a unique Swedish example, the key habitat concept (Hansson 2001). Sweden has always had its focus on species protection; the key habitat concept is the keystone species concept applied to small habitats, especially where red-listed species may tend to occur. Red-listed species, which are used mostly, tend to be stationary organisms like lichens, fungi and bryophytes, which however overcome isolation by mobile diaspores (Hansson 2001). The key habitat concept focuses on the cryptogams rather than on vertebrates and vascular plants alone.

Fire as a natural disturbance is quite similar to Canada as well, but the policy of forest companies and forest certification requirements to burn a specific amount of land within their management in Europe (Granstrom 2001) may not be applicable to Canada. In Canadian boreal forests, fire seems to occur in much larger scales, 100 000 ha fires are common (Simberloff 2001) so fire as certification requirement may not be implemented because of the large tracts of forests and also because plantation forestry is not practiced in Canada.

The green tree retention (GTR) concept (Vanha-Majamaa and Jalonen 2001) is another idea which is being adopted. The concept focuses on three major objectives: 1) " lifeboating" species and processes over the regeneration phase 2) leads to more structural variation of the forest stand (Vanha-Majamaa and Jalonen 2001) and 3) to increase connectivity at the landscape level (Franklin et al. 1997).

It has been suggested by Vanha-Majamaa and Jalonen (2001) that GTR can be carried out with prescribed burning to increase chances of restoration of forest continuity. Similarly it has been suggested that GTR could be implemented in Canada with other regeneration methods as well (Anon. 1995).

Retention of coarse woody debris (CWD) on site has been discussed by Ehnstrom (2001). However, the relevancy towards Canadian forestry needs to be reviewed since the study has focused on intensive forestry, which has been carrying out plantation managed stands with no or little coarse woody debris in managed stands in Scandinavia, where as in Canada practices have in recent times left coarse woody debris within stands. However, the importance of CWD cannot be over emphasized between managed and unmanaged stands. carried out a study with regards to potential biodiversity indicators in

boreal forests. Their results indicate that assumptions of using one set of indicator species within boreal forests cannot be made, and that indicator species, if chosen, should be from several species groups (Jonsson and Jonsell 1999). Relationships do exist between various species groups and CWD (Bader et al. 1995; Okland et al. 1996), various other organismal-groups of red-listed forest species also tend to differ with their habitat requirements with respect to forestry practices (Berg et al. 1995). Some of the suggestions regarding leaving dead wood, i.e. parts that are cut off to be left in the cutover area, and trees other than spruce be turned into stumps and leave standing trees of birch and aspen, is already practiced by some forest companies (Tembec 2001) in Manitoba. These are part of the certification criteria being adopted by the companies in Canada as well (Keenan 2002).

Certification criteria for the forestry companies seem to vary with national/ regional conditions, which shows there is impetus for more local and region specific requirements in certification of forests. There is a need to connect with the information that is being collected from these very similar ecosystems; the only distinction pertained to the differences in species but with almost identical assemblages performing the same ecosystem functions. Proper integration of this knowledge would lead to better management and understanding of our forests.

To conclude, forestry practices in Canada seem to be synchronous with research and forestry practices in Scandinavian countries, with similar indicators being adopted. However, there is still a wealth of information to be learned by sharing information between the two continents in managing for biodiversity and sustainable forestry practices.

### 3.3.0. Canada:

### 3.3.1. Important milestones in Canadian Biodiversity Conservation:

### 3.3.2. Convention on Biological Diversity:

Biodiversity came into prominence in Canada and the rest of the world in the last decade. The conference on Environment and Development held at Rio de Janeiro, Brazil 1992, was the first to recognize the global decline of biodiversity as one of the major environmental concerns facing the world (Biodiversity Convention Office 1995). Subsequently, Canada was the first industrialized country to ratify the United Nations Convention on Biological Diversity in December 1992. One hundred and fifty six countries and the European community signed the convention, which was built upon the Brundtland report "Our Common Future"(1987) and World Conservation Strategy (1980) (Biodiversity Convention Office 1995).

The Biodiversity Convention recognized three objectives:

- The conservation of biodiversity
- The sustainable use of biological resources; and
- The fair and equitable sharing of benefits resulting from the use of genetic resources.

### 3.3.3. Canada's response to the Convention on Biological Diversity:

The main requisite of the signatories of the convention was to develop a national biodiversity strategy as a guide to implement conservation of biodiversity. A Canadian Biodiversity Working Group was established in 1993, involving federal and provincial

departments and within two years the Canadian Biodiversity strategy (CBS) was developed. (Biodiversity Convention Office 1995)

### 3.4.0. Canadian Biodiversity Strategy:

### 3.4.1. Vision:

The vision of the CBS states "A society that lives and develops as a part of nature, values the diversity of life, takes no more than can be replenished and leaves to future generations a nurturing and dynamic world, rich in its biodiversity" (Biodiversity Convention Office 1995).

### 3.4.2. Goals:

Five goals of the Canadian Biodiversity Strategy: (Biodiversity Convention Office 1995).

- To conserve biodiversity and use biological resources in a sustainable manner.
- To improve our understanding of ecosystems and increase our resource management capability.
- To promote an understanding of the need to conserve biodiversity and use biological resources in a sustainable manner.
- To maintain or develop incentives and legislation that support the conservation of biodiversity and the sustainable use of biological resources.
- To work with other countries to conserve biodiversity, use biological resources in a sustainable manner and share equitably the benefits that arise from the utilization of genetic resources.

### 3.5.0. The Criteria and Indicator concept in Sustainable Forest Management:

Canada, according to the goals of the Canadian Biodiversity Strategy, met with twelve other countries and agreed to develop a set of criteria and indicators to aid conservation and sustainable management of boreal and temperate forests. This has come to be recognized as the Montreal Process criteria and indicators, which is described in detail in the indicator review section.

### 3.6.0. Importance of Criteria and Indicators in Forestry:

The criteria and indicator framework has become the driving force for monitoring and conserving biodiversity in the forest industry and also at all levels of management in the forest industry. The conservation of biodiversity and C&I have become increasingly important as a means to certification (Noss 1998; FSC 1999; Dorma 2001). The criteria and indicators need to be a part of certification in almost all standards like the CSA (Canadian Standards Association), FSC (Forest Stewardship Council), ISO (International Organization for Standardization) 14001, and it is imperative that some form of criteria and indicator frame work be built in to the decision support modeling tool.
A number of indicators are utilized for monitoring biodiversity in the boreal forest (Mclaren et al. 1998; Jonsson and Jonsell 1999; Model Forest 2000; Ehnstrom 2001; Mikusinski et al. 2001). The first step is to understand what indicators are available to measure and conserve biodiversity, and bring together a matrix of all available indicators.

### 3.7.0. Montreal Process Criteria and Indicators:

The 1992 United Nations Conference on Environment and Development (UNCED), called upon all nations to ensure sustainable management of forests

(Biodiversity Convention Office 1995). The Statement of Forest Principles, and Conventions on Biodiversity were produced at the summit in Rio (Biodiversity Convention Office 1995). One of the goals of the Convention on Biodiversity was to work with other countries in conserving biodiversity, which led to the formation of a coalition of 12 countries, other than the European countries, coming together to develop criteria and indicators for the conservation and sustainable management of boreal and temperate forests (Canadian Council of Forest Ministers 1997). European countries report to what is known as the Helsinki process. This conference on security and cooperation met in Montreal. This was the first detailed multinational discussion on sustainable forestry criteria and indicators, which led to what is now known as the Montreal process (Canadian Council of Forest Ministers 1997).

The Montreal Process C&I (MP C&I) are national level indicators reporting on Canada's international commitments. The MP C&I report has a total of nine indicators for criterion one (Conservation of Biodiversity), of which five indicators report on the ecosystem or landscape diversity and two indicators each that report on the species and genetic diversity (Santiago Declaration 1995). The species based indicators focus on the number of forest dependent species and their status with respect to maintaining viable breeding populations the data for this indicator is partly available from COSEWIC'S (Committee on the Status of Endangered Wildlife in Canada) recommendations. Genetic diversity will be reported by assessing forest dependant species at their current distribution with respect to their former range. This indicator when able to report will be able to assess the genetic isolation of the concerned species (www.mpci.org 2002). The other indicator on genetic diversity will report on population levels of representative

species based on their range and diversity of habitats. Data on genetic diversity indicators need to be collected.

**Table 1: Montreal Process indicators for conservation of biodiversity.**

| Landscape Diversity Based Indicators | Species Diversity Based Indicators | Genetic Diversity Based Indicators |
|---|---|---|
| Extent of area by forest type relative to total forest area | The number of forest dependent species | Number of forest dependent species that occupy a small portion of their former range |
| Extent of area by forest type and by age class or successional stage | The status (threatened, rare, vulnerable, endangered, or extinct) of forest dependent species at risk of not maintaining viable breeding populations, as determined by legislation or scientific assessment (at the national level). | Population levels of representative species from diverse habitats monitored across their range |
| Extent of area by forest type in protected area categories as defined by IUCN or other classification systems | | |
| Extent of areas by forest type in protected areas defined by age class or successional stage | | |
| Fragmentation of forest types | | |

### 3.8.0. Canadian Council of Forest Ministers Criteria and Indicators:

The CCFM criteria and indicators are used to report to the Montreal Process as part of Canada's commitment to conservation of biodiversity. The criteria and indicators provide a scientific reference point and provide the impetus to evaluate the state of Canada's forests at the National level. CCFM's initial document *Defining Sustainable Forest Management: A Canadian Approach to criteria and indicators* (1995) described 6 criteria and 83 indicators. CCFM's first technical report *Criteria and indicators of*

*sustainable forest management in Canada: Technical report,* released in 1997 described Canada's ability to report on the proposed indicators and agreed to review the numbers of indicators in the CCFM framework. The CCFM status report released in 2000 (Canadian Council of Forest Ministers 2000) describes 62 indicators.

While the criteria define a set of values to sustain, indicators focus on scientific factors that report on the state of forests in Canada.

The six criteria are:

1. Conservation of Biodiversity.
2. Maintenance and enhancement of forest ecosystem condition and productivity.
3. Conservation of soil and water resources.
4. Forest ecosystem contributions to global ecological cycles.
5. Multiple benefits to society.
6. Accepting society's responsibility for sustainable development.

Criterion one (Conservation of Biodiversity) is represented by six indicators, three indicators accounting for ecosystem/landscape diversity and three accounting for species diversity. Genetic diversity, however, has not been reported in this status report. Indicators reported by the CCFM (2000) status report are all at the Ecozone level of ecological land classification, within the CCELC hierarchy. Species information is being collected directly depending upon its sensitivity index based on COSEWIC's (Committee on the Status of Endangered Wildlife in Canada) recommendations. There are 116 species that are at risk in Canada that are forest dependent. The first species based

indicator rates the total number of species at risk with the number of known forest dependent species. The immense amount of data to be collected and then assimilating it will be a challenging task. Species that are forest dependent are categorized based on their degree of forest dependence by the CFS (Canadian Forest Service). The Second species indicator is partially fulfilled with the data available from the report prepared by Alvo (1998) (for the CFS, Canadian Pulp and Paper Association and the Biodiversity Convention Office) and COSEWIC (1999) (Canadian Council of Forest Ministers 2000). The third species based indicator describes species based on range; however this leads to different interpretations while either referring to plants (it may be found in a smaller percentage of habitats formerly occupied within its historic range) or a mammal (with its present range being significantly smaller than its original range) (Canadian Council of Forest Ministers 2000).

The CCFM C&I and the MP C&I are complementary to each other (Canadian Council of Forest Ministers 2000), the CCFM C&I differ from the Montreal Process C&I with one less criterion, the criterion being "Legal, institutional and economic framework for forest conservation and sustainable management" This criterion, is however, partly fulfilled by indicators 3 and 4 under criterion 5 (i.e. contribution to the National economy and non-timber values) and indicators 3,4, and 5 under criterion 6 (i.e. sustainability of forest communities, fair and effective decision making, informed decision making) of the CCFM C&I framework (Canadian Council of Forest Ministers 2000).

**Table 2: CCFM criteria and indicators on conservation of biodiversity.**

| Landscape Based Indicators CCFM | Species Based Indicators CCFM |
|---|---|
| Percentage and extent in area, of forest types relative to historical condition and to total forest area. | Number of known forest dependant species classified as extinct, threatened, endangered, rare or vulnerable relative to total number of known -forest dependent species. (At the Ecozone level of ELC.) |
| Percentage and extent of area by forest type and age class. | Population levels and changes over time of selected species and species guilds |
| Area, percentage and representatives of forest types in protected areas | Number of known forest dependant species that occupy only a small portion of their former range |

### 3.9.0. Provincial Indicators:

### 3.9.1.Ontario:

Ontario and Quebec are the two Canadian provinces, which have developed full-fledged provincial indicators (State of Canada's Forests 2000). Provincial indicators for Ontario are discussed below. Ontario has classified indicators under criterion one, conservation of biological diversity, into four elements, instead of the traditional three (i.e. ecosystem, species, and genetic diversity) (Canadian Council of Forest Ministers, 1995; 1997; 2000). Landscape diversity is addressed separately from ecosystem diversity. However, the demarcation of a landscape and an ecosystem is not clear with considerable overlap of these levels and varies with respect to scale. The species indicators monitored at the landscape level can also be done at the ecosystem level.

**Table 3: Provincial indicators for Ontario on conservation of biodiversity:**

| Landscape Diversity | Ecosystem Diversity | Species Diversity | Genetic Diversity |
|---|---|---|---|
| Composition and structure of forest types by age class | Representation (area and percent of forest types by protected area category) | Forest dependant species at risk | Landscape-scale forest management guideline. |
| Composition and structure of terrestrial and aquatic systems | Forest access roads | Forest dependant featured species | |
| Frequency distribution and pattern of harvest and natural disturbance areas. Frequency distribution of clearcut and wildfire sizes used as proxy indicator | Ecologically sensitive areas (including riparian areas) identified and managed according to forest management guidelines. | | |
| Levels of fragmentation and connectedness of forest ecosystem components. Landscape pattern indices and forest fragmentation (patchiness and juxtaposition) (spatial analysis) and forest diversity indices (richness, evenness) (non-spatial) used as proxy indicators. | Trends in downed woody debris and standing dead trees | | |
| Quantity and distribution of old growth forest ecosystems. | | | |

These indicators follow the C&I Montreal process framework for selection of indicators. Landscape indicators are monitored by utilizing provincial satellite coverage as a proxy for ecosystem composition and structure. Frequency disturbance patterns are estimated by comparing data from 1970 to 1995 and this has been done as a first approximation this would be further analyzed as more data becomes available (State of the Forest Report 2001). Levels of fragmentation and connectedness are obtained by two separate data sources, from the management unit level (forest resource inventory) and provincially by the percentage of 28 land cover types based on satellite imagery (State of the Forest Report 2001). The percentage of forest access roads is calculated from the forest resource inventory, which contains information on unclassified land; the normal practice of companies is to set aside 5% of the harvestable area for roads. The amount of unclassified land is also assessed at the ecoregion level. The ecologically sensitive areas are natural areas prone to disturbance (State of the Forest Report 2001). Data for downed woody debris is being collected as part of the provincial forest growth and yield program, plus information from forest ecosystem classification plots. Two indicators monitor species diversity: forest-dependant species at risk and forest-dependant species. Sixty forest dependent species are at risk in Ontario (State of the Forest Report 2001), of these only 16 are known to occur within the forest planning area. They are managed by appropriate management activities that are enforced by the provincial forest compliance program (State of the Forest Report 2001). The Ontario Ministry of Natural Resources is developing a coarse filter - fine filter approach (Noss 1987; Hunter 1991; Baydack et al. 1999) to species diversity management (i.e. the landscape as the coarse filter and site-specific habitat characteristics as the fine filter) (State of the Forest Report 2001). The

approach to monitoring genetic diversity is currently being developed with a landscape-scale forest management guide that focuses on natural disturbance patterns (State of the Forest Report 2001).

### 3.10.0. Model Forest Indicators on Conservation of Biodiversity:

The next in the C&I hierarchical framework are model forest indicators developed to monitor sustainable forest management at the local level (i.e. Forest management level).

Indicators for monitoring biodiversity are classified similar to the CCFM Criteria and Indicators; the first criterion is the conservation of biological diversity with three elements: ecosystem diversity; species diversity; and genetic diversity. These indicators for each of the model forests were developed by consultation, and a working group of partners sharing varied perspectives on social, economic and environmental issues surrounding forest management (Model Forest 2000) Model Forest indicators work towards filling the gap that exists at the local level, and provide the necessary information and framework for on-site monitoring activities (Mosquin et al. 1995; Canadian Council of Forest Ministers 2000; Working Group 2001). Several companies in Canada apply Model Forest indicators in sustainable forest management in their regions. The indicators monitored by these companies across Canada are represented in a matrix (Table 4).

**Table 4: Model Forest indicators for conservation of biodiversity across Canada.**

**(Model Forest 2000)**

| Landscape Diversity Based Indicators | Species Diversity Based Indicators | Genetic Diversity Based Indicators |
|---|---|---|
| Percent and extent of area by forest type and age class in (ha) | Proportion of pre-harvest assessment crews trained in the recognition/identification of VTE species and habitat (proportion of crews trained) | Adherence to seed zones (% of stock from correct seed zone) |
| Area of each forest type, by age class in (ha) | Proportion of identified VTE for which appropriate management action have been taken (# of sites) | Implementation of an ex-situ/ in-situ gene conservation strategy |
| Distribution of cover types and age classes per cover type (%) | Number of species classified as extinct, extirpated, endangered, threatened or vulnerable (# of species) | Changes in population, genetic diversity and structure and gene flow for selected species |
| Composition of the forest in terms of Forest Ecosystem FEC V-types (ha) | Number of known forest-dependent species classified as extinct, extirpated, endangered, threatened or vulnerable relative to total number of known forest - dependant species (to be developed) | All naturally occurring species are maintained within sub-regions (species presence using a checklist approach) |
| Percent and extent of area of forest community and age class by ELC, relative to pre-European settlement condition and total forest area (ha) | Population levels/ indices of vulnerable of threatened and endangered species (# of observations) | Absence of species or visible subspecies from formerly populated areas (to be developed) |
| Area of forest land by land use designation (number of ha) | Forest management activities, not set out in management plan, in the habitat of threatened, vulnerable or exotic species (frequency and ha) | Degree of range reduction of sensitive species (to be developed) |
| Identification and protection of local sites of significance (ha and %in IUCN categories I II III IV and V) | Diversity of bird populations (abundance) | Population size and reproductive success are adequate to maintain levels of genetic diversity (to be developed) |
| Percent and representativeness of forest types in protected areas (% of area in ha) | Population size and reproductive success of species at risk | Utilization of commercial tree genetic material in tree propagation (descriptive) |

| | | |
|---|---|---|
| Percent and representativeness of protected areas within the site districts of which the unit is a part (area in ha of forest community group by IUCN class) | Population size and reproductive success of species dependant upon interior forest conditio ns | Size of parent population having produced regeneration (# of individuals) |
| Proportion of each eco-region in protected status (% in ha) | Population levels of caribou (population estimates) | Distribution of commercial tree establishment from provincial tree improvement sources, natural seed collection within seed zone and regeneration from local site seed source. (descriptive) |
| Forest management activities, not set out in the management plan, in rare or fragile ecosystems (alder stands, denuded, semi-denuded, islands and islets) (frequency & ha) | Population levels/ indices of selected species or guilds (# per area) | Changes in genetic diversity of species undergoing selective pressures (to be developed) |
| Protected areas (proportion of each ecosystem sub-region that is in a protected status) | Relative abundance, species richness and diversity of migratory songbirds (estimated populations) | No significant changes in gene frequencies in trees (to be developed) |
| Forest fragmentation (outlining maps) | Area and percent of each forest stand type protected (ha) | |
| Special features status (by feature) | Percent of Prince Albert Model Forest area within 1 km of an active access road | |
| Level of forest fragmentation and connectedness of forest ecosystem components (km of road/$km^2$ of area) | Habitat quality and quantity for selected species (to be developed) | |
| Level of forest fragmentation and connectedness (fragmentation indices) | Number of known forest-dependent species that occupy only a small portion of their former range in the region | |
| Surface area and size distribution of areas located more than 1, 5 and 10 km from roads (ha) | Number of habitat units for the winter range of Owl Lake Woodland Caribou herd (habitat unit) | |

| | | |
|---|---|---|
| Amount and percentage of interior forest space (% of total forest area) | Continued partnership in the Integrated Forestry/Woodland Caribou Management Committee (descriptive) | |
| Change in roadedness per volume of trees removed associated with modified forest practices (length of road per unit area) | Percentage productive area < 80 years by Caribou Zone (%) | |
| Patch-size distribution by natural disturbance type by landscape unit by age class (to be developed) | Distribution of Newfoundland Marten (distribution map based on available habitat) | |
| Size and distribution of contiguous patches (to be developed) | Percentage productive area < 3 m height by Caribou corridor (% area) | |
| Amount and distribution of edge (to be developed) | Area harvested in Grizzly habitat zones (area harvested/ total grizzly habitat) | |
| Relative distribution of seral stages following natural (burned) and human (harvested) disturbances (ha) | Exploitation rates of Biological resources (% species decrease/yr, % decrease/ha) | |
| Relative distribution and diversity of vegetation species following natural (burned) and human (harvested) disturbances (ha) | Number of known forest-dependant species classified as endangered to vulnerable and the number of recovery plans for these species (to be developed) | |
| Percentage productive area > 100 years in Forest Ecological Networks (% of area fulfilling specific requirement) | Area of habitat suitable and available for selected species and or species guilds (to be developed) | |
| Percentage productive area < 3 m height in Forest Ecological Networks (area/area x 100) | Amount of area with natural cover type suited to the Acadian Forest Region and Site (to be developed) | |
| Nature of patch size and shape resulting from harvesting approximating natural landscape patterns (to be developed) | | |
| Changes in patch size distribution in relation to natural patterns of disturbance (to be developed) | | |

| | | |
|---|---|---|
| Average area of total clear cut (ha) | | |
| Naturally regenerated areas relative to reforested areas (ha) | | |
| Abundance and composition of residual stand structure (ha) | | |
| Changes in amount and complexity of vertical habitat structure (measurement of the height of each layer) | | |
| Abundance of coarse woody debris, snags, etc. (tree per unit area and mass per unit area) | | |
| Density of roads (ha/ $km^2$) | | |
| Percent of proposed harvest blocks subject to pre-harvest assessment (% ha) | | |
| Total forest area by percent and extent in all the combinations of forest cover types and maturity classes (to be developed) | | |
| Area of forest permanently converted to non-forest land use, e.g., urbanization. Also includes agriculture and golf courses (to be developed) | | |

### 3.10.1. Manitoba Model Forest Indicators on Conservation of Biodiversity: Monitoring by Tembec Industries Pine falls operations.

The Manitoba Model Forest (Table 5) developed biodiversity indicators by joint consultations and working with various focus groups. These indicators have been applied by Tembec Industries, since the Manitoba Model Forest does not have management responsibility for the specified management area (Keenan 2002). The Manitoba Model Forest and Tembec have developed 8 landscape-based indicators, 5 species based indicators, and 3 genetic diversity based indicators. Techniques for monitoring these indicators are being finalized and reporting is anticipated to begin from 2004-2006. (Tembec C&I report 2001).

**Table 5: Manitoba Model Forest indicators on conservation of biodiversity: (Tembec C&I report 2001)**

| Landscape diversity based Indicators | Species diversity based Indicators | Genetic diversity based Indicators |
|---|---|---|
| Percent and extent of area by forest type and age class | Proportion of pre-harvest assessment crews trained in the recognition/identification of VTE species and habitat | Adherence to seed zone |
| Composition of the forest in terms of Forest ecosystem V-types | Proportion of identified VTE for which appropriate management action have been taken | Utilization of commercial tree genetic material in tree propagation |
| Proportion of each eco region in protected status | Habitat quality and quantity for selected species | Distribution of commercial tree establishment from provincial tree improvement sources, natural s seed collection within seed zone and regeneration from local site seed source. |
| Patch -size distribution by natural disturbance type by landscape unit by age class | Number of habitat units for the winter range of Owl Lake Woodland Caribou Herd | |
| Nature of patch size and shape resulting from harvesting approximating natural landscape patterns | Continued partnership in the Integrated Forestry / Woodland Caribou Management committee | |
| Abundance and composition of residual stand structure | | |
| Density of roads | | |
| Percent of proposed harvest blocks subject to pre-harvest assessment | | |

### 3.11.0. Indicator Matrix Discussion:

The Matrix yielded a much larger proportion of ecosystem or landscape indicators (Hunter 1990). Single species indicators like Woodpeckers (Mikusinski et al. 2001) were also expressed. Overall there has been a synchronous effort in measuring indicators in the management strategies of forest companies. The species related information and indicators incorporated focus on characteristics that relate to habitats of the proposed indicator species as well and highlight the importance given to biodiversity at the landscape level. Considering the fact that vascular plants and vertebrates occupy only a small percentage of the world's biodiversity (Franklin 1993), and in order to maintain diversity at all levels, efforts need to focus on perceiving the ecosystem as a whole entity. Hence, managing ecosystems will address conservation of biodiversity; this is being achieved by developing landscape level monitoring strategies (Lindenmayer et al. 2000). The Landscape-based biodiversity indicators reported are cost effective compared to monitoring certain species-based indicators alone. Some of the forest structural (Lindenmayer et al. 2000) indicators in use have data already available, or data being collected as part of the forest resource inventory refer CCFM C&I (CCFM 2000) and provincial indicators of Ontario (State of the Forest Report 2001). However, identifying certain relevant species based indicators and determining what needs to be measured still needs to be given attention.

The charts (Figure 6- 11) compare and provide a visual representation of the relative numbers of landscape indicators to species and genetic diversity indicators, in place across Canada in the C&I hierarchy. There is a consistency in the importance given to landscape or ecosystem based indicators.

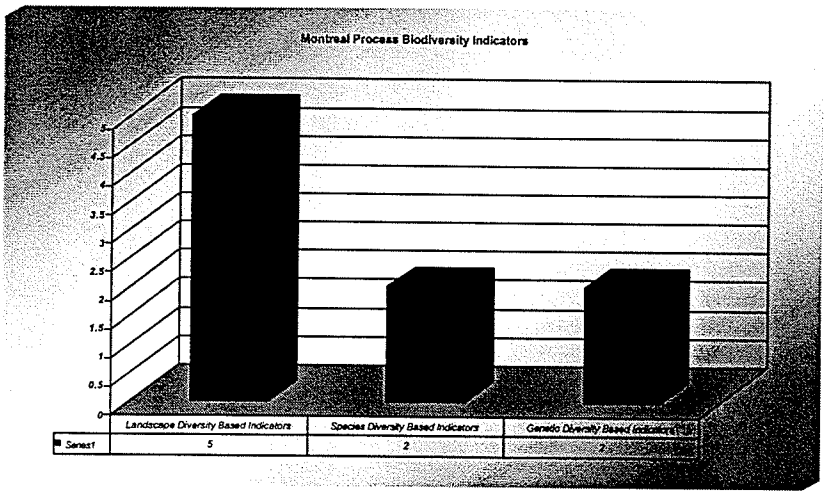


**Figure 6: Montreal Process Biodiversity Indicators**

Landscape/ Ecosystem Indicator: 5, Species Diversity Indicator: 2, and Genetic Diversity Indicator: 2

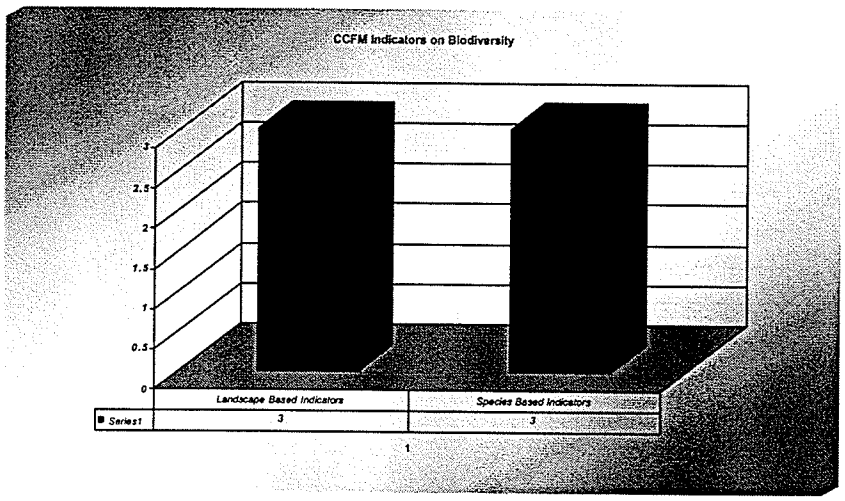


**Figure 7: CCFM Biodiversity Indicators**

Landscape / Ecosystem Indicators: 3, and Species Diversity Indicators: 3.

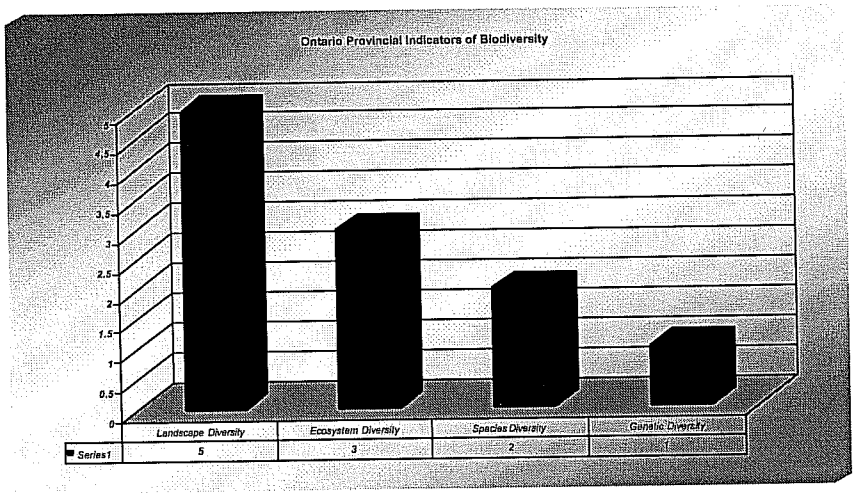


**Figure 8: Ontario Provincial Indicators of Biodiversity**

Landscape Diversity Indicator: 5 Ecosystem Diversity Indicators: 3, Species Diversity Indicators: 2, and Genetic Diversity Indicator: 1.

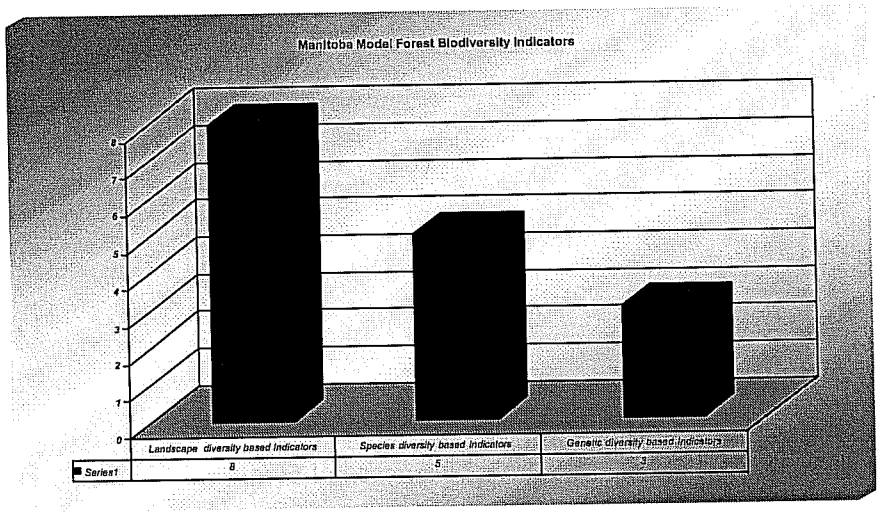


**Figure 9: Manitoba Model Forest Biodiversity Indicators.**

Landscape/Ecosystem Indicators: 8, Species Div Indicators: 5, Genetic Div Indicators: 2

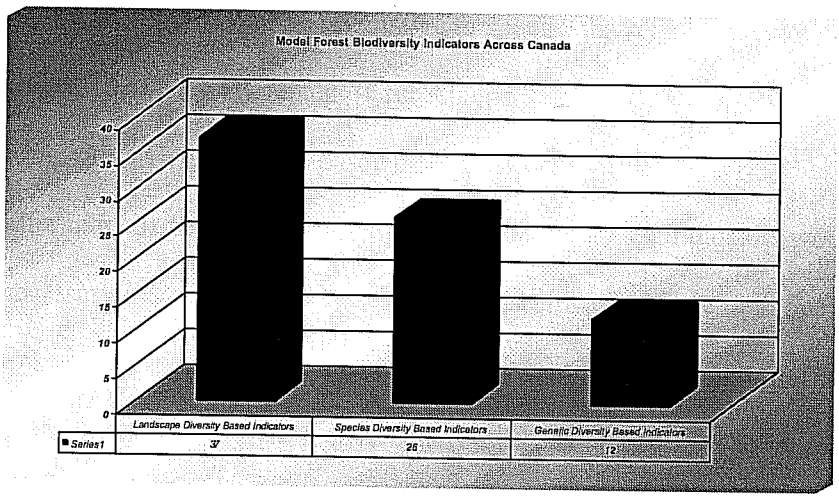


**Figure 10: Model Forest Indicators on Biodiversity across Canada.**

Landscape Diversity Based Indicators: 37, Species Diversity Based Indicators: 26, Genetic Diversity Based Indicators: 12.

The consolidated biodiversity indicator chart gives a clear picture of the number of landscape based indicators monitored with respect to species and genetic diversity based indicators. There are 53 landscape diversity based indicators, 33 species diversity based indicators and 15 genetic diversity based indicators.

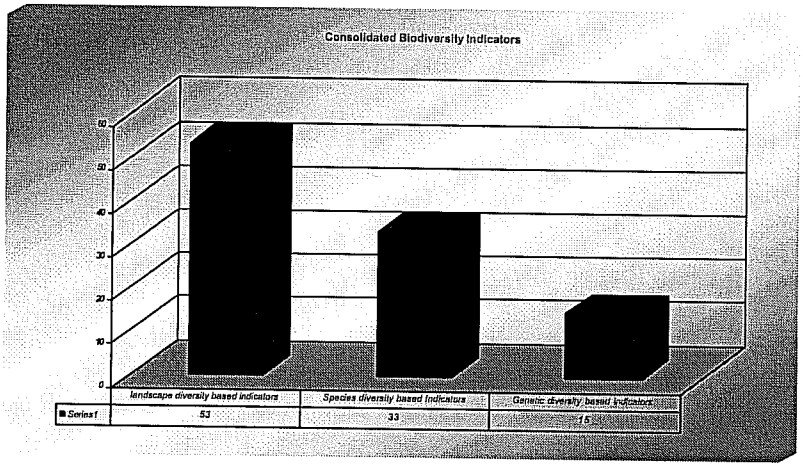


**Figure 11: Consolidated Biodiversity Indicators.**

Landscape Diversity Based Indicators: 53, Species Diversity Based Indicators: 33, and Genetic Diversity Based Indicators: 15.

It is essential to develop and maintain an up-to-date inventory of forest polygons, the linkages between landscape level indicators and inventory needs to be more clearly emphasized. Focusing on landscape and habitat elements as indicators of ecosystem

pattern and function as an alternative to species that represent ecological pattern or function has been attempted. (C&I Alberta 1998). Landscape indicators are an essential component for ecosystem-based management (Haufler et al. 1999) especially as a coarse filter in a coarse-fine filter approach. Landscape-based indicators would also provide the necessary linkages to an ecological land classification since both operate on similar spatial scales, which is an important component for conservation of biodiversity (Sims et al 1996). However, for effective conservation of biodiversity to be achieved, monitoring of all levels (i.e. landscape, species, and gene) is essential (Canadian Council of Forest Ministers. 1995), but with monetary constraints in indicator monitoring especially with standardization, duration and continuity (C&I Alberta 1998), landscape based diversity indicators focusing on structural components (Lindenmayer et al. 2000; Rolstad et al. 2002) has been the first priority.

However, further research is necessary to determine whether landscape based indicators provide an accurate measure of the " status " of biodiversity in an area. Research is also needed to verify if cost, technology, data availability and or any other factor acts as a limiting force in monitoring biodiversity.

Further the analysis of expert perceptions will assist in determining the importance accorded to landscape indicators and determine what indicators may be implemented in the near future and if cost constraints are an important factor in monitoring for biodiversity.

## 4.0.0 Results

### 4.1.0. Introduction:

Two sets of iterations were carried out through the Delphi approach so as to refine the matrix and the different indicator groups. Iterations helped to understand changes in expert perceptions, and facilitated informed decision-making. The first iteration was carried out with a limited number of biologists, and the second iteration consisted of a larger group of experts from the three groupings.

### 4.2.0. 1st Iteration:

### 4.2.1. Spearman Rank Correlations:

**Table No: 6. Spearman rank correlation 1st iteration.**

| | Structure. & Pattern | Protected Area | Disturbance & Frag | Species | Gene |
|---|---|---|---|---|---|
| Structure & Pattern | 1.000 | | | | |
| Protected. Areas | 0.554 | 1.000 | | | |
| Disturbance & Fragmentation | 0.429 | 0.323 | 1.000 | | |
| Species | -0.286 | -0.258 | 0.317 | 1.000 | |
| Gene | -0.136 | 0.123 | -0.318 | 0.572 | 1.000 |

### 4.2.2. Perceptual Map of Indicator Groups Ranked as Best:

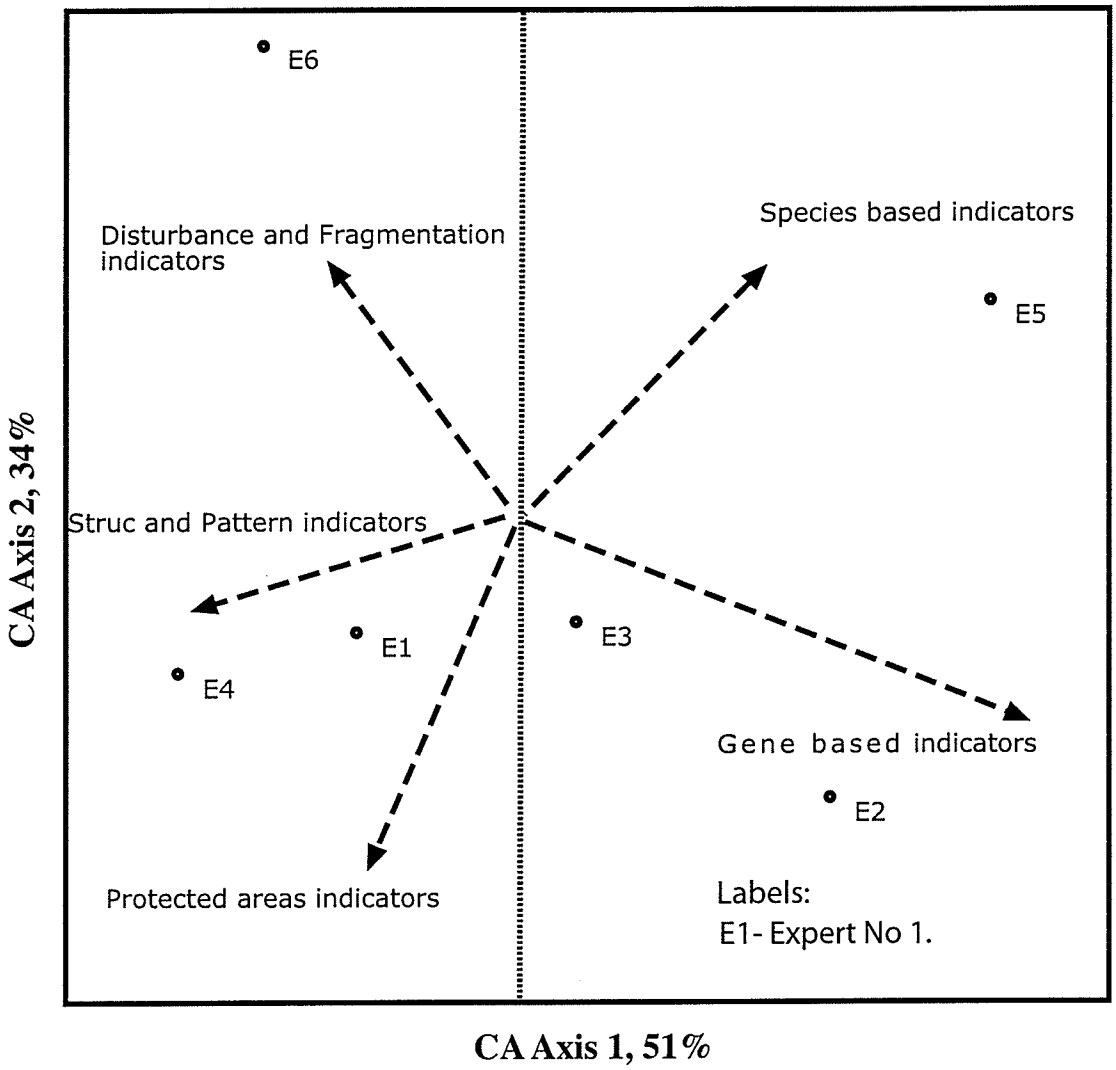


**Figure 12: Biplot of biodiversity indicators groups ranked as best by expert opinion.**

The results in Table 6 and figure 12 show a clear dichotomy between landscape-based indicators and species and gene indicators. The CA first axis shows a 51% variance and the second axis shows a 34% variance.

### 4.2.3. Perceptual Map Interpretation:

Each vector (Figures 13-18) represents an expert and has "E "as a prefix followed by a number, and the relative length of the vector indicates the expert's view of developing and monitoring these indicators. The proximity of a vector towards an indicator expresses a preference of that expert towards that individual indicator. A "Q" prefix and a number denote each indicator. Each expert is denoted by numbers 1-6 in the first iteration and 1- 13 in the second iteration.

Certain indicators of significance and indicator clusters that share an affinity are highlighted with a polygon enclosing them (Figures 13-18). A change in direction of vectors implies a change in perception of the expert as to what a particular group of indicators may achieve. The close proximity of any two objects or vectors to each other implies the similarity expressed by the experts or similar ranking of those two objects.

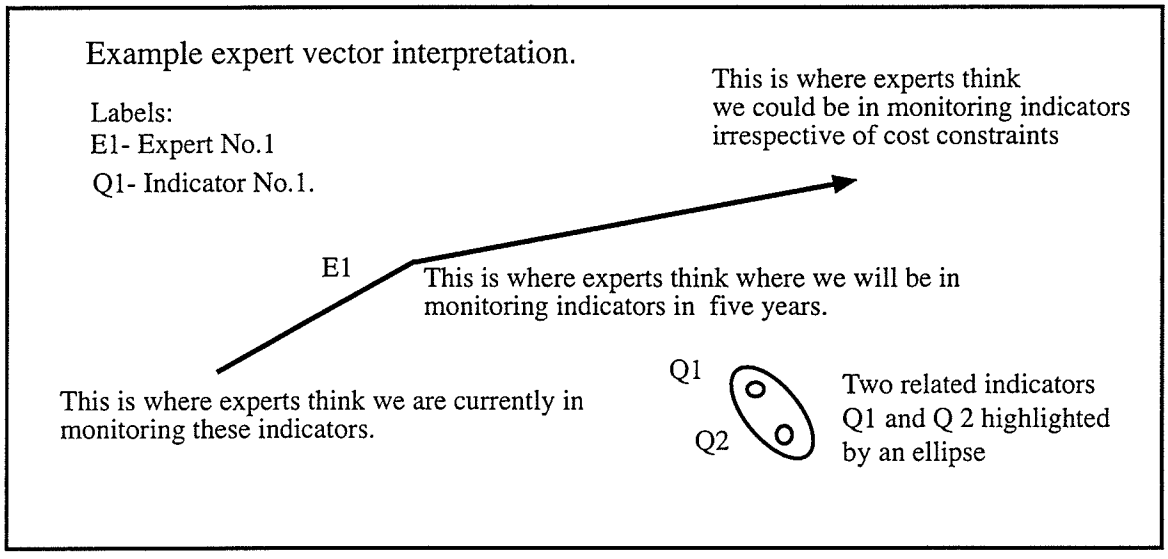


**Figure 13: Example interpretation of biodiversity indicators Perceptual Map.**

### 4.2.4. Expert perceptions of Individual sub-groups:

In the first iteration, perceptual maps of individual subgroups were carried out, so as to better understand expert perceptions of the individual groups, and the individual indicators as well.

#### 4.2.4.1. Structure and Pattern Perceptual Map:

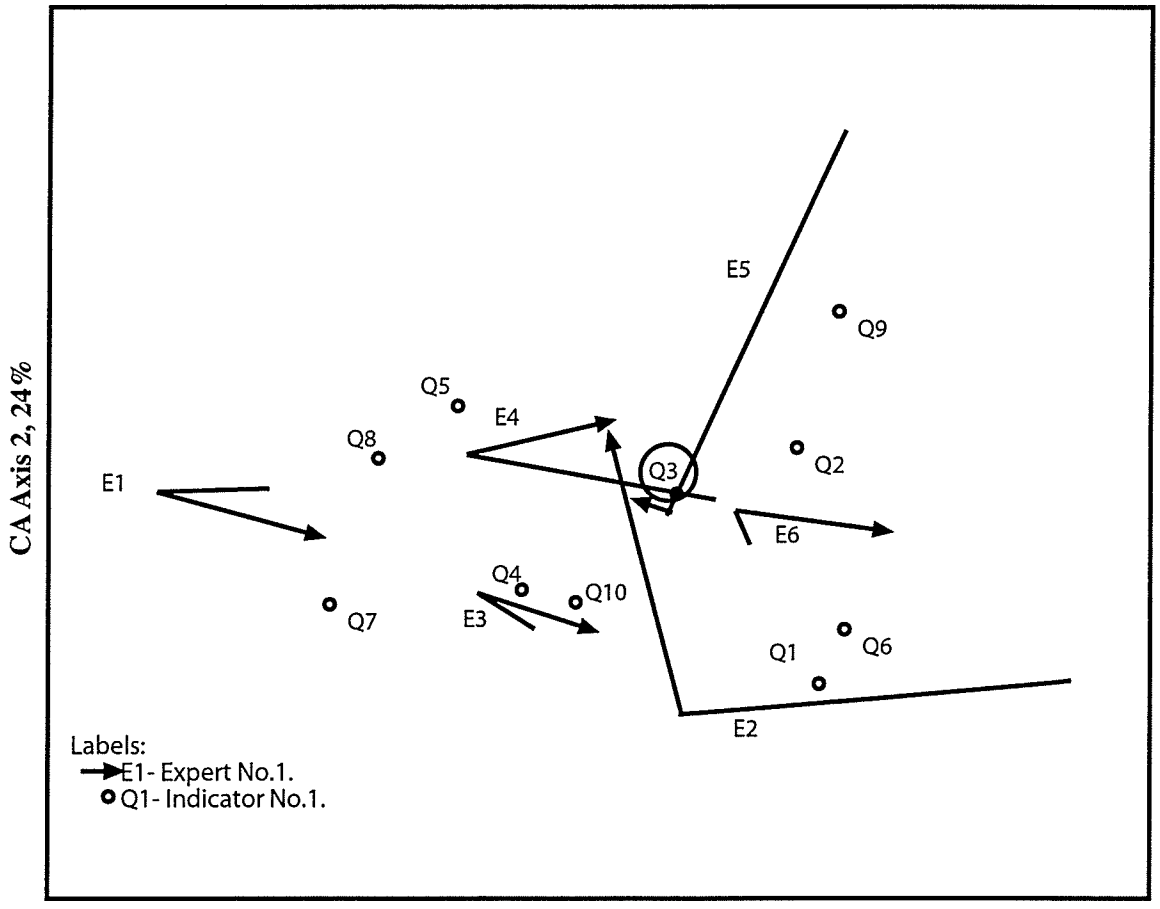


**Figure 14: Perceptual Mapping of expert opinion on Landscape based structure and pattern subgroup of indicators (See figure 13 for example interpretation).**

The first CA axis had 33% variance and the second CA axis had 24% variance.

### 4.2.4.2. Protected Areas Perceptual Map:

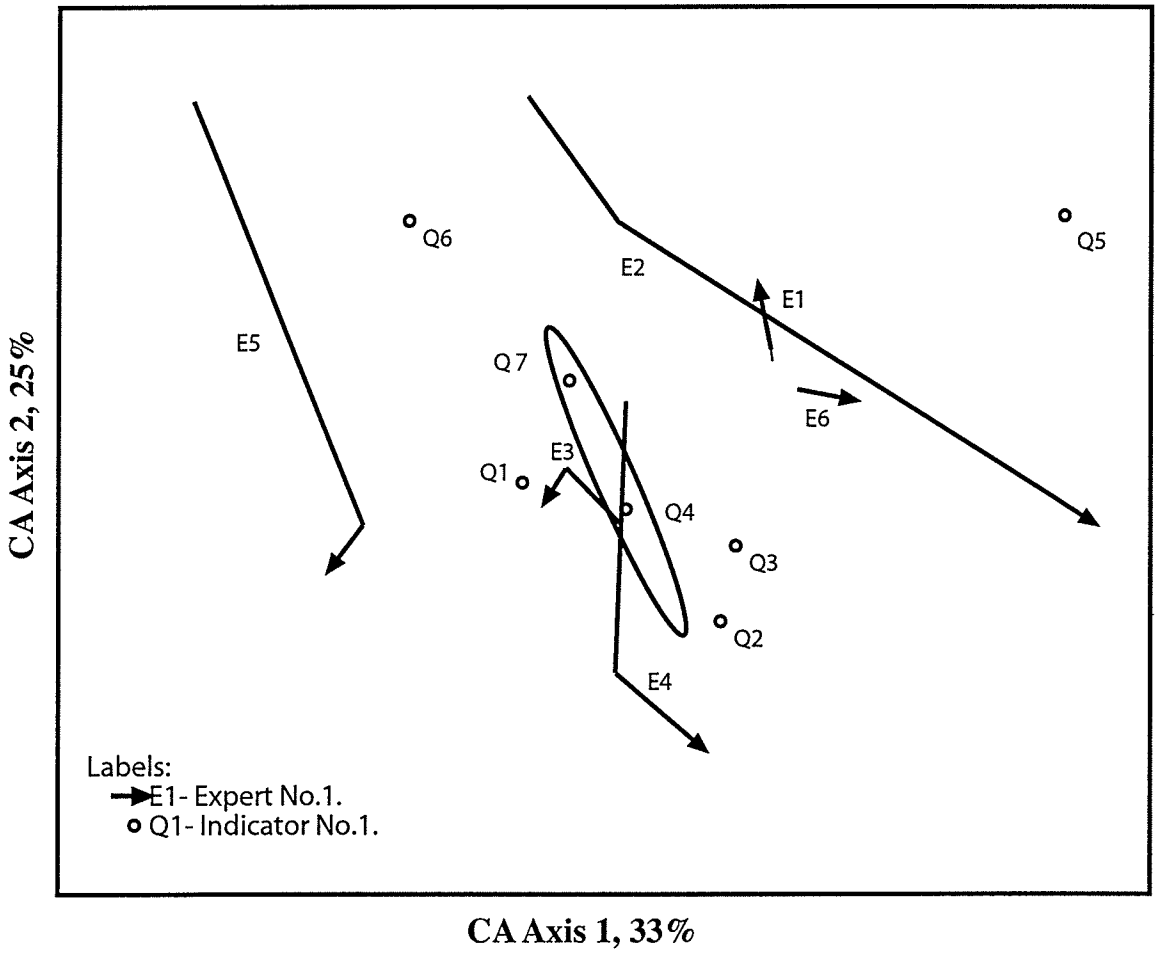


**Figure 15: Perceptual Mapping of expert opinion on Landscape based protected areas subgroup of indicators (See figure 13 for example interpretation).**

The first CA axis had a variance of 33%, and the second CA axis had a variance of 25%. In the first iteration the protected areas sub-group had only seven indicators, this was revised and increased to ten indicators in the second iteration.

### 4.2.4.3. Disturbance and Fragmentation Perceptual Map:

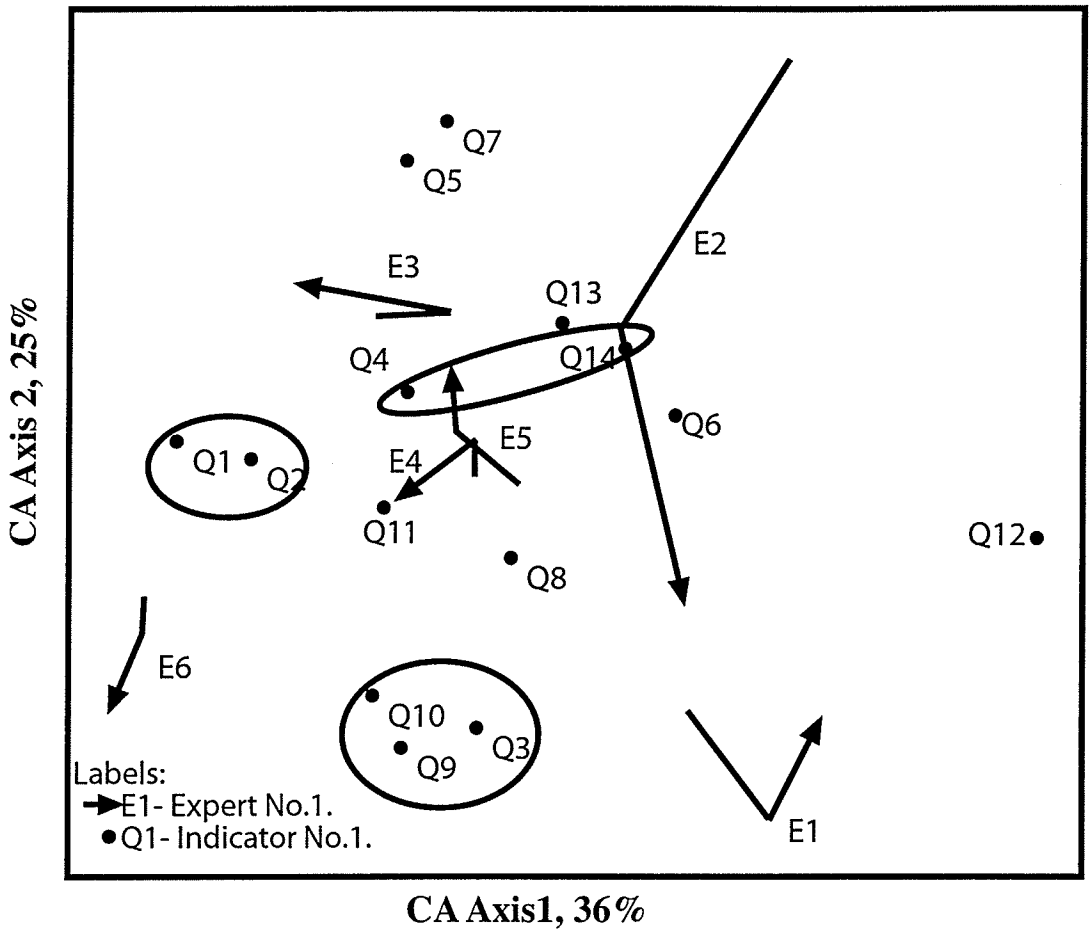


**Figure 16: Perceptual Mapping of expert opinion on Landscape based disturbance and fragmentation subgroup of indicators (See figure 13 for example interpretation).**

The percent variance in the first CA axis was 36% and 25 % in the second CA axis respectively.

### 4.2.4.4.Species Indicators Perceptual Map:

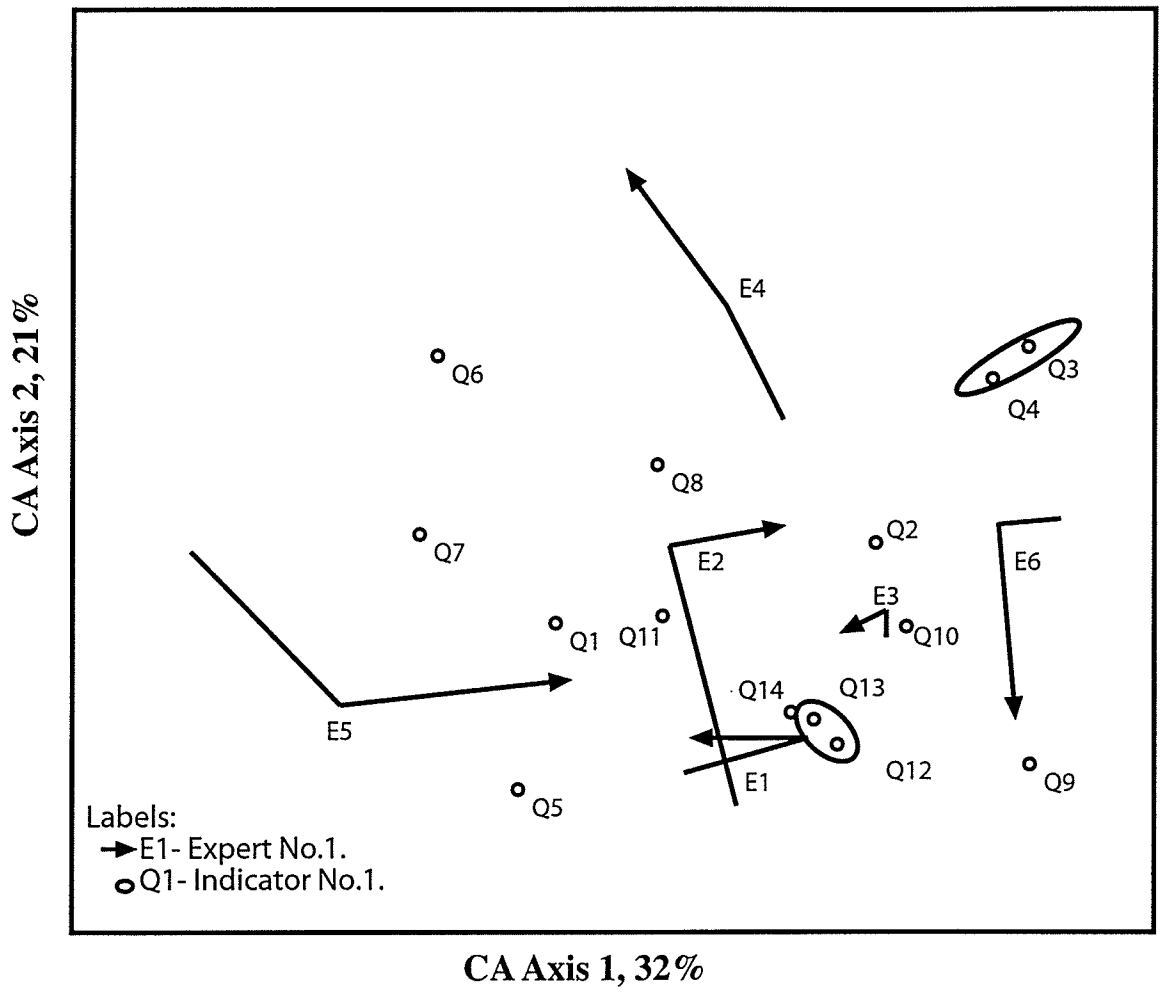


**Figure 17: Perceptual Mapping of expert opinion on Species indicators (See figure 13 for example interpretation).**

The first CA axis had 32% variance and the second CA axis had 21% variance.

### 4.2.4.5.Gene Indicators Perceptual Map:

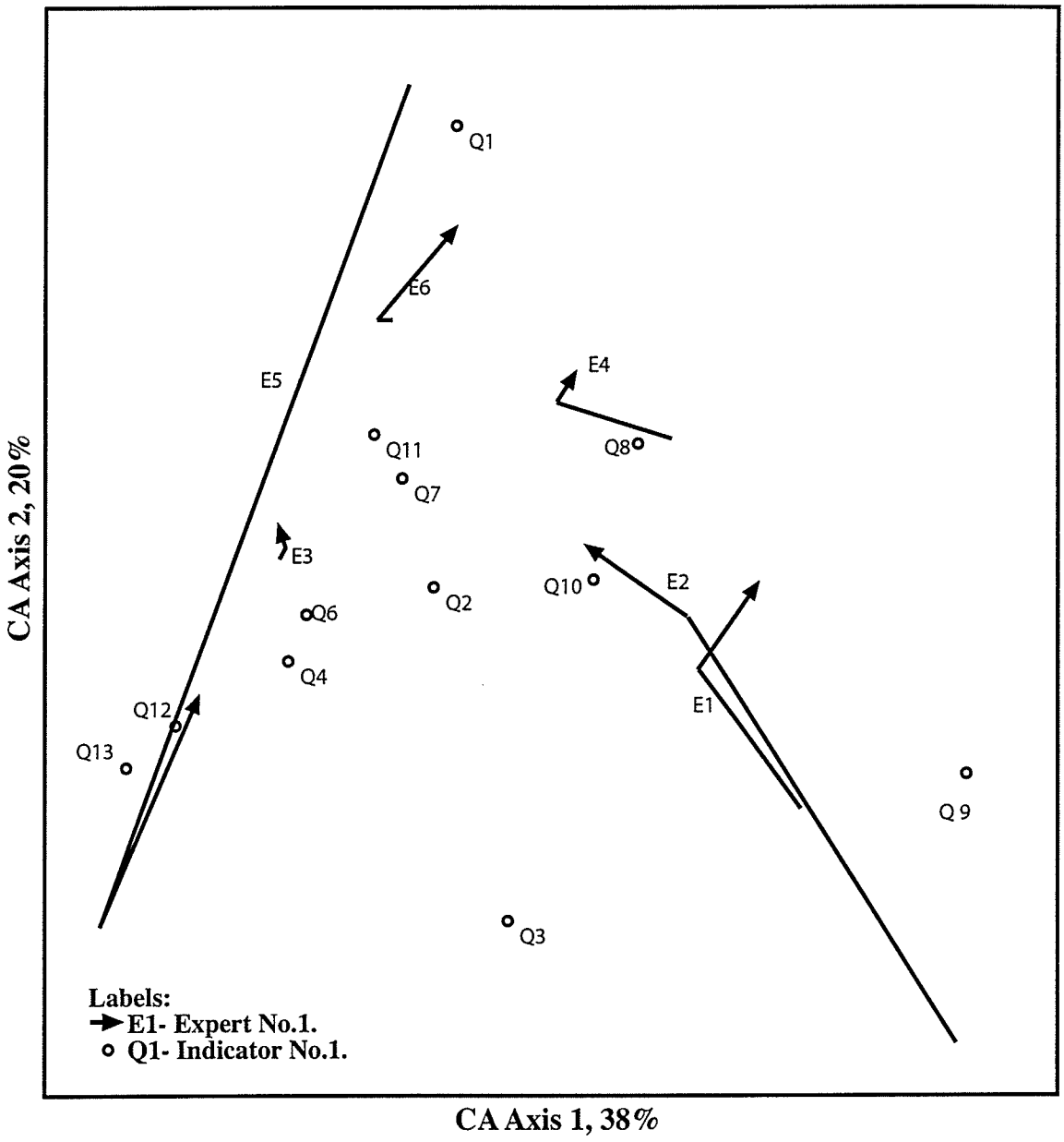


**Figure 18: Perceptual Mapping of expert opinion on Gene indicators (See figure 13 for example interpretation).**

In the gene group, the first CA axis had 38% variance and the second CA axis had 20% variance. In all the groups and subgroups the first two axes accounted for about 50 –60% of the variance.

### 4.3.0. 2nd Iteration:

### 4.3.1. Spearman Rank Correlations:

Two sets of Spearman rank correlations were carried out in the second iteration. The first was what the experts considered to be the best group to fulfill their area of expertise, and the second Spearman rank correlations was to understand correlations about what experts perceived about each group and their relationships.

**Table 7: Spearman rank correlation 2nd iteration.**

| | Structure & Pattern | Protected Areas | Disturb & Frag. | Species | Gene |
|---|---|---|---|---|---|
| Structure & Pattern | 1.00 | | | | |
| Protected Areas | 0.35 | 1.00 | | | |
| Disturb & Frag. | -0.05 | 0.49 | 1.00 | | |
| Species | 0.16 | 0.49 | -0.10 | 1.00 | |
| Gene | -0.16 | 0.47 | 0.20 | 0.45 | 1.00 |

### 4.3.2. Multiple Discriminant Analysis:

Experts constrained by profession, were analyzed to determine if professions played a major role in ranking indicator groups.

Perceptual Map of expert opinion on indicator groups constrained by profession.

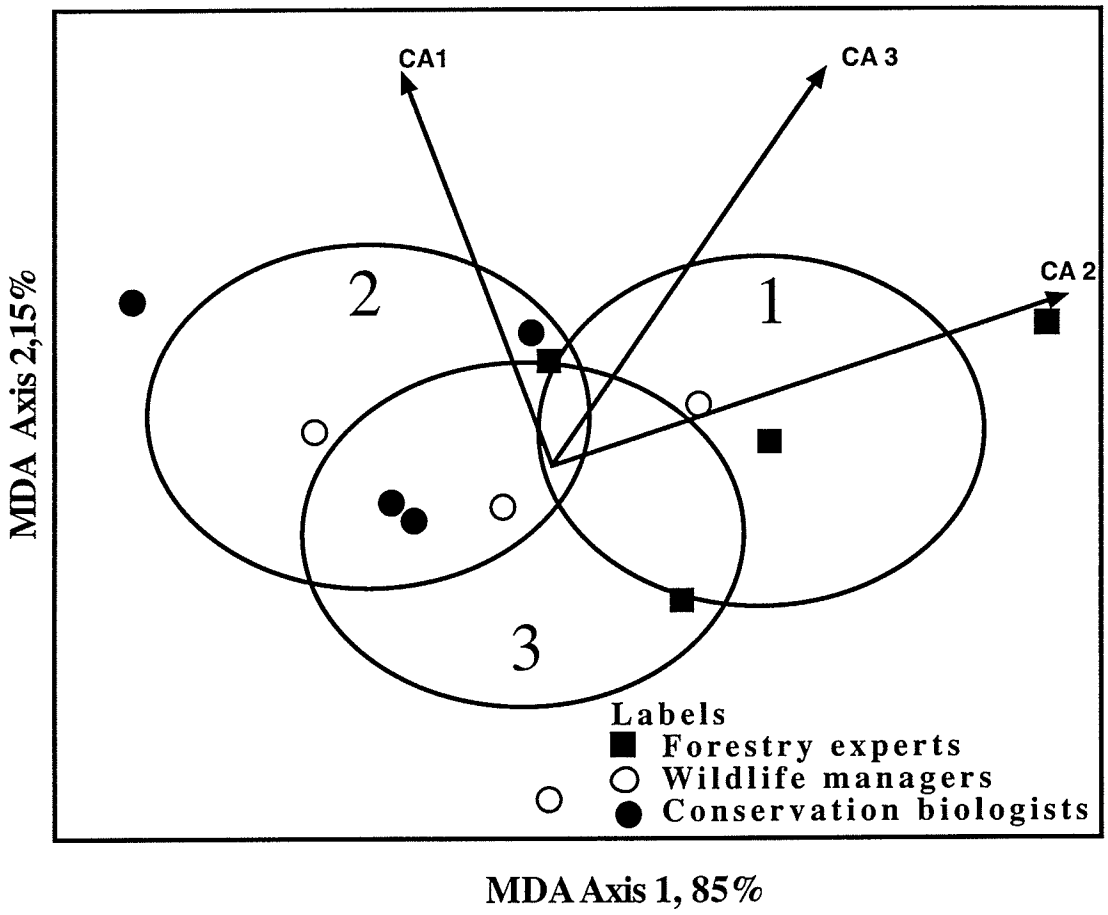


**Figure 19: Perceptual Map of expert opinion on indicator grouping based on occupation.**

The MDA Axis 1 accounted for 85% variance and the MDA Axis 2 for 15%.

### 4.3.4. Perceptual Map of Indicator Groups:

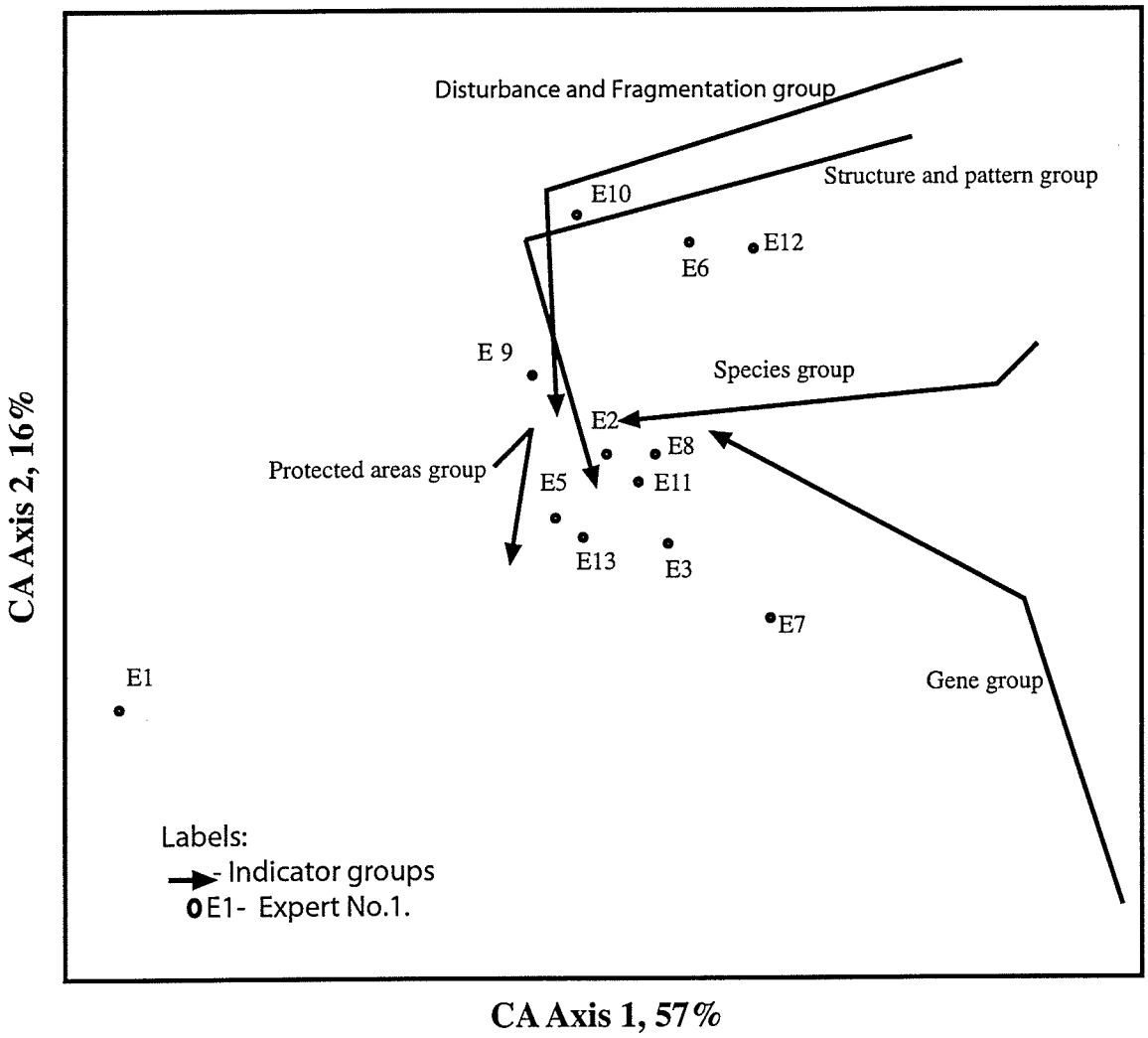


**Figure 20: Perceptual Mapping of expert opinion on biodiversity indicator groupings.**

An "E" prefix denotes the experts, and the indicator groups are represented by vectors.

The first CA axis had 57% Variance and the second CA axis had 16% Variance.

### 4.3.5. Perceptual Map of Indicator Groups Ranked as Best:

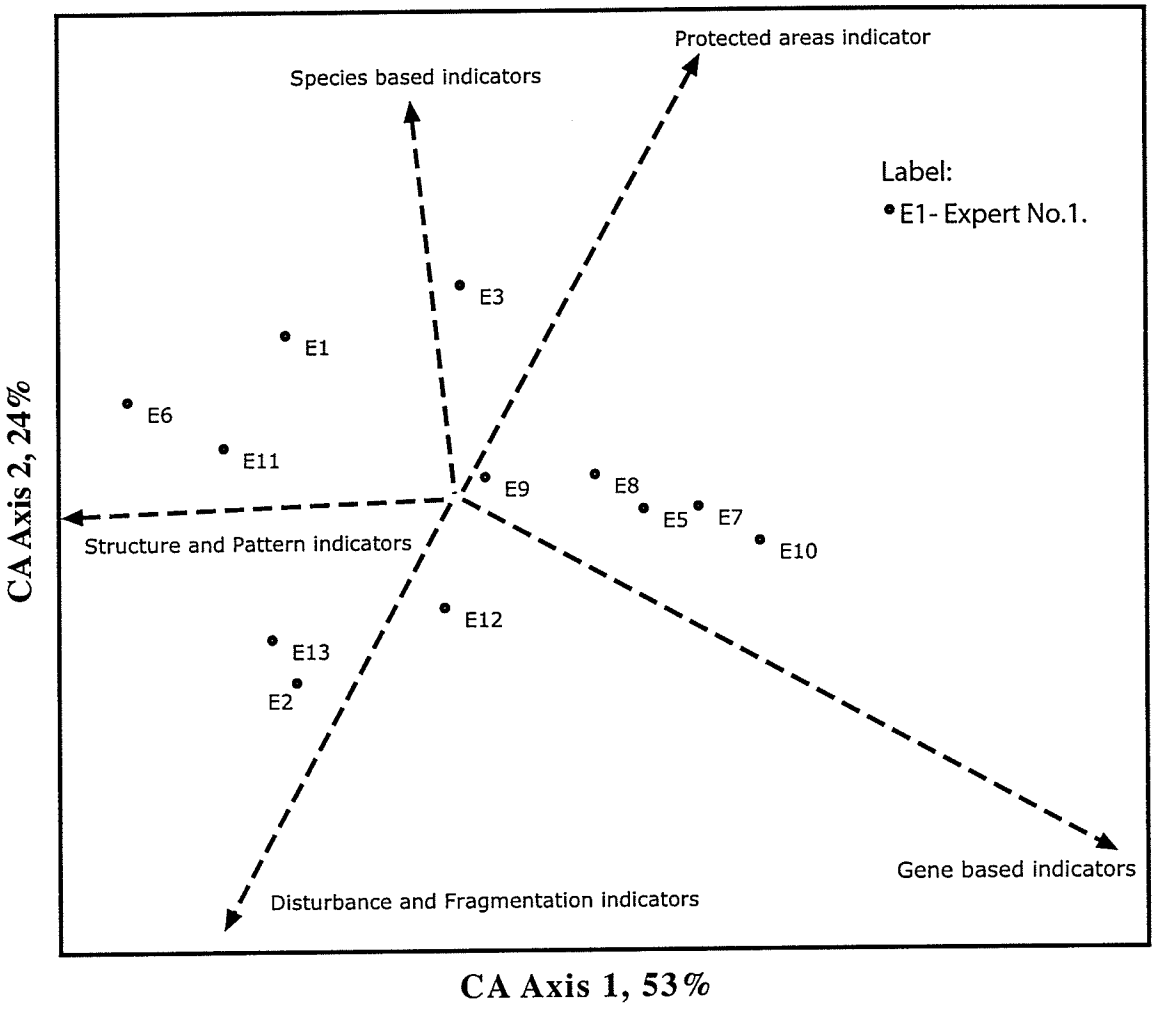


**Figure 21: Biplot of biodiversity indicators groups ranked as best by expert opinion.**

The CA axis 1 had 53% variance and the second axis had 24% variance.

### 4.3.6. Expert Perceptions of Individual sub-groups:

#### 4.3.6.1. Landscape/community:

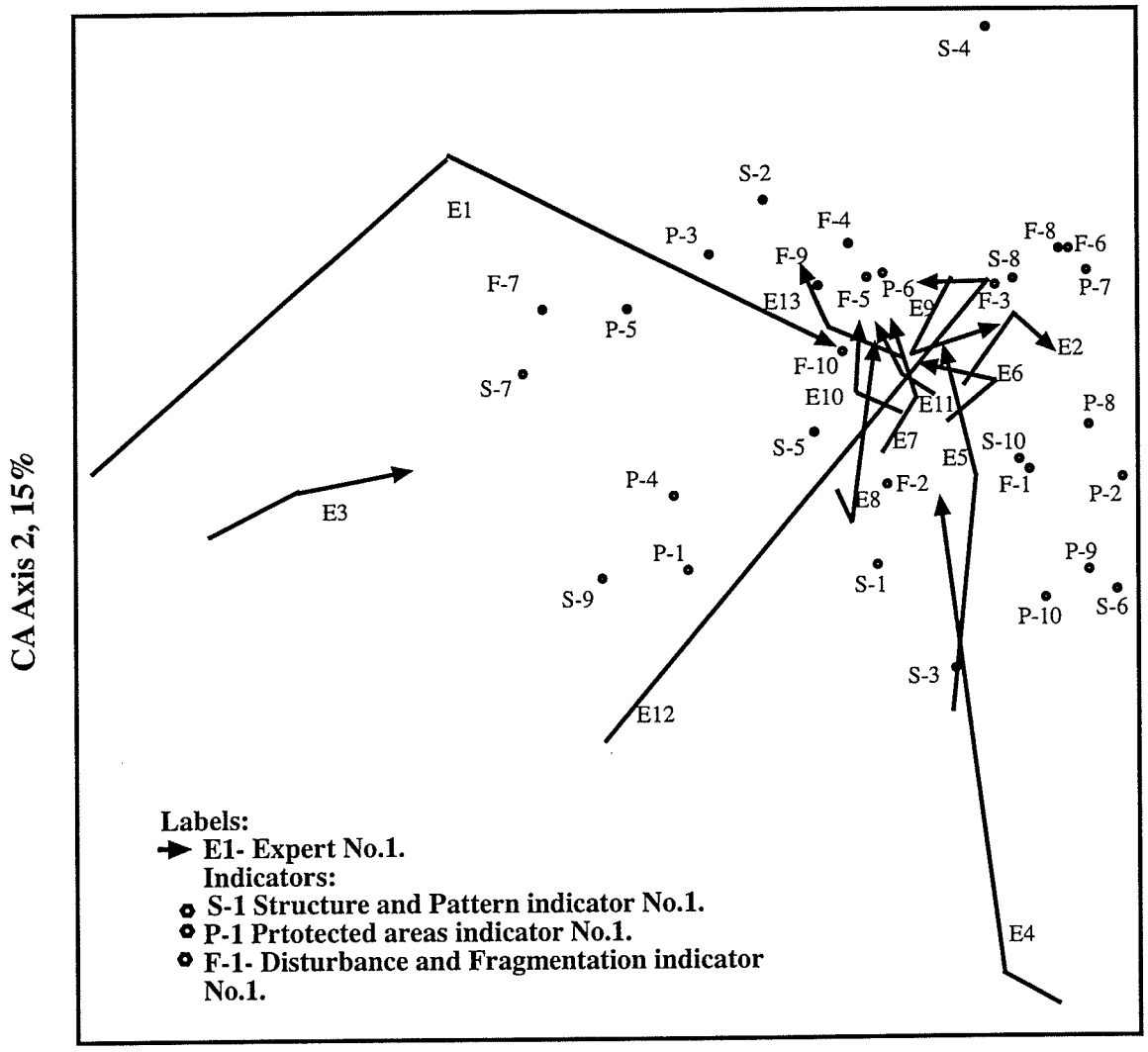


**Figure 22: Perceptual Mapping of expert opinion on Landscape based indicators (See figure 13 for example interpretation).**

The CA first axis had 30% variance, and the CA second axis had 15% variance. Each vector (Figures 19, 21, and 23) represents an expert and the relative length of the vectors indicates the expert's view of developing and monitoring these indicators. The

proximity of a vector towards an indicator indicates a preference of that expert towards that individual indicator.

#### 4.3.6.2. Species based indicators:

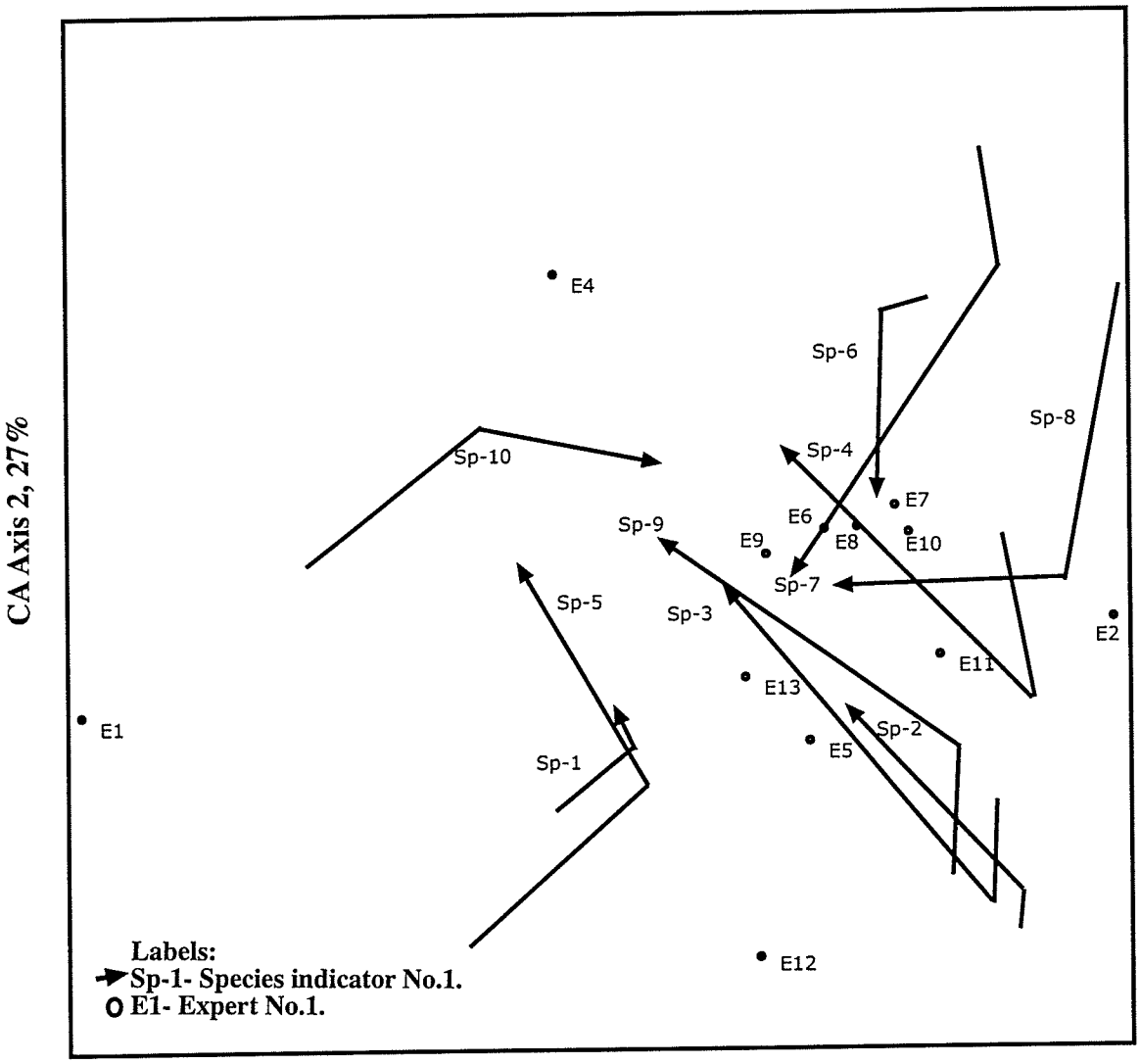


**Figure 23: Perceptual Mapping of expert opinion on Species indicators.**

The CA axis 1 had 36% variance, and the CA second axis 2 had 27 % variance.

### 4.3.6.3. Gene based indicators:

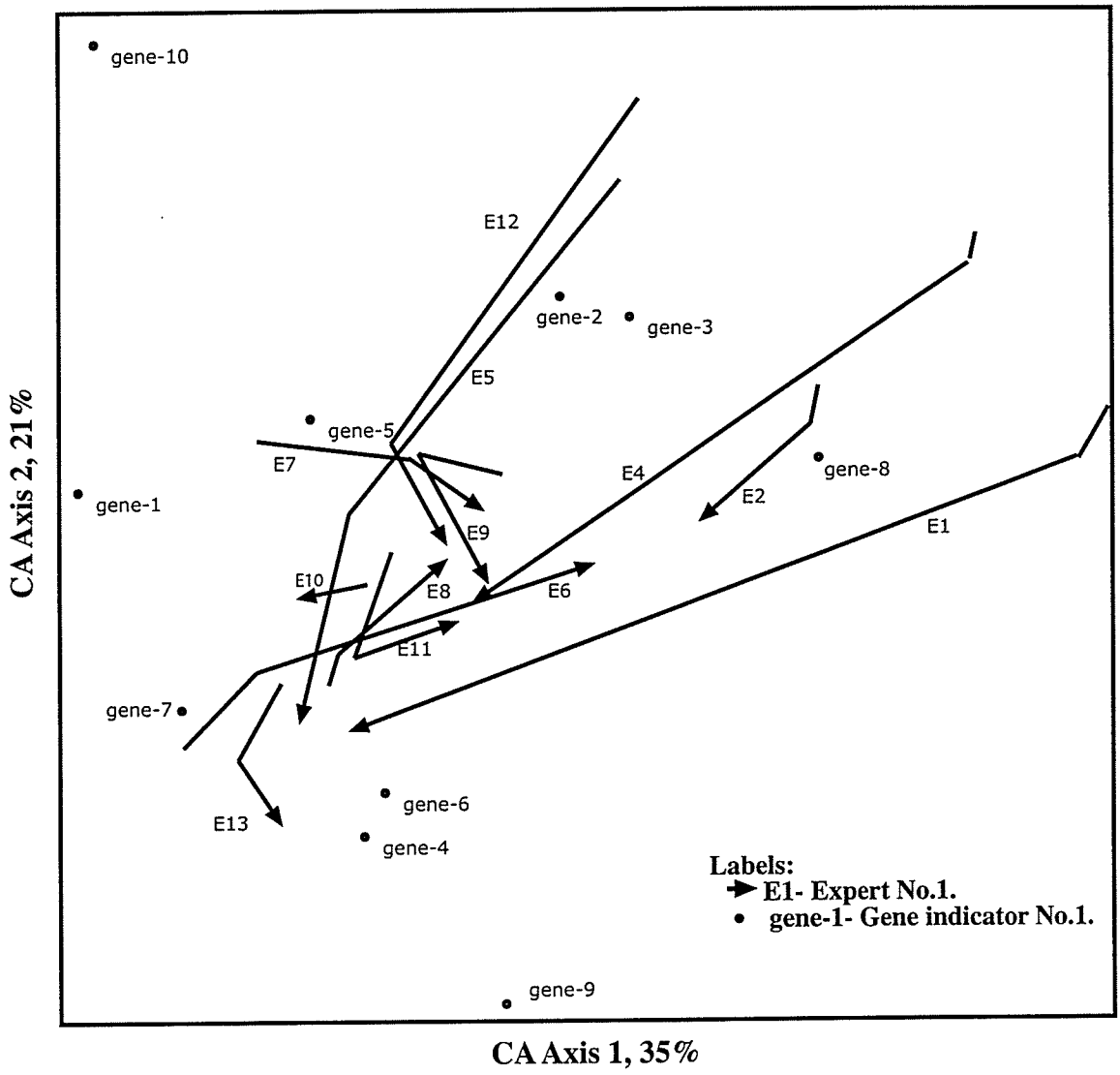


**Figure 24: Perceptual Mapping of expert opinion on Gene indicators (See figure 13 for example interpretation).**

The CA axis 1 had 35% variance and the CA axis 2 had 21% variance.

### 4.3.7. Expert Perceptions of Individual Indicator Groups Ranked as Best:

#### 4.3.7.1.Landscape/community:

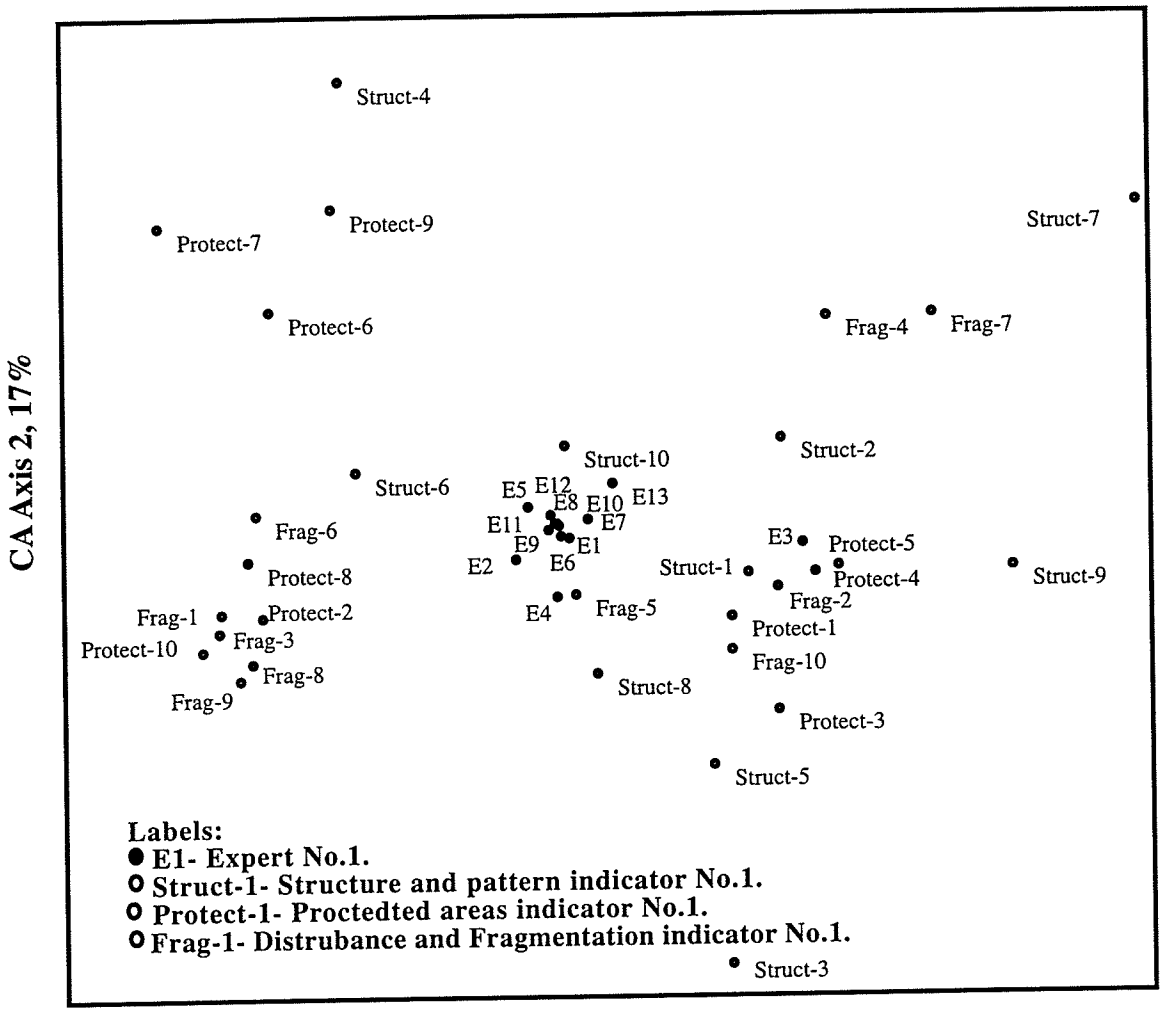


**Figure 25: Biplot of Landscape based biodiversity indicators ranked as best by experts (See figure 13 for example interpretation).**

The CA1 axis had 39% variance and the CA2 axis had 17% variance.

### 4.3.7.2. Species based indicators:

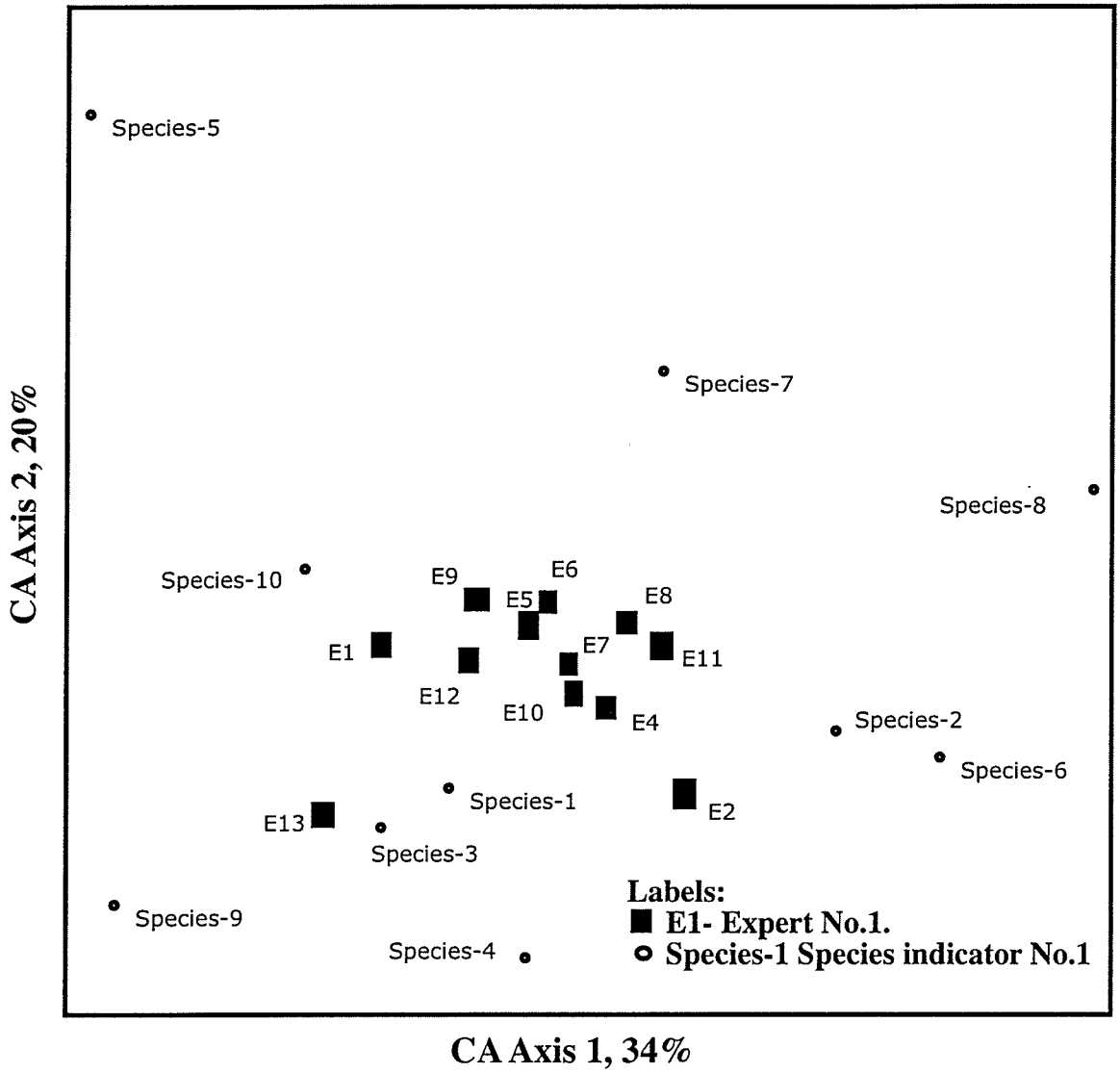


**Figure 26: Biplot of Species based biodiversity indicators ranked as best by experts (See figure 13 for example interpretation).**

The CA axis 1 had a variance of 34% and CA axis 2 had a variance of 20%.

### 4.3.7.3. Gene based indicators:

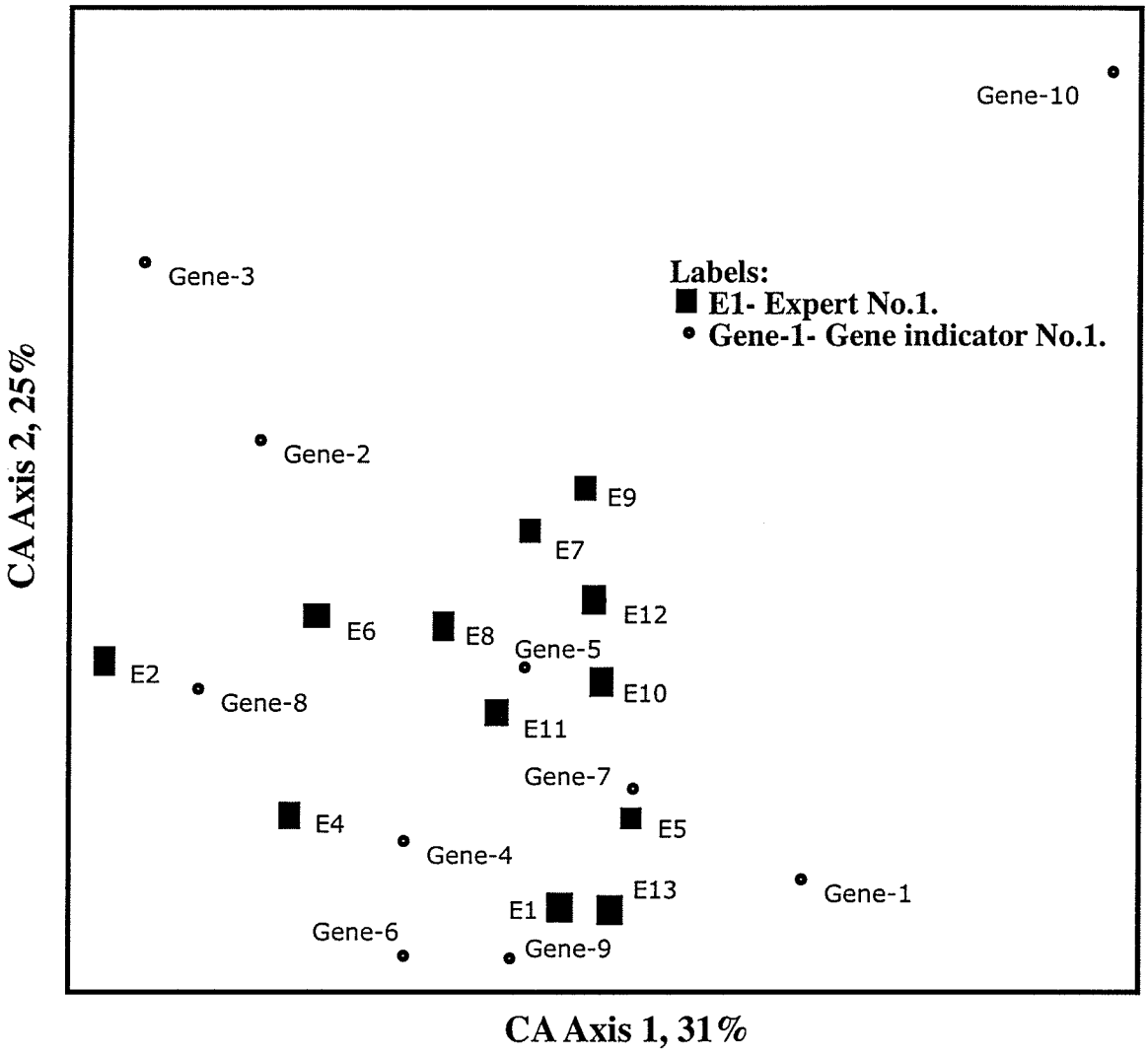


**Figure 27: Biplot of Gene based biodiversity indicators ranked as best by experts (See figure 13 for example interpretation).**

The CA axis 1 had 31% variance and CA axis 2 had 25% variance.

## 5.0.0. Discussion

### 5.1.0. 1st Iteration:

### 5.1.1. Spearman Rank Correlation:

As a preliminary analysis of perception mapping a Spearman rank correlation (Table 6) was carried out to understand relationships among experts and between the scaling groups. The landscape sub-groups all had positive correlations among them. The analysis highlighted a strong positive correlation between species and gene-based indicators. Gene had a weak negative and species had a weak positive correlation with disturbance and fragmentation. However, this was not expressed in the second iteration (Table 7) with a larger number of experts.

### 5.1.2. Perceptual Map of Indicator Groups Ranked as Best:

To further understand these relationships between the indicators and map them, Correspondence Analysis (CA) (Figure 12) of the responses from questionnaire D (Appendix 1D) was carried out. The CA produced results similar to the Spearman correlation. First axis scores corresponded with the scaling hierarchy. The first axis also showed a clear dichotomy, separating the landscape subgroup from species and gene indicators. Experts that ranked gene-based indicators low also ranked the landscape indicators highly, especially disturbance and fragmentation. This was an intriguing result given that fragmentation indices are often indirect measures of changes to gene flow and genetic bottlenecks (Bacles et al. 2004), but then in the second iteration (Figure 21) this was reversed with gene and fragmentation subgroups having a weak positive correlation. A distinct preference by experts for landscape indicators followed by species based

indicators was expressed. Which suggests there is preference for indicators that are economically viable, and also for indicators for which data is readily available.

### 5.1.3. Expert perceptions of Individual sub-groups:

#### 5.1.3.1. Structure and Pattern Perceptual Map:

Further expert opinion was analyzed with respect to each of the sub-groups, and perceptual maps of the five groups were carried out. Experts' perceptions of indicator feasibility for current implementation, implementation in five years, and best indicators irrespective of cost were mapped. Each vector indicates an expert, and their relative lengths suggest the expert's perception of developing and monitoring these indicators. Closer the proximity of a vector towards an indicator, the greater the preference of that expert to that indicator. The first landscape based indicator sub-group, structure and pattern (Figure 14), had ten indicators, and three experts felt there was a need to develop irrespective of cost or constraints indicator 3 (Figure 14) which dealt with structure and composition based on age class. Structure and pattern indicators focusing on habitat diversity (Thomas 1979; Oliver 1992; 1994) have been viewed from an ecosystem management perspective (Haufler 1999).

Indicators 4 and 10 dealt with wetlands and aquatic ecosystems, and the experts ranked them similarly, wetlands in biodiversity conservation has been realized and efforts are underway to incorporate them through satellite data and geographic information systems (GIS) at the landscape level (Aaviksoo et al. 2000). Three of the experts indicated there is a need for a lot of improvement in structure and pattern indicators, similar to suggestions from Lindenmayer et al. (2000).

### 5.1.3.2. Protected Areas Perceptual Map:

Protected areas, the second sub-group in the landscape indicator group (Figure 15), had seven indicators. Indicators 4 and 7 (Figure 15), having a close affinity dealing with ecologically sensitive areas and fragile ecosystems, are expressed close to each other. Likewise indicators 2 and 3 are ranked similarly both deal with different aspects of percentage and quantity of area represented (Figure 15).

Three of the experts felt there was a need to improve these indicators substantially, however there were some variations in their perceptions depending upon their need, whether it was irrespective of cost or in five years. Cooperider et al. (1999) have suggested a number of approaches to conserve biodiversity through the Bioreserve Strategy. An important function of protected areas is the fact they also act as a resource for information on the effects of management on the landscape (Leopold 1941; 1949; Christensen et al. 1996; Cooperider et al. 1999) an essential component for sustainable forestry.

### 5.1.3.3. Disturbance and Fragmentation Perceptual Map:

The last of the landscape based indicator sub-group, disturbance and fragmentation, (Figure 16) had fourteen indicators. Expert 2 felt there was a need for tremendous improvement. The relative perceptions of the rest of the experts were similar as expressed by the length of the vectors. Clusters of indicators with similar objectives are expressed close to each other. Indicators 4, 6, and 14, dealing with forest roads, were expressed close together (Figure 16). Indicators dealing with forest roads are important in forest management, especially when incorporating new roads involved in resource extraction (Noss and Csuti 1994; Haskell 2000; Gucinski et al. 2001; Watkins et al. 2003)

Experts ranked indicators 10, 9, and 3, (Figure 16), dealing with forest patches and connectedness, similarly. Research on comparing canopy structure of trees otherwise known as patch dynamics as an indicator has also been demonstrated in northern hardwood forests (Bormann and Likens 1979). Indicators 1 and 2, which focus on fragmentation are closer together, and indicator 11, dealing with forest edge, is placed midway between the forest patch indicators (10, 9, 3) and the fragmentation indicators (1,2) clusters (Figure 16). Fragmentation and some other spatial properties of landscape features have been proposed as measures for monitoring biodiversity. (McGarigal and Marks 1995; O' Neill et al. 1995; Haufler et al. 2002)

**5.1.3.4. Species Indicators Perceptual Map:**

The fourteen species based indicators (Figure 17) were addressed in questionnaire B (Appendix 1B). Experts ranked related species based indicators similarly. Indicators 12 and 13 are clustered together: they both represent birds, and indicator 9, also representing bird diversity, is closest to this cluster studies utilizing birds as indicators have been carried out in the boreal forest (Mikusinski et al. 2001). Indicators 6, 7, 8 that focus on species from a forest management perspective, are all expressed on one side of the map (Figure 17). Experts all felt indicator 2 (Figure 17), the number of known forest dependant species classified as extinct, threatened, endangered, rare or vulnerable relative to total number of known- forest dependant species (At the ecozone or eco regional level of Ecological Land Classification) was important, However studies indicate that focusing on these species as conservation targets may not be sufficient to monitor overall species richness of a region (Chase et al. 2000; Bonn et al. 2002). Indicators 3 and 4 both focused

on forest species at risk of being threatened or endangered and are closest to indicator 2 in the perceptual map (Figure 17).

The perception of all the experts is the necessity to see significant improvement on species indicators irrespective of cost. This could probably be explained by the high cost associated with monitoring programs for species based indicators (Roloff and Haufler 1997; C&I Alberta. 1998; Haufler et al. 2002) compared to the other scaling groups. Species monitoring is common when dealing with threatened, endangered, rare or species of special concern, where legislation also plays a major role (Haufler et al. 2002) in monitoring. However this issue needs to be viewed in a more holistic manner as successive iterations have highlighted this attribute.

**5.1.3.5. Gene Indicators Perceptual Map:**

The gene-based indicators (Figure 18) were addressed in questionnaire C (Appendix 1C). Since there were relatively few number of indicators, clustering of the indicators has not occurred. From the length of the vectors, it can be determined that three of the experts felt that there was a need for substantial improvement in gene based indicators, and they felt improvement should be possible in the next five years. The remaining three experts expressed the view of a relatively less need for these indicators or felt there was less of a need for improvement this could in part imply that experts felt a lot might not be achieved even without cost constraints. Another possibility could be that the experts misconstrued the indicators, this possibility was considered and efforts were taken to address this issue by ensuring the experts were well informed. This issue can best be overcome by implementing an iterative approach and the second iteration showed promising results with a convergence of views expressed by the experts.

### 5.2.0. 2nd Iteration:

### 5.2.1. Spearman Rank Correlations:

The second iteration produced two sets of Spearman rank correlations, the first (Table 7) correlation exhibited results different from the first iteration. The gene sub-group had strong positive correlations with species and protected areas. Gene also had weak positive and weak negative correlations with the disturbance and fragmentation sub-group and structure and pattern sub-group, respectively. This was contrary to the results seen in the first iteration. Fragmentation and metapopulation studies (Hanski 1998; Haufler et al. 2002) have also highlighted these correlations.

### 5.2.2. Perceptual Map of Indicator Groups Ranked as Best:

The results from the Biplot (Figure 21) show some similarities with the 1st iteration Biplot (Figure 12), and some different opinions as well. Gene indicators continued to be the least preferred among the groups as shown by the vector being farthest away from the experts. Species and protected areas were positively correlated, and exhibited closer together as well; this is consistent with the general opinion of usually considering conservation of species with protected areas (Haufler et al. 2002). This is especially true when there is an increase in the number of threatened, and endangered species, so a protected area approach is adopted and possible causes for the change in species shift are identified (Haufler et al. 2002). Species and structure and pattern were ranked equally and were given the most importance as exhibited by their proximity to the experts.

### 5.2.3. Perceptual Map of Expert Opinion on Indicator Groups Constrained by Profession:

Multiple Discriminant Analysis (MDA) was used to discriminate along the lines of expert occupations. Conservation biologists and forestry personnel were the most widely dispersed groups with the wildlife and species biologists overlapping these two groups (Figure 19). The CA second axis was the best to describe the dispersion along occupational lines.

### 5.2.4. Perceptual Map of Indicator Groups:

The perceptual map of indicator groups (Figure 20) displays a consensus on what the experts think would be the best indicators without cost constraints. Convergence of the indicator groups towards the center of the map is seen (Figure 20).
Experts agree that there will be less improvement in species based indicators over the next five years, but significant improvement is possible in the best species indicators without the cost factor. Experts agree that structure and fragmentation indicators will see significant development in the next five years, as expressed by the length of their vectors (Figure 20) and this implies the amount of data that will become available in the next five years. Lindenmayer et al. (2000) also express the need for better data.

The current gene indicator grouping is the farthest away, implying that the least is being done with regards to these indicators, and also that gene is the group that will require the most attention, followed by structure and fragmentation indicators.

Haufler et al. (2002) also agree that there may never be sufficient resources to study and monitor genetic diversity for a significant part of an ecosystem. Therefore

focusing on specific taxa, especially one which may be more informative than others could be the best option in monitoring genetic diversity (Haufler et al. 2002).

### 5.2.5.Expert Perceptions of Individual sub-groups:

#### 5.2.5.1. Landscape based indicators:

The perceptual map of experts on the Landscape sub-groups shows a consensus as to what they think need to be monitored. Fragmentation indicators 9, 10 and 3, protected areas indicators 6, 7, and 8, and structure and pattern indicators 5 and 8 (Appendix 1A) were considered to be the most important.

Experts one, four and twelve connected with forest management had the greatest expectation in developing these landscape indicators.

Overall there seems to be a consensus emerging from what experts think needs to be monitored with regards to landscape-based indicators. This is also the sentiment expressed by Haufler et al. (1999) and stress the fact even with the existing data gaps it is important for resource managers to pursue landscape level monitoring.

#### 5.2.5.2. Species based indicators:

The perceptual map of species based indicators (Figure 23), is different from the other perceptual maps in representation. These vectors represent indicators and are shown as how experts think they are being monitored.

The experts are spread over the map expressing their very different interests. The indicator vectors also suggest the need for improving monitoring of these indicators.

Experts felt many of the indicators were actually the best, but seemed to differ if improvement will be seen in the next five years. Experts five, thirteen, and nine found

indicators two, three and nine (Appendix 1B) to be the most important, and agreed upon the need to further develop these indicators.

#### 5.2.5.3. Gene based indicators:

The gene indicator perceptual map (Figure 24) exhibits tremendous improvement in consensus of opinion about gene indicators compared to the first iteration (Figure 18). All experts agree that a lot of the gene indicators can be considered as best without cost constraints and also seem to agree that development of these indicators will not occur in the nest five years. The experts also seem to agree in what is currently being implemented, and what will likely be implemented in the next five years, which they agree will not be any different from what is currently being implemented, similar to Haufler et al. (2002).

Gene indicators four, five and six (Figure 24) were considered to be most important (Appendix 1C).

### 5.2.6. Expert Perception Biplot of Individual Indicator Groups Ranked as Best:

#### 5.2.6.1. Landscape/community based indicators:

Expert perception Biplot (Figure 25) was used to identify indicators that would be the best, irrespective of current implementation or future use in five years.

The Biplot highlighted indicators that showed a slightly different set of favored indicators when experts were asked to consider only what was best. Structure and pattern indicators 1 and 10, fragmentation indicator 5 and protected areas indicator 1 were considered to be the most important. The least important were structure and pattern indicators 3, 4, 7 and 9, and protected areas indicator 10 (Appendix 1A).

### 5.2.6.2. Species based indicators:

The expert perception Biplot of species based indicators (Figure 26) again shows a consensus of expert opinion, as they are closely expressed together. Indicators one, two and ten followed by three, seven and six were considered to be best (Appendix 1B). Indicators four, five, eight and nine were considered to be least important (Appendix 1B).

### 5.2.6.3. Gene based indicators:

The experts' perceptions in the Biplot (Figure 27) were similar to the results seen in the perceptual map of gene indicators (Figure 24). Indicators four, five, seven and eight were considered to be best. Expert two found indicator eight to be most important. Experts one and fifteen found indicator nine to be important. Indicator ten was considered to be the least important (Figure 27).

## 5.3.0. Conclusion:

Two iterations of perception mapping were completed in this research. The results suggest perceptual mapping can be used as a tool to evaluate biodiversity indicators and decipher where a forest manager's focus needs to be in developing and monitoring these indicators. Importantly, expectations of experts on indicators when considered without cost constraints were significant. Expert perception of the future use, and irrespective of cost constraints, factors seems to vary between the various scaling groups. The gene group of indicators needs the most attention in the area of development, but experts also agree that there might not be much development in the near future (Haufler et al. 2002) While comparing the two iterations, there has been a consistent trend towards a consensus on what indicators need to be monitored and developed. The development of indicators that also focus on landscape features has been highlighted in other studies

(Hunter 1990; Lindenmayer et al. 2000; Haufler et al. 2002) However, some differences still exist in the opinions expressed by experts, especially, with species based efforts (Chase et al. 2000; Mikusinski et al. 2001). Efforts have also focused on using indicators to monitor and model species richness (Mac Nally and Fleishman 2002), but species indicators may not be sufficient to monitor overall species diversity of an area (Bonn et al. 2002). Divergence in opinion expressed by experts on species indicators implies the need to test relationships between indicator species and the entities they are supposed to indicate about (Lindenmayer et al. 2000) before they are incorporated as indicators in decision-making.

Whether the differences that exist in opinions are ultimately important for conservation of biodiversity needs to be explored. Landscape-based indicators are important for ecosystem-based management (Haufler et al. 1999). A coarse-fine filter (Hunter 1991; Haufler et al. 1999; Haufler et al. 2002) approach may be implemented with landscape-based indicators and selected species-based as the fine filter. The landscape-based indicators also provide linkages to an ecological land classification, since both operate of similar spatial scales (Sims et al. 1996). But with experts citing monetary constraints as a major factor in indicator monitoring especially with its standardization, duration and continuity (C&I Alberta. 1998), landscape-based diversity indicators focusing on structural components (Lindenmayer et al. 2000; Haufler et al. 2002; Rolstad et al. 2002) as a coarse filter and species indicators (McLaren et al. 1998; Mikusinski et al. 2001) should be the first priority.

Global environmental change has impacts across different spatial and temporal scales (Peterson 2000), and forest management has to take into account climate change

(Noss 2001). This is considerably different from forest management under more stable conditions. Studies have been carried out on the global scenarios of different Biomes of global biodiversity (Sala et al. 2000), the predicted changes in the boreal forest suggests, the two major drivers would be climate and land-use change followed by nitrogen deposition, direct forest management will influence the last two drivers. When encountering such radically changing climatic scenarios, it is all the more important to constantly monitor sustainable forest management plans (Noss 2001) and biodiversity indicators. Perceptual mapping could play a major role tracking this rapidly changing scenario.

Information obtained by applying this technique of mapping expert perceptions of indicators will be valuable for incorporation into the Ecosite Decision Support System (DSS) for Sustainable Forest Management (SFM) in Manitoba. Experts suggest some of the landscape-based indicators will be measured at the ecosite level (Anon. 2004) when the ecosite ecological land classification is incorporated into the forest management plans of the companies.

## 6.0.0. Conclusions and Recommendations:

### 6.1.0. Conclusions

This research has highlighted the importance of biodiversity indicators and the need to monitor them in Sustainable Forest Management (SFM). Expert input and extensive review of literature was carried out to determine a possible set of indicators. This set of indicators was further refined using perception mapping. The indicator lists (Appendix 2) have been established with ten indicators per group.

Objective 1: To identify and obtain biodiversity indicators critical to the conservation of biodiversity in Manitoba through expert opinion.

The biodiversity indicators were identified through an extensive literature review of indicators. However, their applicability to Manitoba and the ability to monitor them were needed. Therefore expert opinion from Provincial, Forestry experts and Biologists was utilized and indicators important to Manitoba were identified.

Objective 2: To decipher what experts perceive these indicators are achieving or not achieving.

How experts perceived these indicators was determined and the perception of experts suggested which groups of indicators they considered important.

Experts found the landscape-based indicators to be important followed by species and gene-based indicators.

Perception mapping was used to track perception change of experts over time. This research has demonstrated perception mapping can be carried out by relatively

inexpensive means, within a short time frame. Successive iterations can also be carried out over time to further determine the changes and development of these sets of indicators.

Objective 3: Highlight the underlying relationships that exist between these various indicator groups and relate it to the ecosite level of ecological classification.

The underlying relationships between the various sub-groups were analyzed and affinities between the different landscape sub-groups were strongly expressed in the first iteration. Consensus was well established as what to monitor in landscape indicators compared to the other two groups of indicators in the second iteration.

The landscape group of indicators, with disturbance and fragmentation sub-group followed by the structure and pattern sub-group, will likely see the most improvement in the next five years, as better data becomes available with an improved inventory.

This list of indicators can be incorporated into a decision support-modeling tool and would help forest managers implement sustainable forest management principles. Experts gave importance to landscape/ecosystem-based indicators, since most of these indicators will be gleaned from forest inventory data. Structure and pattern based indicators with disturbance and fragmentation based indicators will play an important role in the years to come.

The need to focus on species based indicators has also been expressed, as it may be important for forest managers to monitor rare, threatened and endangered species. However, the opinion obtained from the experts has been rather diverse with regards to species indicators.

The perception of the experts implies that most of the experts depending upon their occupational affiliation tend to marginally gravitate towards a particular group (i.e. conservation biologists towards species-based indicators and forestry personnel towards landscape-based indicators) in other words occupation does tend to bias the indicators being chosen.

Gene-based indicators are the most neglected group and this groups needs improvement in monitoring but the impression expressed by the experts suggests that gene based indicators may not be monitored in the near future (i.e. five years). Disturbance and fragmentation indicators surrogates for gene flow and genetic bottlenecks had a negative correlation with gene-based indicators in the first iteration, and a positive correlation in the second iteration.

Forest companies in Manitoba may be in a position to implement many of these indicators in the next five years, as more data becomes available with improved inventory standards to measure these indicators. Forest mangers and provincial personnel can utilize this research for developing and streamlining various indicators groups. The landscape-based indicators will be compatible for incorporation into the ecosite level of ecological land classification.

Objective 4: Apply perception mapping as a tool for analyzing expert opinion with regards to biodiversity indicators in sustainable forest management and protected areas management.

Perception mapping was successfully applied to expert opinion of biodiversity indicators in sustainable forest management. This represents the first time this approach

was used in this field. The need to understand indicators of biodiversity at this juncture of significant changes occurring to our environment cannot be over emphasized.

Objective 5: To recommend best practices for the development of future indicators in sustainable forest management.

Lists of biodiversity indicators have been made available for forest managers. Perception mapping and the supporting literature have suggested methods to incorporate biodiversity indicators into sustainable forest management plans.

### 6.2.0. Recommendations:

1) Forest managers and policy makers are encouraged to utilize the indicator lists (Appendix 2) developed for Manitoba and incorporate them into their sustainable forest management plans.
2) Landscape-based indicators are compatible with ecosites and can be implemented at the ecosite level of ecological land classification.
3) Species indicators should be implemented as a fine filter in forest management plans along with landscape-based indicators as the coarse filter.
4) Focus on developing gene-based indicators as efforts to monitor them are lacking in Manitoba and elsewhere in the world.

**Literature Cited:**

Aaviksoo, K., Paal, J., and Dislis, T. 2000. Mapping of wetland habitat diversity using satellite data and GIS: An example from the Alam-Pedja nature reserve, Estonia. *Proceedings of the Estonian Academy of Science. Biology Ecology* 49(2): 177-193.

Alvo, R. 1998. *National Status of 20 Selected Animal Species Inhabiting Canada's Forests*. Report prepared for the Canadian Pulp and Paper Association, Biodiversity Convention Office and Natural Resources Canada—Canadian Forest Service. Gavia Biological Services. Hull, QC. 328.

Angelstam, P., and Andersson, L. 2001. Estimates for the needs for forest reserves in Sweden. *Scandinavian Journal of Forestry Research Supplement* 3: 38-51.

Anon. 1995. *Forest Practices Code of British Colombia, Biodiversity Guidebook.* BC Environment, BC Ministry of Forests. 99.

Anon. 2004. Personal communication. Forestry expert.

Babbie, E.R. 1998. *The Practice of Social Research* 465. Belmont, California. Wadsworth Publishing Company.

Bacles, C. F. E., Lowe, A. J., and Ennos, R. A. 2004. Genetic effects of chronic habitat fragmentation on tree species: the case of *Sorbus aucuparia* in a deforested Scottish landscape. *Molecular Ecology* 13 (3): 573-584.

Bader, P., Jansson, S., and Jonsson, B.G. 1995. Wood-inhabiting fungi and substratum decline in selectively logged boreal spruce forests. *Biological Conservation* 72: 355-356.

Baydack, R.K, Campa, H., and Haufler, J.B., 1999. *Practical Approaches to the Conservation of Biological Diversity.* Washington, D.C: Island Press.

Berg, A., Ehnstrom, B., Gustavsson, L., Hallinback, T., Jonsell, M., and Weslien, J. 1995. Threat levels and Threats to red-listed species in Swedish forests. *Conservation Biology* 9: 1629-1633.

Berrenberg, J. L., Finlay, K.A., Stephan, W. G., and Stephan, C. 2002. Prejudice toward people with cancer or AIDS: Applying the integrated threat model. *Journal of Applied Biobehavioral Research* 7(2): 75-86.

Bigne, J.E., Alda´s-Manzano, J., Ku¨ster, I., and Vila, N. 2002. The concept mapping approach in marketing: an application in the travel agencies sector. *Qualitative Market Research* 5(2): 87-95.

Biodiversity Convention Office. 1995. *Canadian Biodiversity Strategy Canada's Response to the Convention on Biological Diversity.* Hull, Quebec, Biodiversity Convention Office, Environment Canada.

Bonn, A., Rodrigues, A.S.L., Gaston, K.J. 2002. Threatned and endemic species: are they good indicators of patterns of biodiversity on a national scale. *Ecology Letters* 5: 733-741.

Bormann, F.H., and Likens, G.E. 1979. *Pattern and Process in a Forested Ecosystem: Disturbance, Development, and the Steady-State Based on the Hubbard Brook Ecosystem Study.* Springer-Verlag, New York, USA.

Bradu, D., and Gabriel, K. 1978. The Biplot as a diagnostic tool for models of two-way tables. *Techometirics* 20 (1): 47-68.

Brundtland, G.H. 1987.*Our Common Future* Oxford; New York: Oxford University Press.

Canada Committee on Ecological Land Classification. 1977. *Ecological (biophysical) Land Classification in Canada.* Thie, J. and Ironside, G. (Eds), Lands Directorate, Environment Canada, Ottawa, ELC Series No.1. 269.

Canadian Council of Forest Ministers. 1995. *Defining Sustainable Forest Management a Canadian Approach to Criteria and Indicators*. Ottawa: Ontario. Canada.

Canadian Council of Forest Ministers. 1997. *Criteria and Indicators of Sustainable Forest Management in Canada National Status 1997*. Ottawa: Ontario. Canadian Council of Forest Ministers.

Canadian Council of Forest Ministers. 2000. *Criteria and Indicators of Sustainable Forest Management in Canada National Status 2000*. Ottawa: Ontario Canadian Council of Forest Ministers.

Castañeda, F. 1999. FAO Why National and Forest Management Unit Levels Criteria and Indicators for Sustainable Forest Management of Dry Forests in Asia/South Asia. Paper to *FAO/UNEP/ITTO/IIFM Workshop on National Level Criteria and Indicators for Sustainable Forest Management of Dry Forests in Asia/South Asia.* Bhopal, India.

Chase, M.K., Kristan III, W.B., Lynam, A.J., Price, M. V., and Rotenberry, J.T. 2000. Single Species as Indicators of Species Richness and Composition in California Coastal Sage Scrub Birds and Small Mammals. *Conservation Biology* 14 (2): 474-487.

Christensen, N.L., Bartuska, A.M., Brown, J.H., Carpenter, S., D'Antonio, C., Francis, R., Franklin, J.F., MacMohan, J.A., Noss, R.F., and Parsons, D.J. 1996. The report of the Ecological Society of America committee on the scientific basis for ecosystem management. *Ecological Applications* 6: 665-691.

Clason, D.L., and Dormody, T.J. 1994. Analyzing data measured by individual Likert-type items. *Journal of Agricultural Education* 35 (4): 31-35.

Coughlan, B.A.K., and Armour, C.L.1992. *Group Decision-Making Techniques for Natural Resources Management Applications.* U.S.Fish and Wildlife Service, Resource Publication 185, Washington, D.C.

Crance, J.H. 1987. *Guidelines for Using the Delphi Technique to Develop Habitat Suitability Index Curves.* U.S. Fish and Wildlife Service Biological Report 82.

Crichton, N.J. 1999. Information point: Spearman's rank correlation. *Journal of Clinical Nursing* 8: 763.

Criteria and Indicators for Monitoring Biodiversity in Alberta's Forests. 1998. *Part I: Review of Legislation, Policies, External Agreements, and Programs.* A Progress Completion Report. Alberta Research Council

Dalkey, N. and Helmer, O. 1963. An experimental application of the Delphi method to the use of experts. *Management Science* 9(3): 458-467.

Dalkey, N.C., Brown, B.B., and Cochran, S. 1969. *The Delphi Method.* Santa Monica, California: Rand Corp.

Delbecq, A.L., Van de Ven, A.H., and Gustafson, D.H. 1975. *Group Techniques for Program Planning a Guide to Nominal Group and Delphi Processes.* Glenview, Ill: Scott, Foresman.

Diamantopoulos, A., Souchon, A.L., Durden, G.R., Axinn C. N., and HolzmuÈller, H.H. 2003. Towards an understanding of cross-national similarities and differences in export Information utilization. A perceptual mapping approach. *International Marketing Review* 20 (1): 17-43.

Dorma, C. 2001. *Achieving Biodiversity Conservation Objectives: A Case Study of Canada's Forest Industry.* Master's Thesis Dissertation. Natural Resources Institute. University of Manitoba.

Ecological Stratification Working Group. 1996. *A National Ecological Framework for Canada.* Agriculture and Agri-food Canada –Research Centre for Land and Biological Resources Research and Environment Canada –State of the Environment Directorate –Ecozone Analysis Branch, Ottawa, On/Hull, QC. 125+ Map.

Ehnstrom, B. 2001. Leaving dead wood for insects in boreal forests – suggestions for the future. *Scandinavian Journal of Forest Research Supplement* 3: 91-98.

Farnham, T. J. 2002. *The Concept of Biological Diversity: The Evolution of a Conservation Paradigm.* Ph.D. dissertation. Yale University, New Haven, Connecticut.

Flather, C. H., and Sieg, C. H. 2000. Applicability of Montreal Process criterion 1 - conservation of biological diversity - to rangeland sustainability. *International Journal of Sustainable Development and World Ecology* 7: 81-96.

FLITAC. 2000. *Development of a Forest Lands Inventory for Manitoba.* Final Report.

Franklin, J.F.K., and Cromack, W.D. 1981. *Ecological characteristics of Old growth Douglas Fir forests. USDA Forest Service General Technical Report* PNW-118. Pacific Northwest Forest and Range Experiment Station. Portland. Oregon.

Franklin, J.F. 1993. Preserving biodiversity: Species, ecosystems or landscapes? *Ecological Applications* 3: 202-205.

Franklin, J.F., Berg, D.R., Thronburgh, D.A., and Tappeiner, J.C. 1997. Alternative silvicultural approaches to timber harvesting: Variable retention systems. In Kohm, K.A. & Franklin, J.F. (eds), *Creating Forestry for the 21st Century. The Science of Forest Management.* Island press, Washington. 111-139.

FSC (Forest Stewardship Council). 1999. *Document 1.2. Principles and Criteria for Forest Stewardship.* Oaxaca, Mexico.

Fusfeld, A.R., and Foster, R.N. 1971. The Delphi technique: Survey and comment. *Business Horizons* 14 (6): 63-74.

Gabriel, K.R. 1981. Biplot Display of Multivariate Matrices for Inspection of Data and Diagnosis.in *Interpreting Multivariate Data*, eds V. Barnett, London. John Wiley&sons, inc.

Granstrom, A. 2001. Fire management for biodiversity in the European boreal forest. *Scandinavian Journal of Forestry Research Supplement* 3:62-69.

Greenacre, M.J. 1984. *Theory and Application of Correspondence Analysis.* London Academic Press.

Gucinski, H., Furniss, M. J., Ziemer, R. R., and Brookes, M. H. 2001. *Forest Roads: A Synthesis of Scientific Information.* Gen. Tech. Rep. PNW-GTR-509. Portland,

OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 103.

Gupta, A.K. 2001. *Criteria and Indicators of Sustainability in Rural Development: A Natural Resource Perspective.* New Delhi and Calcutta: Oxford & IBH Publishing Co .Pvt.Ltd.

Hanski, I. 1998. Metapopulation dynamics. *Nature* 396: 41-49.

Hansson, L. 2001. Key habitats in Swedish managed forests. *Scandinavian Journal of Forestry Research Supplement* 3: 52-61.

Hare, F.K., and Ritchie, J.C. 1972. The boreal bioclimates. *Geographical Review* 62: 333-365.

Haskell, D.G. 2000. Effects of Forest Roads on Macroinvertebrate Soil Fauna of the Southern Appalachian Mountains. *Conservation Biology* 14 (1): 57.

Haufler, J.B. 1999. Chapter 2: Strategies for Conserving Terrestrial Biological Diversity. In *Practical Approaches to the Conservation of Biological Diversity.* Eds Baydack, R.K, Campa, H., Haufler J.B.,. Washington, D.C: Island Press. 107-125.

Haufler, J.B., Mehl, C.A., and Roloff, G.J., 1999. Chapter 7: Conserving Biological Diversity Using a Coarse-Filter Approach with a species assessment. In *Practical Approaches to the Conservation of Biological Diversity.* Eds Baydack, R.K., Campa, III, H., Haufler J.B. Washington, D.C: Island Press. 107-125.

Haufler, J.B., Baydack, R.K., Campa, III, H., Kernohan, B. J., Miller, C., O'Neil, L. J., and Waits, L. 2002. *Performance Measures for Ecosystem Management and Ecological Sustainability.* Wildlife Society Technical Review 02-1. 33.

Hawksworth, D.L.1995. *Biodiversity Measurement and Estimation.* 1st ed. London:Chapman & Hall.

Henry, J.D. 2002. *Canada's Boreal Forest.* Smithsonian natural history series.

Higgs, N.T. 1990. Practical and innovative uses of correspondence analysis. *The Statistician* 40: 183-194.

Hoffman, D.L. and Franke, G.R. 1986. Correspondence Analysis: Graphical Representation of Categorical Data in Marketing Research. *Journal of Marketing Research.* 23 (3): 213-228.

Hunter, M.L., 1990.*Wildlife, Forests, and Forestry: Principles of Managing Forests for Biodiversity.* Prentice hall, NJ.

Hunter, M.L., 1991. Coping with Ignorance: The coarse filter strategy for maintaining biodiversity. Pages 266-281 in Kohm K.A., ed. *Balancing on the Brink of Extinction.* Washington (DC): Island press.

Imbeau. L., Mönkkönen. M., and Desrochers, A. 2001. Long-Term Effects of Forestry on Birds of the Eastern Canadian Boreal Forests: a Comparison with Fennoscandia. *Conservation Biology* 15 (4): 1151.

Jonsson, B.G., and Jonsell, M. 1999. Exploring potential biodiversity indicators in boreal forests. *Biodiversity and Conservation* 8: 1417-1433.

Keenan,V. 2002. Personal communication. Tembec, Pine Falls operations.

Kuhfeld W.F. 2004. Marketing Research: Uncovering Competitive Advantages. In *Marketing Research Methods in SAS.* SAS 9.1 edition. SAS Institute Inc., Cary, NC, USA.

Larsson, S. and Danell, K. 2001 Science and the management of boreal forest diversity. *Scandinavian Journal of Forest Research Supplement.* 3, 1-123.

Legendre, L., and Legendre, P. 1998. *Numerical Ecology*. 2nd ed. Amsterdam , New York : Elsevier.

Leopold, A. 1941. Wilderness as a land laboratory. Living Wilderness 6: 3.

Leopold, A. 1949. *A Sand County Almanac*. New York: Oxford University Press.

Likert, R. 1932. A Technique for the Measurement of Attitudes. *Archives of Psychology*. New York.

Lindenmayer, D.B., Margules, C.R., and Botkin, D.B. 2000. Indicators of Biodiversity for Ecological Sustainable Forest Management. *Conservation Biology* 14(4): 941-950

Louis I., Mönkkönen, M., and Desrochers, A. 2001. Long-Term Effects of Forestry on Birds of the Eastern Canadian Boreal Forests: a Comparison with Fennoscandia. *Conservation Biology* 15(4): 1151.

Lovejoy, T.E.1980 in *Conservation Biology: An Evolutionary-Ecological Perspective* edited by Michael E. Soulé and Bruce A. Wilcox. Published: Sunderland, Mass.: Sinauer Associates, c1980. Description: xv, 395.

Mackay, B.G., Mckenny, D.W., and Sims, R.A. 1994. Towards a set of biodiversity indicators for Canadian forests. In *Proceedings of a Forest Biodiversity Indicators Workshop*, held at Sault Ste. Marie, Ontario, November 29-December 1, 1993. Sault Ste. Marie: Natural Resources Canada, Canadian Forest Service – Ontario.

MacNally, R., and Fleishman, E. 2002. Using "Indicator" species to model species richness: Model development and predictions. *Ecological Applications* 12 (1): 79-92.

Malhotra, N.K. and Bartels, B.C. 2002. Overcoming the attribute prespecification bias in international marketing research by using non-attribute-based correspondence analysis. *International Marketing Review* 19(1): 65-79.

Manitoba Round Table for Sustainable Management, 2001. *Recommendations to the Manitoba government regarding Provincial Sustainability Indicators.* Manitoba Conservation.

McGarigal, K., and Marks, B.J. 1995. *FRAGSTATS: Spatial pattern analysis program for quantifying landscape structure.* United States Forest Service General Technical Report PNW-351.

McKenney, D.W. 1994. Towards a set of biodiversity indicators for Canadian forests. In *Proceedings of a Forest Biodiversity Indicators Workshop*, held at Sault Ste. Marie, Ontario, November 29-December 1, 1993. Sault Ste. Marie: Natural Resources Canada, Canadian Forest Service - Ontario.

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(2): 241-248.

Mikusinski, G., Gromadzki, M., and Chylarecki, P. 2001. Woodpeckers as Indicators of Forest Bird Diversity. *Conservation Biology* 15(1) 208-217.

Model Forest. 2000. *A User's Guide To Local Level Indicators Of Sustainable Forest Management: Experiences From The Canadian Model Forest Network.* Natural Resources Canada. Ottawa, On. Canada.

Mollohan, C.M., Patton, D.R., and Wakeling, B.F. 1995. *Habitat Selections and Use by Merriam's Turkey in North Central Arizona: A Final Report.* Arizona Game and Fish Department Technical Report Number 9.

Mosquin, T., Whiting, P.G., and Mc Allister, D.E. 1995. *Canada's Biodiversity: The Variety of Life, Its Status, Economic Benefits, Conservation Costs and Unmet Needs.* Canadian Museum of Nature. Ottawa, On.

Nass, C., Foehr, U., Brave, S., and Somoza, M. 2001. The effects of emotion of voice in synthesized and recorded speech. *Proceedings of the AAAI Symposium Emotional and Intelligent II: The Tangled Knot of Social Cognition.* North Falmouth, MA.

National Forest Strategy.1992. *Sustainable Forests: A Canadian Commitment. National Forest Strategy.* Canadian Council of Forest Ministers. Ottawa.

National Forest Strategy. 1998. *Sustainable Forests: A Canadian Commitment. National Forest Strategy.* Canadian Council of Forest Ministers. Ottawa.

Norse, E. A., and McManus, R. E. 1980. Ecology and Living resources biological diversity. In *Council on Environmental Quality, Eleventh Annual Report* 31-80. Washington, D.C.: Council of Environmental Quality.

Norse, E.A., Rosenbaum, K.L., Wilcove, D.S., Wilcox, B.A., Romme,W.H., Johnston, L.S. 1986. *Conserving Biological Diversity in Our National forests.* The Wilderness Society, Washington D.C.

Norse, E.A. 1996. A river that flows to the sea: the marine biological diversity movement. *Oceanography.* 9(1): 5-9.

Norse, E.A., and Carlton. J.T., 2003. World Wide Web Buzz about Biodiversity. *Conservation Biology* 17(6): 1475-1476.

Noss, R.F. 1987. From plant communities to landscapes in conservation inventories: A look at The Nature Conservancy (USA). *Biological Conservation.* 41: 11-37.

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

Noss R.F. and Csuti, B. 1994. Habitat fragmentation. In *Principles of Conservation Biology.* Edited by Meffe, G.K., and Carroll, C.R. Sinaur Associates Inc., Sunderland, MA. 237–264.

Noss, R.F. 1998. A big-picture approach to forest certification: A report for World Willdlife Funds's Forests for Life campaign in North America. In *Defining a Forest Vision: World Wildlife Funds North American Forests for Life Conference*, eds. Kessler, K., DellaSala, D.A., and Hackman, A. Washignton, D.C.: World Wildlife Fund.

Noss, R.F. 2001. Beyond Kyoto: Forest Management in a time of Rapid Climate Change. *Conservation Biology* 15(3): 578-590.

O'Neill, R.V., Hunsaker, C.T., Jones, D., Klopatek, J.M., Dale, V.H., Turner, M.G., Gardner, R.H., and Graham, R. 1995. Sustainability at landscape and regional scales: The biogeophysical foundations. In *Sustainability at Landscape and Regional Scales.* Eds. M. Munasinghe and W.Shearer. United Nations University, Washington, D.C.

Okland, B., Bakke. A., Hagvar, S., and Kvamme, T. 1996. What factors influence the diversity of saproxylic beetles? A multiscaled study from a spruce forest in southern Norway. *Biodiversity and Conservation* 5: 75-100.

Oliver, C.D. 1992. A landscape approach: Achieving and maintaining biodiversity and economic productivity. *Journal of Forestry* 90(9): 20-25.

Oliver, C.D. 1994. Rebuilding biological diversity at the landscape level. *Proceedings of the Conference on Forest Health and Fire Danger in Inland Western Forests.* Harmon press.

Pan, D.W., and Baker, J.A.W. 1998. Perceptual mapping of banned substances in Athletics. *Journal of Sport & Social Issues* 22(2): 170-182.

Parks Canada. 2000. *Working Together: Parks and Protected Areas in Canada* / Federal Provincial Parks Council.

Pearson, D.L. 1995. Selecting indicator taxa for the quantitative assessment of biodiversity. In *Biodiversity Measurement and Estimation.* Hawksworth, D.L. Ed. London: Chapman & Hall.

Peterson, G.D. 2000. Scaling Ecological Dynamics: Self-Organization, Hierarchical Structure, and Ecological Resilience. *Climate Change* 44: 291-309.

Racey, G.D., Harris, A.G., Jeglum, J.K., Foster, R.F., and Wickware, G.M. 1996. *Terrestrial and Wetland Ecosites of Northwestern Ontario*. Ministry of Natural Resources, Northwest Science& Technology Field Guide.

Rice, J.M. 1989. Motivation- how do we measure it? *Proceedings of the Isida conference on Consumer Behaviour and Strategic Marketing: Anything New?*

Roloff, G.J., and Haufler, J.B. 1997. Establishing population viability planning objectives based on habitat potentials. *Wildlife Society Bulletin* 25: 895-905.

Rolstad, J., Gjerde, I., Vegard S.G., and Sætersdal, M. 2002. Use of Indicator Species to Assess Forest Continuity: a Critique. *Conservation Biology* 16 (1): 253-257.

Rowe, G., Wright, G., and Bolger, F., 1991. Delphi A Reevaluation of Research and Theory. *Technological Forecasting and Social Change* 39: 235-251.

Rowe, J. S. 1961. The level-of-integration concept and ecology. *Ecology* 42: 420-427.

Rowe, J. S. 1992. The ecosystem approach to forestland management. *The Forestry Chronicle* 68(1): 222-224.

Sala, O.E., Chapin III, F. S., Armesto, J.J., Berlow, E., Bloomfield, J., Dirzo, R., Sanwald- Huber, E., Huenneke, L. F., Jackson, R. B., Kinzig, A., Leemans, R., Lodge, D.M., Mooney, H.A., Oesterheld, M., Poff, N. L., Sykes, M. T., Walker, B. H., Walker, M., and Wall, D. H. 2000. Global Biodiversity Scenarios for the Year 2100. *Science* 287: 1770-1774.

Santiago Declaration. 1995. Statement on Criteria and Indicators for the Conservation and Sustainable Management of Temperate and Boreal Forests. *Journal of Forestry* 93(4).

Schuster, E.G., Frissell, S.S., Baker, E.E and Loveless, Jr., R.S. 1985. *The Delphi Method: Application to Elk Habitat Quality.* U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, Utah, USA.

Simberloff, D. 2001. Management of boreal forest biodiversity - a view from outside. *Scandinavian Journal of Forestry Research Supplement* 3: 105-118.

Sims, R. A., Corns, I.G.W., and Klinka, K.1996. Introduction –Global to Local: Ecological Land Classification. *Environmental Monitoring and Assessment* 39: 1-10.

Sjoberg, K., and Danell, K. 2001. Introduction of lodgepole pine in Sweden- ecological relevance for vertebrates. *Forest Ecolgy Management* 141: 143-153.

Spearman, C. 1904. The Proof and Measurement of Association Between Two Things. *American Journal of Psychology* 15: 72-101.

State of Canada's Forests. 2000. *Forests in the New Millennium*. Natural Resources Canada. Canadian Forest Service.

State of the Forest Report. 2001. Ministry of Natural Resources, Ontario. Forest Information Series. Ontario, Canada.

Steiner, I.D., 1972. *Group Process and Productivity*. Academic Press, New York.

Tembec C&I report. 2001. *Monitoring of Criteria and Indicators.* Forest Resource Management. Tembec Industries Inc. Pine Falls Operations.

Thomas, J.W. 1979. Wildlife habitats in managed forests: the blue mountains of Oregon and Washington. *Agricultural Handbook.* Washington, D.C. USDA Forest Service.

Turoff, M.1970. The design of a policy Delphi. *Technological Forecasting and Social Change* 2:149-171.

Uhl, N.P. 1983. *Using Research for Strategic Planning.*

Uhmann, T. V. 2001. *The Development of a Habitat Suitability Index Model for Burrowing Owls in Southwestern Manitoba and Southeastern Saskatchewan.* Thesis Dissertation, Natural Resources Institute. University Of Manitoba.

Urban, D.l., O'Neill, R.V., and Shugart, H.H. 1987. Landscape ecology. *Bioscience* 37:119-127.

U.S. Forest Service. 1990. *Conserving Our Heritage- America's biodiversity.* Washington, D.C.: U.S. Forest Service.

Vanha-Majamaa, I., and Jalonen, J. 2001. Green tree retention in Fennoscandian forestry. *Scandinavian Journal of Forestry Research Supplement* 3: 79-90.

Walker, D.J. 2004. Personal Communication. Winnipeg, Manitoba, Canada.

Watkins, R. Z., Chen, J., Pickens, J., and Brosofske, K.D. 2003. Effects of Forest Roads on Understory Plants in a Managed Hardwood Landscape. *Conservation Biology* 17(2): 411-419.

Wiken, E.B., and Ironside, G. 1977. The Development of Ecological (Biophysical) Land Classification in Canada. *Landscape Planning* 4: 273-282.

Williams, H.A., and Lawson, M. J. 2001. Mapping students' perceptions of interesting class lessons. *Social Psychology of Education* 5: 127-147.

Wilson, E. O. 1988. *Biodiversity*. National Academy Press. Washington. D.C.

Winkler, R. L., and Hays, W. L. 1975 *Statistics: Probability, Inference and Decision.2nd Edition.* New York: Holt, Rinehart and Winston Inc.

Wittenschlaeger, T. A., and Fiedler, J. A. 1997. Current Practices in Perceptual Mapping. *Proceedings of the 1997 Sawtooth Software Conference.*

Working Group. 2001. *Scaling National Criteria and Indicators to the Local Level.* Working Group on Criteria and Indicators for the Conservation and Sustainable Management of Temperate and Boreal Forests, Canadian Forest Service, Ottawa: Ontario. Science Branch, Canadian Forest Service.

World Conservation Strategy. 1980. *World Conservation Strategy: Living Resource Conservation for Sustainable Development* / prepared by the International Union for Conservation of Nature and Natural Resources (IUCN); Gland, Switzerland.

Zuboy, J.R. 1981. A new tool for fishery managers: the Delphi technique. *North American Journal of Fisheries Management* 1: 55-59.

**Web References:**

www.borealforest.org 2002. Obtained on 8-11-2002 at 4:30 am.

www.canadianforestry.com 2001. Obtained on 3-8- 2001 at 8:30 pm.

www.mpci.org 2002. Obtained on 8-11-2002 at 3:20 am.

www.ucmp.berkeley.edu/glossary/gloss5/biome/forests.html 2003 Obtained at 9-11-2002 at 6:30 pm.

## Appendix 1A Questionnaire A.

| Q.No. | Ecosystem Diversity: Structure and Pattern | [1]Rank indicator irrespective of cost/imp | [2]Rank indicator currently implemented in your field/industry | [3]Rank indicator to be implemented in next 5 years. |
|---|---|---|---|---|
| 1 | Area of forest, by type and age class, and wetlands in each ecozone. | | | |
| 2 | Percentage and extent in area, of forest types relative to historical condition and to total forest area (Hectares) | | | |
| 3 | Percent of wetlands in effective forest management | | | |
| 4 | Composition and structure of aquatic systems | | | |
| 5 | Composition of the forest in terms of Forest Ecosystem types (FEC) V-types (Hectares) | | | |
| 6 | Area of forest land by land use designation (Hectares) | | | |
| 7 | Naturally regenerated areas relative to reforested areas (Hectares) | | | |
| 8 | Changes in amount and complexity of vertical habitat structure (Measurement of the height of each layer) | | | |
| 9 | Percent of proposed harvest blocks subject to pre-harvest assessment (% hectares) | | | |
| 10 | Composition and structure of forest types by age class. | | | |
| 11 | | | | |



[1]Rank (1:worst to 10:best) the measures that would make the best indicator regardless of cost and or implementation difficulty. (i.e. what are the best)

[2]Rank (1:worst to 10:best) the measures that you currently implement as an indicator in your field. (i.e. what are the best currently in use.)

[3]Rank (1:worst to 10:best) the measures that will be operational as an indicator within five years. (i.e. what do you think will be the best we can do in five years given the trends in certification)

| Q.No. | Ecosystem Diversity: Protected Areas | [1]Rank indicator irrespective of cost/imp | [2]Rank indicator currently implemented in your field/industry | [3]Rank indicator to be implemented in next 5 years. |
|---|---|---|---|---|
| 1 | Extent of area by forest type in protected area categories as defined by IUCN (International Union for Conservation of Nature) or other classification systems (Including provincial) | | | |
| 2 | Area of forest, by type and age class, wetlands, soil types and geomorphological feature types in protected areas in each ecozone. | | | |
| 3 | Quantity and percentage of old growth forest ecosystems | | | |
| 4 | Ecologically sensitive areas (including riparian areas) identified and managed according to forest management guidelines | | | |
| 5 | Identification and protection of local sites of significance (Hectares and %) | | | |
| 6 | Proportion of each eco-region in protected status (%hectares) | | | |
| 7 | Forest management activities, not set out in the management plan, in rare or fragile ecosystems (alder stands, denuded, and semi-denuded) (frequency and hectares) | | | |
| 8 | Area of forest permanently converted to non-forest use, e.g., urbanization. Also includes agriculture and golf courses. | | | |
| 9 | Percentage of protected area that is road accessible. | | | |
| 10 | Area & percentage of forest types in protected areas | | | |
| 11 | | | | |



[1]Rank (1:worst to 10:best) the measures that would make the best indicator regardless of cost and or implementation difficulty. (i.e. what are the best)

[2]Rank (1:worst to 10:best) the measures that you currently implement as an indicator in your field. (i.e. what are the best currently in use.)

[3]Rank (1:worst to 10:best) the measures that will be operational as an indicator within five years. (i.e. what do you think will be the best we can do in five years given the trends in certification)

| Q.No. | Ecosystem Diversity: Disturbance and Fragmentation | [1]Rank indicator irrespective of cost/imp | [2]Rank indicator currently implemented in your field/industry | [3]Rank indicator to be implemented in next 5 years. |
|---|---|---|---|---|
| 1 | Percent and amount of fragmentation in forest types | | | |
| 2 | Frequency distribution and pattern of harvest compared with natural disturbance areas | | | |
| 3 | Levels of fragmentation and connectedness of forest ecosystem components using landscape pattern indices (Eg. Patchiness and juxtaposition, Shannon or other diversity indices) | | | |
| 4 | Patch – size distribution by natural disturbance type by landscape unit by age class. | | | |
| 5 | Size and distribution of contiguous patches (Hectares) | | | |
| 6 | Surface area and size distribution of areas located more than 1, 5and 10 km from roads (Hectares) | | | |
| 7 | Changes in roadedness per volume of trees removed associated with forest practices (length of road per unit area) or Density (ha/km$^2$) | | | |
| 8 | Size and distribution of edge (Hectares) | | | |
| 9 | Abundance and composition of residual stand structure (Hectares) | | | |
| 10 | Abundance of coarse woody debris, snags, etc. (tree per unit area and mass per unit area) | | | |
| 11 | | | | |



[1]Rank (1:worst to 10:best) the measures that would make the best indicator regardless of cost and or implementation difficulty. (i.e. what are the best)

[2]Rank (1:worst to 10:best) the measures that you currently implement as an indicator in your field. (i.e. what are the best currently in use.)

[3]Rank (1:worst to 10:best) the measures that will be operational as an indicator within five years. (i.e. what do you think will be the best we can do in five years given the trends in certification)

## Appendix 1B Questionnaire B.

| Q.No. | Species Diversity: | [1]Rank indicator irrespective of cost/imp | [2]Rank indicator currently implemented in your field/industry | [3]Rank indicator to be implemented in next 5 years. |
|---|---|---|---|---|
| 1 | The status of forest-associated species at risk. | | | |
| 2 | Number of known forest dependant species classified as extinct, threatened, endangered, rare or vulnerable relative to total number of known- forest dependant species. | | | |
| 3 | Number of known forest dependant species that occupy only a small portion of their former range. | | | |
| 4 | Distribution of selected forest-associated species. | | | |
| 5 | Proportion of pre-harvest assessment crews trained in the recognition/ identification of rare, threatened and endangered species (RTE) and habitat (Proportion of crews trained) | | | |
| 6 | Population levels of selected forest-associated species like RTE mammals (Eg.Caribou) and birds (Eg. Pileated Woodpecker) | | | |
| 7 | Population size and reproductive success of species dependant upon interior forest conditions. | | | |
| 8 | Relative abundance, species richness and diversity of species (Eg. Shannon's index) | | | |
| 9 | Number of invasive, exotic forest associated species. | | | |
| 10 | Percentage of area determined to have high suitability (HSI) for target species in forest management | | | |
| 11 | | | | |



[1]Rank (1:worst to 10:best) the measures that would make the best indicator regardless of cost and or implementation difficulty. (i.e. what are the best)

[2]Rank (1:worst to 10:best) the measures that you currently implement as an indicator in your field. (i.e. what are the best currently in use.)

[3]Rank (1:worst to 10:best) the measures that will be operational as an indicator within five years. (i.e. what do you think will be the best we can do in five years given the trends in certification)

## Appendix 1C Questionnaire C.

| Q.No. | Genetic Diversity | [1]Rank indicator irrespective of cost/imp | [2]Rank indicator currently implemented in your field/industry | [3]Rank indicator to be implemented in next 5 years. |
|---|---|---|---|---|
| 1 | Number of forest dependent species that occupy a small portion of their former range | | | |
| 2 | Genetic diversity of reforestation seed-lots. | | | |
| 3 | Status of in-situ and ex-situ conservation efforts for native tree species within each ecozone. | | | |
| 4 | Changes in population, genetic diversity and structure and gene flow for selected species | | | |
| 5 | All naturally occurring species are maintained within sub-regions (Species presence using a checklist approach) | | | |
| 6 | Absence of species or visible subspecies from formerly populated areas | | | |
| 7 | Degree of range reduction of sensitive species | | | |
| 8 | Percentage of natural seed collection within seed zone and regeneration from local site seed source | | | |
| 9 | No significant changes in gene frequencies in trees | | | |
| 10 | Utilization of commercial tree genetic material in tree propagation. | | | |
| 11 | | | | |



[1]Rank (1:worst to 10:best) the measures that would make the best indicator regardless of cost and or implementation difficulty. (i.e. what are the best)

[2]Rank (1:worst to 10:best) the measures that you currently implement as an indicator in your field. (i.e. what are the best currently in use.)

[3]Rank (1:worst to 10:best) the measures that will be operational as an indicator within five years. (i.e. what do you think will be the best we can do in five years given the trends in certification)

## Appendix 1D Questionnaire D.

| Elements & Subgroups | [1]Rank best element irrespective of cost/imp | [2]Rank best element currently implemented in your field/industry | [3] Rank best element to be implemented in the next 5 years. |
|---|---|---|---|
| Ecosystem Diversity: Structure and pattern | | | |
| Ecosystem Diversity: Protected areas | | | |
| Ecosystem Diversity: Disturbance and fragmentation | | | |
| Species Diversity | | | |
| Gene Diversity | | | |



[1]Rank (1:worst to 10:best) the measures that would make the best indicator regardless of cost and or implementation difficulty. (i.e. what are the best)

[2]Rank (1:worst to 10:best) the measures that you currently implement as an indicator in your field. (i.e. what are the best currently in use.)

[3]Rank (1:worst to 10:best) the measures that will be operational as an indicator within five years. (i.e. what do you think will be the best we can do in five years given the trends in certification)

**Appendix 2 A. Landscape based Indicators: Structure and Pattern.**

| Q.No. | Landscape Diversity: Structure and Pattern |
|---|---|
| 1 | Area of forest, by type and age class, and wetlands in each ecozone. |
| 2 | Percentage and extent in area, of forest types relative to historical condition and to total forest area (Hectares) |
| 3 | Percent of wetlands in effective forest management |
| 4 | Composition and structure of aquatic systems |
| 5 | Composition of the forest in terms of Forest Ecosystem types (FEC) V-types (Hectares) |
| 6 | Area of forest land by land use designation (Hectares) |
| 7 | Naturally regenerated areas relative to reforested areas (Hectares) |
| 8 | Changes in amount and complexity of vertical habitat structure (Measurement of the height of each layer) |
| 9 | Percent of proposed harvest blocks subject to pre-harvest assessment (% hectares) |
| 10 | Composition and structure of forest types by age class. |

**Appendix 2 A. Landscape based Indicators: Protected Areas.**

| Q.No. | Landscape Diversity: Protected Areas |
|---|---|
| 1 | Extent of area by forest type in protected area categories as defined by IUCN (International Union for Conservation of Nature) or other classification systems (Including provincial) |
| 2 | Area of forest, by type and age class, wetlands, soil types and geomorphological feature types in protected areas in each ecozone. |
| 3 | Quantity and percentage of old growth forest ecosystems |
| 4 | Ecologically sensitive areas (including riparian areas) identified and managed according to forest management guidelines |
| 5 | Identification and protection of local sites of significance (Hectares and %) |
| 6 | Proportion of each eco-region in protected status (%hectares) |
| 7 | Forest management activities, not set out in the management plan, in rare or fragile ecosystems (alder stands, denuded, and semi-denuded) (frequency and hectares) |
| 8 | Area of forest permanently converted to non-forest use, e.g., urbanization. Also includes agriculture and golf courses. |
| 9 | Percentage of protected area that is road accessible. |
| 10 | Area & percentage of forest types in protected areas |

**Appendix 2 A. Landscape based Indicators: Disturbance and Fragmentation.**

| Q.No. | Landscape Diversity: Disturbance and Fragmentation |
|---|---|
| 1 | Percent and amount of fragmentation in forest types |
| 2 | Frequency distribution and pattern of harvest compared with natural disturbance areas |
| 3 | Levels of fragmentation and connectedness of forest ecosystem components using landscape pattern indices (Eg. Patchiness and juxtaposition, Shannon or other diversity indices) |
| 4 | Patch – size distribution by natural disturbance type by landscape unit by age class. |
| 5 | Size and distribution of contiguous patches (Hectares) |
| 6 | Surface area and size distribution of areas located more than 1, 5and 10 km from roads (Hectares) |
| 7 | Changes in roadedness per volume of trees removed associated with forest practices (length of road per unit area) or Density ($ha/km^2$) |
| 8 | Size and distribution of edge (Hectares) |
| 9 | Abundance and composition of residual stand structure (Hectares) |
| 10 | Abundance of coarse woody debris, snags, etc. (tree per unit area and mass per unit area) |

**Appendix 2 B. Species based Indicators.**

| Q.No. | Species Diversity indicators |
|---|---|
| 1 | The status of forest-associated species at risk. |
| 2 | Number of known forest dependant species classified as extinct, threatened, endangered, rare or vulnerable relative to total number of known- forest dependant species. |
| 3 | Number of known forest dependant species that occupy only a small portion of their former range. |
| 4 | Distribution of selected forest-associated species. |
| 5 | Proportion of pre-harvest assessment crews trained in the recognition/ identification of rare, threatened and endangered species (RTE) and habitat (Proportion of crews trained) |
| 6 | Population levels of selected forest-associated species like RTE mammals (Eg.Caribou) and birds (Eg. Pileated Woodpecker) |
| 7 | Population size and reproductive success of species dependant upon interior forest conditions. |
| 8 | Relative abundance, species richness and diversity of species (Eg. Shannon's index) |
| 9 | Number of invasive, exotic forest associated species. |
| 10 | Percentage of area determined to have high suitability (HSI) for target species in forest management |

**Appendix 2 C. Gene based Indicators.**

| Q.No. | Genetic Diversity Indicators |
|---|---|
| 1 | Number of forest dependent species that occupy a small portion of their former range |
| 2 | Genetic diversity of reforestation seed-lots. |
| 3 | Status of in-situ and ex-situ conservation efforts for native tree species within each ecozone. |
| 4 | Changes in population, genetic diversity and structure and gene flow for selected species |
| 5 | All naturally occurring species are maintained within sub-regions (Species presence using a checklist approach) |
| 6 | Absence of species or visible subspecies from formerly populated areas |
| 7 | Degree of range reduction of sensitive species |
| 8 | Percentage of natural seed collection within seed zone and regeneration from local site seed source |
| 9 | No significant changes in gene frequencies in trees |
| 10 | Utilization of commercial tree genetic material in tree propagation. |