

# **Monitoring and Reporting Ecological Integrity in Canada's National Parks**



**Volume 2: A Park-Level Guide to Establishing EI Monitoring**

**March 2007**

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# **1. INTRODUCTION**

## **1.1 The Guide's Purpose**

This guide is a practical reference for developing, implementing and maintaining a useful, comprehensive and sustainable park ecological integrity (EI) monitoring and reporting program in a national park. Science staff in a park are the target audience for the guide, but the content will also suit the interested non-biologist.

Volume 1 in this series presents guiding principles of the PCA EI Monitoring and Reporting Program. You should understand these fundamentals to get the 'big picture' of the EI monitoring and reporting program, before using this guide.

This guide is more hands-on than Volume 1. It addresses the general question – “How do I take the EI monitoring we are presently conducting and blend that with new initiatives to produce a useful, comprehensive and sustainable monitoring program for my park”?

## **1.2 Scope**

Monitoring ecosystems is a very complicated endeavour, and each of the guide's sections could be a volume of its own. The approach here is to provide enough knowledge to understand and apply the principles described, and to refer the more interested or advanced practitioner to more detailed information: websites, science articles, and books.

Each section:

- introduces the topic,
- explains why we need to know about this area to develop a monitoring program,
- explains fundamentals in each area sufficient for understanding its use and application to monitoring in general, and specifically in relation to other components of monitoring,
- provides references for further work/study in the subject area, and
- shows how this component fits into the overall park monitoring program.

## **1.3 Delivery and Training**

We intend to deliver this first draft of the manual through bioregional training sessions in 2007, in concert with scheduled bioregional meetings. Based on feedback from these sessions, we will produce a final draft product for the end of 2006-2007 fiscal year. This 2007 draft will be subjected to further revision based on feedback from practitioners and a final volume produced for 2008.

## 2. BACKGROUND

This section summarizes the program mission and objectives. See **Monitoring and Reporting EI in Canada's National Parks – Volume 1: Guiding Principles** for details.

### 2.1 We Monitor to Report

Although PCA has been managing parks for their ecological integrity for many years, the new National Parks Act (2001) has created a need for a much clearer focus on measuring and communicating our success at meeting EI objectives. The need to provide clear and scientifically-defensible assessments of the ongoing EI condition of national parks is an over-riding objective of all redesigned park monitoring programs.

**We monitor so we can report to Canadians the state of ecological integrity of their national parks.**

To this end, PCA Executive Board has challenged each park to develop an EI monitoring and reporting program that responds to two fundamental questions:

- 1. What is the State of Park EI, and how is it changing?**
- 2. How are our management activities affecting park EI?**

Many of the past and present monitoring initiatives in parks contribute to question 2, because they were designed to answer specific management questions. Few ongoing monitoring programs provided park-wide answers to a general state of the park. Much of this guide focuses on developing comprehensive EI condition monitoring for a park to answer the question – What is the state of park EI, and how is it changing?

Developing cost-effective EI condition monitoring to report comprehensively on the complex and interacting terrestrial, freshwater, and marine ecosystems that comprise our national parks is a considerable task. The challenge is to measure a relatively small but informative suite of ecological factors across all major park ecosystems at a range of scales that provides a clear, comprehensive, and defensible assessment of park EI.

## **2.2 Working Together**

The general lack of comprehensive EI condition monitoring provides a real opportunity to develop a coordinated approach to meeting this challenge as an Agency. Our general approach is one of common problems and common solutions.

### **Parks working together to find common solutions to common problems**

To this end we are working across parks and bioregions to develop common approaches to:

- EI indicator selection,
- ecosystem conceptual models,
- EI measures and protocols,
- EI indicator assessment methodologies,
- state of the park (SOP) reporting, and
- field technician training.

We are also working with other agencies both within Canada and internationally to find the most cost-effective solutions to establishing long term monitoring in and around protected areas.

## **2.3 Our Challenge**

The challenge is to have park EI monitoring and reporting in place for each park by the end of the 2007-2008 fiscal year. Park monitoring programs will reflect the financial and human resources committed, will be ecologically-comprehensive and scientifically-defensible, will provide clear messages about the state of park EI and how it is changing, and will report on the effectiveness of park management activities.

Your challenge as a park monitoring ecologist is to take the principles in this guide and blend them with your ongoing park monitoring to develop an EI monitoring program for your park that is useful, comprehensive and sustainable.

### **3. PARK EI MONITORING AND REPORTING IN A NUTSHELL**

This section summarizes park EI monitoring and reporting processes.

To provide a conceptual program overview, and to provide an organizational structure for this guide, you can visualize a park EI monitoring and reporting program in 3 interconnected components (see Figure 3-1):

- A. link EI monitoring and reporting to the park management planning process;
- B. develop and implement EI measures, targets and thresholds; and,
- C. analyze, assess and report monitoring results.

#### **3.1 Linking EI monitoring and reporting to the park management planning process**

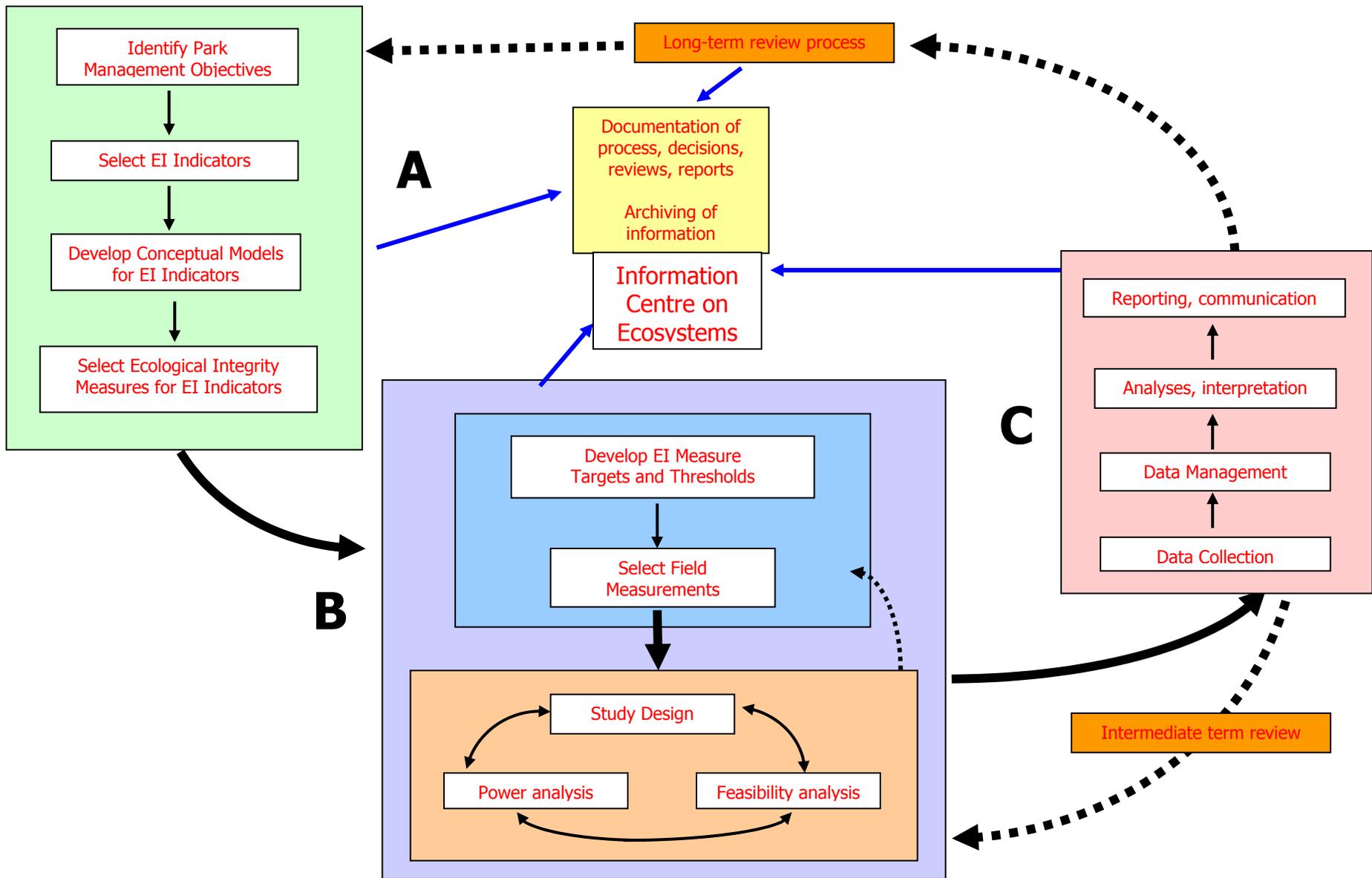
##### **3.1.1 Coordination with Park Management Plan Objectives**

We monitor to report the state of the park and the effectiveness of our management actions according to objectives and targets in the Park Management Plan (PMP). So a critical first step of the park EI monitoring and reporting program is linking our EI measures to the PMP objectives and targets. This process should be iterative and based on an analysis of what is feasible to measure relative to PMP targets and objectives.

All national park PMPs have a general management objective such as “We will protect and present this NP as an outstanding example of the Outstanding Ecozone”. This very important management objective, to maintain overall park EI, links to the first of the two major questions for all EI monitoring programs: “What is the state of park EI?”. Park *EI condition monitoring* should provide our answer to this fundamental management question. The State of the Park report (SOPR) presents monitoring results for each ecosystem/EI indicator to provide a comprehensive ecological assessment for this question. This guide focuses principally on developing a system of indicators, measures, and assessment tools to answer this question through EI condition monitoring.

The PMP also specifies management actions the park will take to maintain or restore park EI, such as:

- introduce a new species,
- take action with a species at risk,
- set targets for visitor use,
- close and decommission an existing road, or
- change recreational fishing regulations.



**Figure 3-1: Schematic outline of the three major components and important linkages in a park EI monitoring and reporting program**

For major projects or policy changes you will need to work with program managers to ensure the results of the project can be expressed in terms of EI, to demonstrate the improvement in EI brought about by the agency investment in the management action. In many cases you will require an environmental assessment (EA) and will conduct follow up observations for some of these projects. The assessments from this kind of monitoring respond to the second fundamental question for the program – “How do our management actions effect park EI?”. In the PCA EI Monitoring and Reporting Program we term this project-specific monitoring *management effectiveness monitoring*. (See section 11 for details.)

### **3.1.2 Identifying and Selecting Park EI Indicators**

Park EI indicators are six to eight summary indices comprised of the individual EI measures that inform them. For most bioregions, EI indicators are defined as the major ecosystems that make up a given park, e.g., forests, tundra, grasslands, freshwater, or wetlands. The EI Indicators:

- provide the structure for the park EI condition monitoring program,
- ensure a comprehensive assessment of park EI,
- provide an ecological frame for selecting and implementing the EI measures, and
- ensure the State of the Park report clearly describes EI condition.

### **3.1.3 Developing Ecosystem Conceptual Models for EI Indicators**

Conceptual ecosystem models:

- reduce ecosystem complexity,
- acknowledge and relate components of ecosystem biodiversity, processes, and stressors,
- identify gaps in monitoring programs, and
- convey what we mean by ‘EI’, for each of the EI measures.

The models also provide an ecological framework for selecting EI measures, and for developing an integrated, ecosystem-based assessment of ecological change in the context of the major park ecosystems/EI Indicators.

### **3.1.4 Selecting EI Measures for EI Indicators**

Selecting ecological factors we will measure to create park EI monitoring and reporting programs is the most important decision for program development. The results of monitoring the measures we select will inform our assessments of park EI for a very long time. The EI measures that we select must be information-rich, feasible to implement, and able to provide a clear and comprehensive assessment of the evolving state of park EI. We select the EI measures through an iterative process. You will consider ongoing monitoring projects, PMP objectives and stakeholder input as well as the conceptual ecosystem models and the national EI monitoring framework. A basic principle of the PCA EI monitoring and reporting program is that EI measures developed

with other parks in the same bioregion will have many advantages over those measures in one park alone. At program establishment, we consider the selected EI measures to be preliminary until we complete the second phase of the program – field implementation and testing.

### **3.2 Implementation, Study Design, and Field Testing of EI Measures**

Field data collection of the EI measures is the central component of the park EI monitoring and reporting program. Some measures will come from ongoing monitoring programs. For others you will initiate new monitoring projects, and for still others you will obtain data from partners or stakeholders.

The over-riding priority for establishing a field program for park EI measures is that the monitoring results answer the question – ‘What is the state of park EI?’ To answer this question we will need to be as ecologically comprehensive as possible. So for example, we must report on all major park ecosystems/EI indicators, although the monitoring effort for each will vary with the conservation importance of the ecosystems assigned by the park. Furthermore, you will need ground-based measures following a study design that permits inference of monitoring results to as wide an area of the park as is feasible. Measures must also reflect an appropriate range of scales to capture park EI. The design of the park field monitoring program and its implementation will be a cooperative effort among the park staff, the bioregional monitoring ecologist, and other science partners.

All EI measures will have an establishment phase where we can assess the feasibility, cost-effectiveness, inter-operability and variability of the preliminary EI measures. Are the measures feasible in terms of sampling logistics, project costs, and the training required to conduct the sampling? Given all measures that are possible, do the data gathered for a particular measure justify the costs required to collect them? Does the sampling for each measure comprise one coherent program that optimizes operational efficiencies? Finally, how variable are the EI measures, and what kind of replication will you require to establish desirable levels of power and significance?

A related issue is the establishment of monitoring targets and thresholds for the EI measures. In some cases, these values will be already established, as for example, water quality targets or well-studied animal populations. For other ongoing EI measures there may be a sufficiently detailed long-term dataset for the park or bioregion that you can use to establish sample replication requirements. For many of the new EI measures we will have to establish temporary targets and thresholds based on information from relevant literature or from expert opinion. These targets and thresholds will improve through the accumulation of data and experience over time.

Finally, you must record all of these methods and project rationale in a useful and repeatable project protocol. The precise replication of project methodologies at assigned sampling intervals is fundamental for reliable ecosystem monitoring, and the development of EI monitoring project protocols is an important program priority.

Appropriate experts can also review protocols to assure credibility and provide feedback on project implementation and sampling.

### **3.3 Analysis, Assessment and Reporting**

It is easy to underestimate the effort required to digitize, tabulate, synthesize, analyze, assess and communicate results of park EI monitoring and reporting. Estimates to conduct this program component range from 15 to 40% of total program costs. We often think of monitoring protocols as mainly describing details of the project's field sampling component. We also expect that well-designed project protocols will provide detailed descriptions of data collection, data management, metadata, and analysis procedures.

Monitoring data, metadata, and protocols for all national parks will be entered and stored in a central data storage system known as the Information Centre on Ecosystems (ICE). The web-based ICE provides an information-dashboard that contains all relevant monitoring information including park indicators and measures with levels and trends, as well as datasets, protocols, summary data, links between EI measures and indicators, and relevant geospatial data.

The State of the Park Report, which each park publishes every five years, is the main vehicle for communicating results of EI monitoring. The EI monitoring results from park and bioregional assessments should also support the national State of the Parks and Heritage Areas report, which is tabled in parliament every two years. A major challenge for the park monitoring and reporting program will be to conduct the sampling, analyze and assess the results, and incorporate them in the SOPR within the five year SOP reporting time frame.

### **3.4 Program Review and Quality Control**

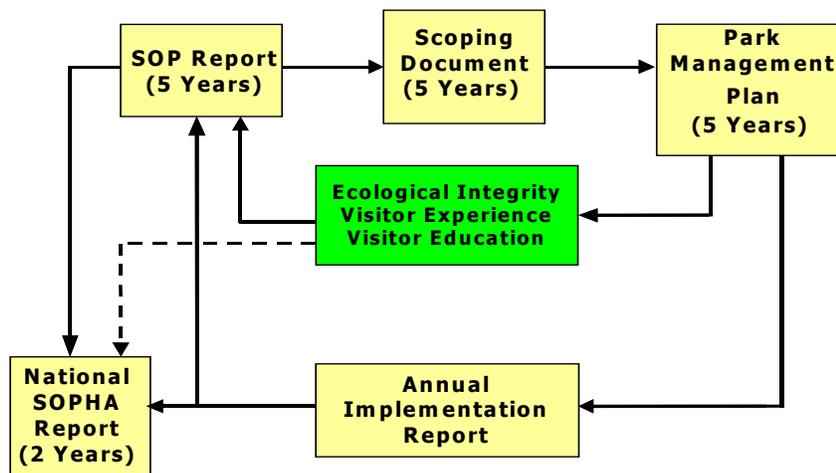
We are establishing park monitoring and reporting programs that will be in place for a long time. Continuity in park programs is important, but inevitably new knowledge, improved methodologies, and evolving social developments and management priorities will necessitate the evolution of some program components. We also want to be confident that our assessments of park EI are based on the best scientific information and theory. Therefore we need to incorporate review and quality control procedures so that the information generated matches the evolution of ecology, social values and management emphasis.

## 4. PARK ECOLOGICAL INTEGRITY INDICATORS

This section describes the role of monitoring in relation to park management and the park management plan. Your park must report every five years on a small group (eight or fewer) of summary indicators. These indicators are common to parks within your bioregion and you generally select them to represent major park ecosystems.

### 4.1 EI Monitoring and the Park Management Plan

A park management plan establishes goals and objectives for park management based on the principle components of the Agency mandate – maintaining and restoring EI, providing memorable visitor experiences, and educating park visitors (Figure 4-1). Park monitoring assesses whether the park has met the goals and objectives set out in the PMP. Thus monitoring is a critical link in the park adaptive management cycle. This guide deals with EI monitoring, but future publications will explain how to measure success in the areas of education and visitor experience.



**Figure 4-1: Park EI monitoring as a critical link in the park adaptive management cycle.**

Because of this relationship between monitoring and the PMP, the goals and objectives set out in the PMP will provide very important input for designing the park EI monitoring and reporting program. EI condition monitoring is in many ways the same from park to park, because it addresses the question – ‘What is the state of the park?’. Thus parks in a bioregion may have similar measures for EI condition monitoring. Direction from each parks’ PMP however, may shift the emphasis of sampling or monitoring. Another key

difference among park EI programs in a bioregion will be the monitoring and reporting of the success of individual management activities set out in the PMP. This management effectiveness monitoring component will be specific to each park.

## 4.2 EI Indicators

EI indicators are our approach to assess and convey results of park EI monitoring. A park's monitoring and reporting program will fall short of a key objective if the SOPR fails to convey timely monitoring results to park managers and a wide audience of Canadians. Therefore, PCA Executive Board emphasizes that the assessment of the park EI needs to be synthesized in a list of six to eight EI 'Indicators' that clearly and comprehensively summarize park condition. In the PCA EI Monitoring and Reporting Program, an EI Indicator is a high level index of individual EI measures for that indicator.

The model we follow for the EI Indicator is the Canadian Forest Fire Danger rating System (CFS 1987) – a widely-known index of fire danger serving a wide audience. The rating system incorporates complex models and detailed science information. Following this approach in the EI monitoring program, results and analyses from the monitoring of EI measures are synthesized in an 'iceberg' model to assess and describe EI condition for each EI Indicator in a park (Figure 4-2).

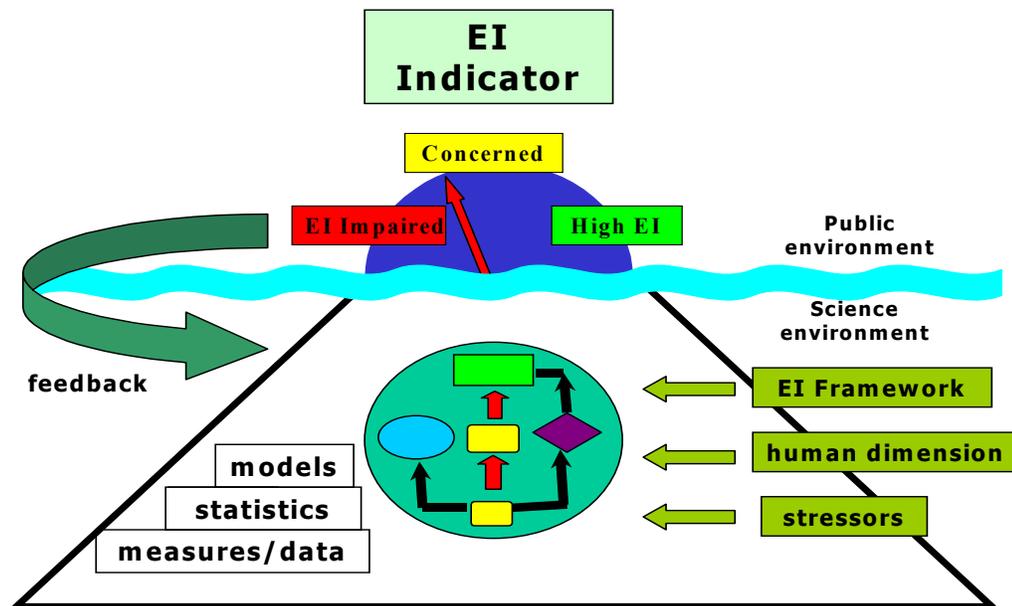


Figure 4-2: Iceberg model for an EI Indicator

Parks in all bioregions report park EI in the SOPR following the same group of EI indicators (Figure 4-3). For all bioregions except the Montane Cordilleran, EI indicators are the major park ecosystems for each bioregion. EI indicators in the Montane Cordilleran are derived from a previous public consultation process, and do not follow the major park ecosystem approach.

<b>EI INDICATORS</b>					
<b>The North</b>	<b>Pacific Coastal</b>	<b>Interior Plains</b>	<b>Great Lakes</b>	<b>Quebec Atlantic</b>	<b>Montane Cordilleran</b>
<b>Forest</b>	<b>Forests and woodlands</b>	<b>Forest</b>	<b>Forest</b>	<b>Forest</b>	<b>Terrestrial Ecosystems</b>
<b>Tundra</b>	<b>Non-forest</b>	<b>Grasslands</b>	<b>Non-forest</b>	<b>'Barrens'</b>	
<b>Wetlands</b>	<b>Lakes and wetlands</b>	<b>Wetlands</b>	<b>Wetlands</b>	<b>Wetlands</b>	<b>Aquatic Ecosystems</b>
<b>Freshwater</b>	<b>Streams and rivers</b>	<b>Lakes</b>	<b>Lakes</b>	<b>Aquatic</b>	<b>Native Biodiversity</b>
<b>Glaciers</b>	<b>Islets/shorelines</b>	<b>Streams</b>	<b>Streams</b>	<b>Coast</b>	<b>Geology and landscapes</b>
<b>Coastal</b>	<b>Inter-tidal</b>		<b>Great Lakes Shore</b>	<b>Marine</b>	<b>Climate and atmosphere</b>
<b>Marine</b>	<b>Sub-tidal</b>				<b>support for EI</b>

**Figure 4-3: EI Indicators for each of 6 bioregions.**

## 5. CONCEPTUAL MODELS

This section tells how to develop the conceptual models that will help you define ecological integrity of park ecosystems. Your park must have a model that documents the key components of each of your major park ecosystems. A generic model for an ecosystem in your bioregion is acceptable. The model must meet the minimum standards listed here. Minimum standards are also recommended for models intended for a general audience. In addition, you must show the degree of fit between the ecosystem, the conceptual model and your monitoring system with the three measures of quality assurance described here.

Conceptual ecological models play a critical role in describing ecosystems' key features. Without conceptual models we lack functional definitions of ecological integrity for our indicator ecosystems. At a minimum, each bioregion should have a conceptual model of each of the ecosystems selected for its indicators. Commonly, you will need to adapt these models to the specific situation in your park. The model must address the aspects of ecological integrity identified in the Canada National Parks Act, namely the persistence of characteristic components of the natural region, including:

- abiotic components,
- abundance of native species,
- composition of biological communities,
- rates of change, and
- rates of supporting processes.

Model design is partly determined by the model's intended purpose. Here, we provide some minimum standards for three purposes:

- documentation of key components,
- presentation to the public, and
- quality assurance.

### 5.1 Documenting key components

Each park must document the relationships among key components in each indicator ecosystem. You can do this with a general bioregional model or a park specific model. The challenge is to capture important aspects of the ecosystem in a single diagram. Sometimes, you may need two diagrams to show the function of the ecosystem at different spatial scales. The minimum standards for this purpose are:

1. Describe the most important pathways for energy and nutrients through the food web. You can do this with general categories such as vegetation, herbivores and filter feeders.
2. Consider the substrate (soil, sediments, etc).
3. Consider large scale (>1 km) components and processes as well as site scale components and processes (<30 m).

4. Include human influences and natural drivers.
5. Append a glossary of technical terms to the diagram.

Arriving at a model involves discussions at either the park or bioregional level (see section 6 – Ecological Integrity Measures). A good approach to conceptual modeling is to begin with the monitoring questions associated with a given indicator. Once you are satisfied that you have listed the key concerns about the ecosystem and have identified biodiversity, ecosystem process and stressor components, you can construct a model according to the above minimum standards. Figure 5.1 gives an example of a diagram documenting known links among components of aquatic ecosystems in the Atlantic-Quebec bioregion.

## 5.2 Public Presentations

Conceptual ecological models, like circuit diagrams or building plans, often appear complex. In fact they do take a bit of time to understand. The minimum standards for public presentation aim at improving the communication value of ecosystem diagrams. Two important considerations are the use of quality graphics and a step-by-step approach to explain the diagram. The first approach is particularly useful for poster presentations. Slide presentations may incorporate both approaches.

Communication also has a cultural context. Thus these standards may not apply for all audiences. You must know your audience to gain their trust and understanding. In particular, incorporating Traditional Ecological Knowledge in the ecological model may change the diagram's content and format.

Presentation quality models are not currently mandatory for monitoring programs but are a long-term objective for parks hoping to convey their mandate clearly. Figure 5.2 is an example of a clear model. Minimum standards are:

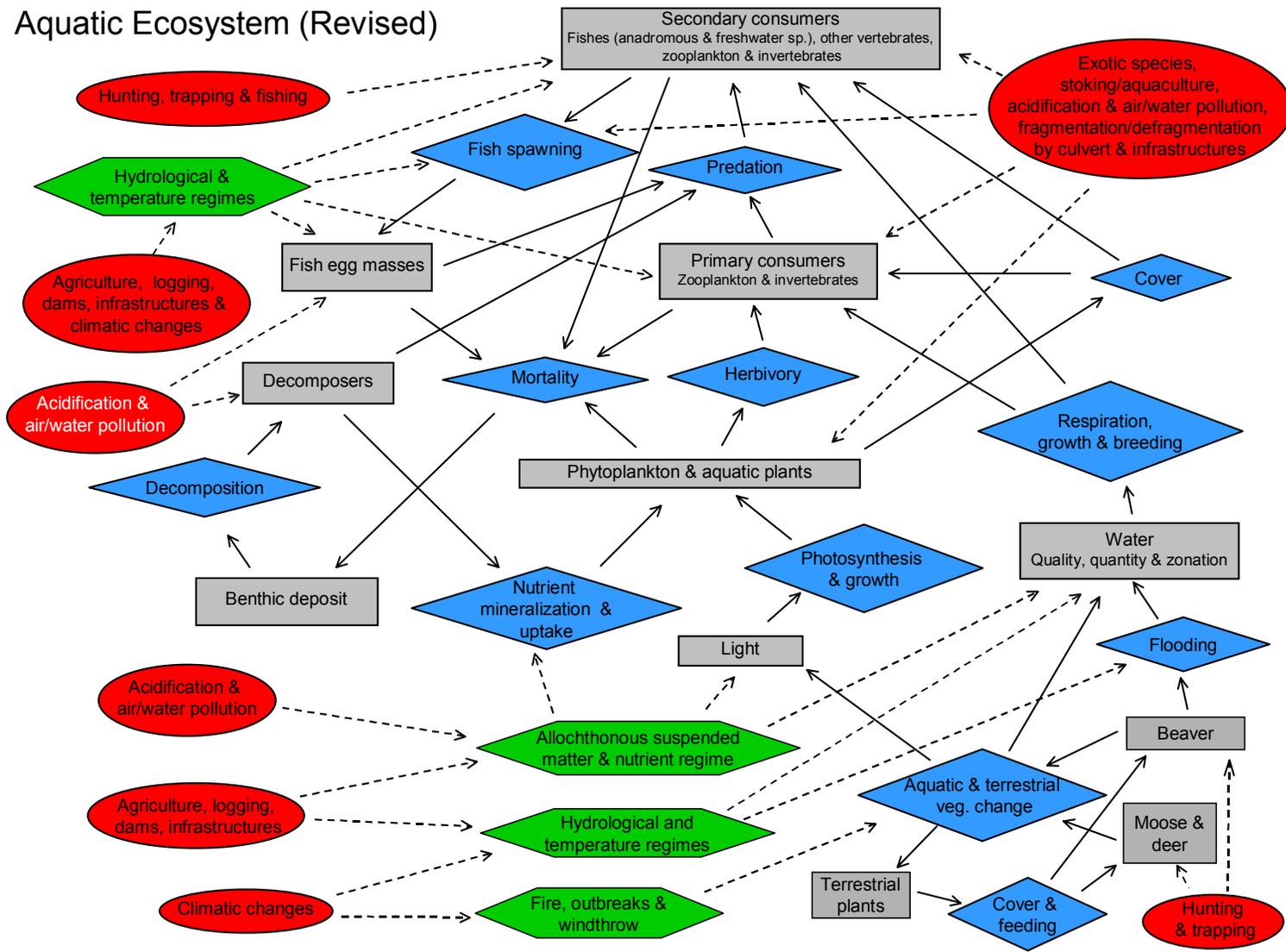
1. Reduce model to fewer than 20 components.
2. Use standard symbols for components and connections and a clear legend to define them (e.g. <http://ian.umces.edu/index.html>).
3. Use photos, video clips and sound recordings where possible.
4. Reduce the average number of connections per component to three or fewer.
5. Introduce five or fewer components per slide.

## 5.3 Quality assurance

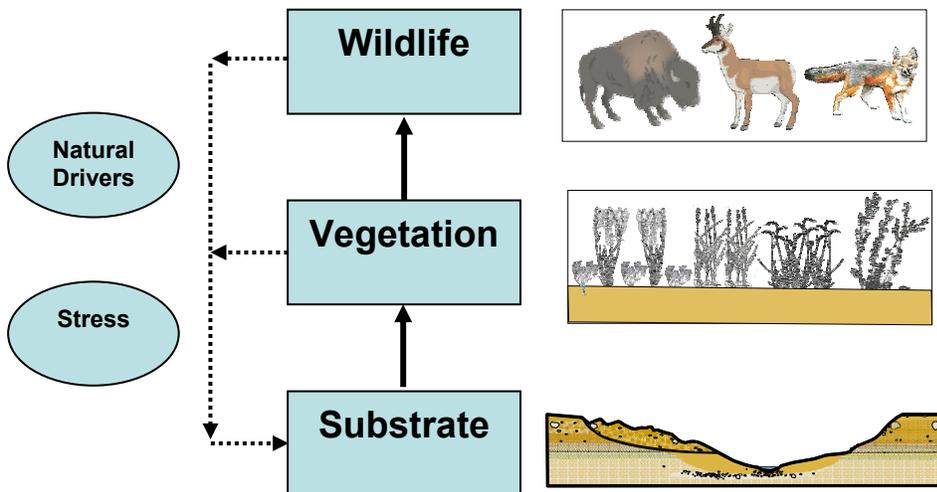
Beyond assuring the minimum standards from the previous two sections, a national network of EI monitoring requires quality assurance on our efforts to i) describe the ecosystem in a conceptual model and ii) design a monitoring program that represents the model's key components. The steps outlined in section 6 ensure that you follow the appropriate process in designing a conceptual model and selecting EI measures. However, these steps do provide feedback on the process's outcome. Here, we provide



# Aquatic Ecosystem (Revised)



**Figure 5.1: A conceptual model to document components of aquatic ecosystems in the national parks of the Atlantic-Quebec bioregion.**



**Figure 5.2: A conceptual model of Grasslands National Park for presentation purposes.**

some standard approaches for assuring the quality of the conceptual models and their representation in practical monitoring programs. As with remote sensing and other complex analyses, some of the approaches described in this section will be handled by specialized staff for several parks. Quality assurance at the program level is particularly important for national reporting to the Office of the Auditor General and for monitoring results included in the State of Protected Heritage Areas report.

### 5.3.1 Correlation and Path Analyses

The most straightforward way to corroborate the relationships shown in a conceptual model is to show the correlations between measures representing the different components of the model. Table 5.1 gives a hypothetical example of the correlations between some measures derived from the conceptual model in Figure 5.1.

In this example, the correlation coefficients describe the relationship between pairs of park-wide measures for a group of ten parks. Notice that a measure's correlation with itself is always 1.0. It is also possible to have a perfect negative correlation with another measure; a coefficient value of  $-1.0$ . This occurs when a measure always decreases to the same extent that the other measure increases. For example, acid rain is the major cause of poor water quality in Eastern Canada. Parks with high levels of acid deposition tend to have lower water quality, and consequently there is a negative correlation between the two measures. When there is no correlation between two measures, the correlation coefficient is 0.0. The question is how many of the relationships predicted by the conceptual model – those underlined in Table 5.1- are corroborated by the correlation table. The general approach to determining the significance of a correlation is to examine the probability that the underlying relationship is the same as one with a coefficient of 0.0. We recommend a 20% (or 1 in 5) chance of having no correlation as a threshold for significance.

**Table 5.1: Hypothetical correlation table for aquatic ecosystem measures**

Measure	Model Component	Acid Deposit	Benthic Decomp.	Water Quality	Water level	Water temp.
Acid Deposition <sup>1</sup>	Acidification	1.0	-0.5	-0.9	0.3	0.4
Benthic Decomposers <sup>2</sup>	Decomposers	<u>-0.5</u>	1.0	<b>0.8</b>	-0.6	0.6
Water quality <sup>3</sup>	Water quality & quantity	<b>-0.9</b>	0.8	1.0	<u>0.4</u>	-0.3
Water level variation <sup>4</sup>	Flooding	0.3	-0.6	0.4	1.0	0.0
Water temperature <sup>5</sup>	Hydrological & temperature regime	0.4	0.6	-0.3	0.0	1.0

1. Acid rain deposition in relation to the critical load that the landscape can absorb
2. Departure from a previously measured community composition of benthic invertebrates
3. Scale of 0-100, describing the number, severity and variety of water quality guidelines exceeded
4. Seasonal standard deviation in water level
5. Departure from long term mean temperature

Since many correlations are examined in a correlation table, you should apply a Bonferroni correction to these tests to reduce the number of spurious correlations that are identified. (See section 13.4.3.) Significant correlations are identified in **boldface** in Table 5.1. In this example, two of the predicted relationships in the conceptual model are corroborated.

Certain considerations apply when using correlation tables (also known as correlation matrices) to corroborate conceptual models:

- *Correlation does not imply causation* - There is a grand philosophical debate behind this condition but the gist of it is "Don't be fooled by early results". Correlations may suggest a functional relationship between two model components that is not borne out in careful experimental study.
- *Lack of correlation does not rule out a functional relationship* – There are many reasons why the correlation between two measures will not demonstrate an underlying relationship. A short list includes: lag times, cyclical effects, spatial variation, imprecise models, threshold effects and non-linear relationships. Nonetheless, strong relationships outlined in well-specified conceptual models should appear in correlations at some spatial or temporal scale.
- *Scale matters* – The most easily available data for calculating correlation tables will be comparisons between parks with similar monitoring measures. These correlations will only support relationships of the most general kind (e.g. coniferous tree cover is related to bird community composition). More subtle, site-specific relationships can only be observed by carefully matching the spatial and temporal scale of measurements. Co-located measurements are important in this regard as are the

frequency and timing of measurement. At least three general scales should be noted when gathering data for correlation tables: between parks, within park (mostly spatial variation between sites) and within site (temporal variation over a large number of observations).

Path analysis is an approach for extending the results of correlation analysis to model components that are not measured in the monitoring program. The analysis requires that you identify the predicted links of the conceptual model. Both one-way (dependence relationships) and two-way arrows (covariance relationships) are acceptable. You can specify starting values and constrain the variability of these non-measured components or else leave them flexible. The analysis uses an iterative process to fit this information to the correlation table and to calculate path coefficients that describe the likely strength of predicted links. You can test these coefficients for significance in the same way as correlation coefficients above. Path analysis will also estimate how well the model fits the data. Path analysis is a form of multiple regression and involves the usual assumptions for linear relationships among many variables. See <http://www2.chass.ncsu.edu/garson/pa765/path.htm> or Kline (1998) for more information.

In summary, we assess the quality of the conceptual model by the percentage of links predicted in the model that can be corroborated with data. In the example above, 50% of the predicted links are supported by data. In some cases, relevant data will already exist. Our intent, however, is to systematically gather and analyze monitoring results to show the relevance of the conceptual model to each individual park. We will begin by examining the correlations among measures for parks with similar monitoring programs and then extend the results to within-park analyses and eventually, through path analysis, to non-measured model components.

### 5.3.2 Topological models

You need not wait for a conceptual model to be supported by monitoring data to determine how well the monitoring system matches the model. You can use information from models like that in Figure 5.1 to rank components' importance and to determine whether your measures of the ecosystem are representative. When you focus on the pattern of connections in a network without knowing the size or strength of those connections, you describe its **topology**. The mathematics of these kinds of connections is called **graph theory**. It is a mainstay of studies in computer science and, though very abstract, (see <http://www.c3.lanl.gov/mega-math/gloss/graph/gr.html>) has some interesting tools to offer ecologists. You can determine the connections of the main components of an ecosystem with some certainty without detailed measurements (e.g. inorganic nutrients contribute directly to plant growth but only indirectly to animal growth). This pattern of connections can answer two questions about monitoring programs:

- Do our EI measures represent the best-connected elements of our conceptual model (i.e. those with the most potential to have ecological effects)?
- Do our EI measures represent the whole conceptual model or are they biased towards a subset of connected components?

To address the first question, you score each of the components in a conceptual model according to three criteria:

- the number of components directly affected by it,
- the number of strong indirect effects that it is a part of, and
- the number of stressors that affect it (both directly and indirectly).

Those components that score well on these criteria are ranked as having a greater potential for ecosystem-wide effects. Table 5.2 gives the scores of the best-connected elements for the aquatic ecosystem conceptual model. See McCanny (2005).

**Table 5.2: Component scores for the aquatic ecosystem conceptual model.**

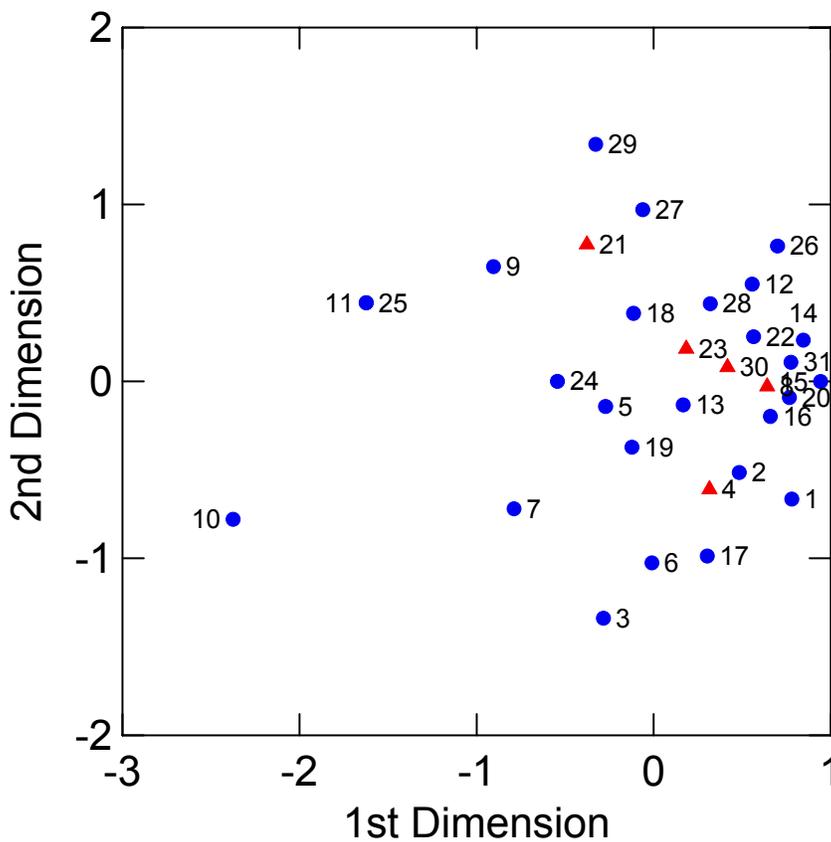
Component	Score	Component	Score
5. Phytoplankton & plants	11.5	17. Decomposition	3.1
1. 2nd Consumers	10.9	26. Hunting, trapping & fishing	3
2. Primary consumers	10.1	27. Agriculture & logging	3
23. Hydrological & temperature regime	9.1	31. Exotic spp. & aquaculture	3
8. Water quality and quantity	7.7	14. Predation	2.9
16. Mortality	7	13. Fish spawning	2.7
30. Acidification & pollution	7	6. Benthic deposit	2.6
4. Decomposers	6.4	18. Nutrient mineralization & uptake	2.6
21. Flooding	6.4	15. Herbivory	2.5
24. Offsite material & nutrient regime	6.1	9. Beaver	2.1
12. Vegetation structure	5.4	10. Moose & deer	2
22. Vegetation change	5.1	25. Fire, insects & windthrow	2
28. Dams, culverts & infrastructure	5	29. Climate change	2
20. Respiration & growth	4.4	7. Light	1.5
3. Fish egg masses	3.7	11. Terrestrial plants	1
19. Photosynthesis & growth	3.4		

To determine how well the selected measures represent the best-connected components of the conceptual model, calculate the sum of component scores represented by your EI measures. Express this sum as a percentage of the maximum score that could be achieved with the same number of measures. In the case of the five components selected for measurement in Table 5.1, the score is 74% of the score that would be achieved with the best-connected components. Many of the most important ecosystem components are difficult or expensive to measure. The intent of evaluating the fit of EI measures to documented conceptual models is to guide decision making for improving the fit, not to reach any pre-set proportion of the maximum achievable fit.

You can address the second question above by grouping components according to their connections. We can use an ordination method to place components with similar connections closer together on a diagram. **Multidimensional scaling** (see <http://www.statsoft.com/textbook/stmulzca.html>) using a **Jaccard distance** to measure the difference between components (see <http://people.revoledu.com/kardi/tutorial/Similarity/Jaccard.html>) allows us to simplify the complex web of links in a two dimensional diagram. Figure 5.2 compares the model components from Figure 5.1 with the measures chosen in the example from Table 5.1.

Components that are close together in Figure 5.2 are linked to similar processes and aspects of the biota. The components selected for measurement in this example represent a good portion of the kinds of connections in the ecosystem. Nonetheless, the average distance between these measured components is 63% of the average distance between all components. This suggests a bias towards certain aspects of the ecosystem, in this case water quality and quantity. A monitoring program with the same average distance between components as the conceptual model that it is based on would capture diverse aspects of the ecosystem.

Though an unbiased representation of the ecosystem is desirable, it is also important to select measures that are potentially correlated with each other, as discussed above.



**Figure 5.2: Comparison of measured (•) and unmeasured (▲) components from the aquatic ecosystems model. Components are ordered according to the similarity of linkages and numbered as in Table 5.2.**

## 6. ECOLOGICAL INTEGRITY MEASURES

This section describes the process for selecting EI measures. You must consult stakeholders and co-management partners in selecting these measures. We advise you to use existing means of consultation and to take advantage of existing documents and courses on the topic. Here, we recommend processes for beginning measure selection in your park and within your bioregion.

### 6.1 Objectives

The EI measure selection process described here is transparent and repeatable. The potential list of measures seems boundless. Biodiversity can include genetic, species, communities, habitats, and landscape measures. Ecosystem processes and functions are complex, and the list of stressors is ever growing. However capacity and finances will restrict you to a few measures. The challenge is to select those that together make a concise and defensible statement about the ecological integrity of the indicator ecosystem. Selecting measures to represent complex ecological systems like national parks is the cornerstone of a monitoring program.

### 6.2 Processes for Selecting Measures

Selecting measures includes: 1) choosing the ecosystem component for measurement (e.g. forest songbirds, invasive plants, climate change; see section 5), and 2) choosing the specific EI measure and its field measurement (s) (e.g. abundance of forest songbirds, % change in element occurrence of noxious weeds, number of frost free days). The processes normally start with a large list of potential measures, and then you filter these to generate a smaller list of prioritized measures. Figure 6.1 describes a process for measure selection.

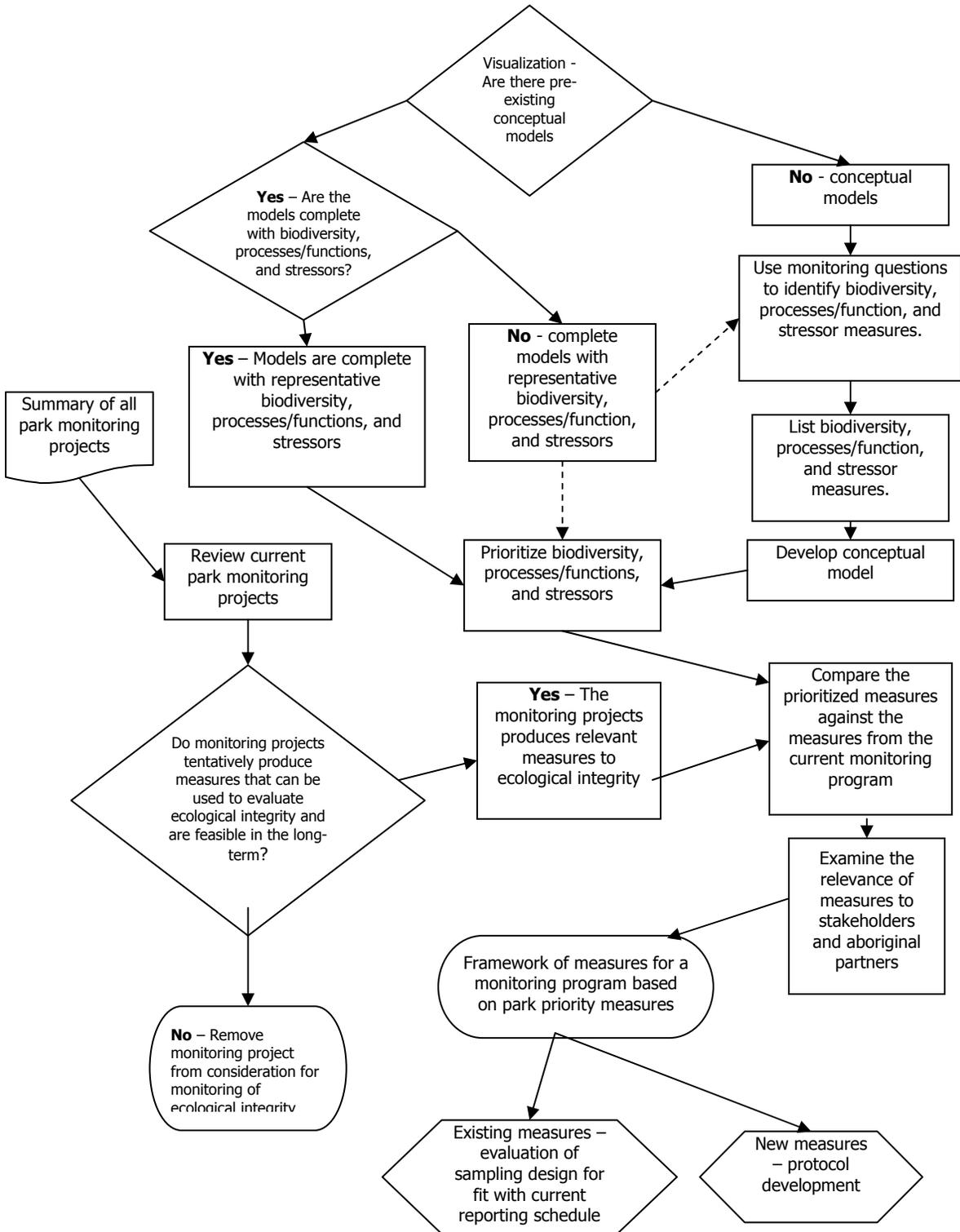
#### 6.2.1 Groups to Consult

Four types of groups must be engaged in designing a monitoring program:

- bioregional groups,
- park based groups,
- science advisory groups, and
- stakeholder groups.

The importance of the latter two types is evident for designing measures that are clear and scientifically credible. Parks Canada consults these groups for various purposes. You should integrate the consultation needs of the monitoring program with those of the

**Figure 6.1: Flowchart of the process for reviewing the existing park monitoring projects and identifying new measures for a completed park monitoring program.**



park generally and use existing committees and processes (e.g. Park Management Planning). There is substantial literature on this topic. See (CCMD 1997). Other resources include:

- the Parks Canada training course, "Skills for Working with Others: Planning and Getting Organized" which addresses reasons for close collaboration with stakeholders and helps park staff and potential partners begin working towards consensus, and
- a guide to consulting aboriginal people, which addresses principles and stages of consultation: [http://intranet/content/aborig-autoch/orig/consultation\\_doc\\_EN.pdf](http://intranet/content/aborig-autoch/orig/consultation_doc_EN.pdf).

Here, we focus on consultation with bioregional and park-based groups.

### 6.2.1.1 Bioregional Groups

Bioregional measures are shared by two or more parks within a bioregion. Bioregional cooperation can vary from minimal, such as periodic consultation on the parks' individual programs to measures analyzed and reported similarly for each park in a bioregion. Generally, the greater the degree of co-operation, the greater the scales of economy and management support for the monitoring project. Furthermore, sampling, analysis, and interpretation of data all benefit from input of personnel in several parks. The monitoring program's success heavily depends on the level of cooperation developed within bioregions.

A good starting point for a bioregional process is compiling measures from each park. The distribution will range from park-specific measures, to those shared by at least two parks, to those shared by all parks. For measures shared by two or more parks, there are various levels of integration (Table 6.2). Starting with a potential list of measures, the parks can work through a prioritizing process similar to that described for a single park. The degree of co-operation depends upon the activities covered in Table 6.2.

You can establish a working group of biologists from each park and a monitoring ecologist to coordinate development and application of bioregional measures.

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**Table 6.2: Levels of co-operation in the integration of bioregional measures, i.e. measures shared by two or more parks.**

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Increasing integration		<ul style="list-style-type: none"> <li>• Consultation on measures</li> <li>• Agreement on measure</li> <li>• Agreement on metrics</li> <li>• Application of similar protocols</li> <li>• Data input into single, shared database</li> <li>• Common analysis to all data</li> <li>• Common integration and reporting format for data</li> </ul>
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### 6.2.1.2 Park Based Groups

All parks have submitted annual monitoring work plans based on current and potential monitoring projects. Appendix 1 gives the criteria for evaluating parks as they complete their monitoring programs. Work plans generally arise from a park-based forum. The forum's main objective is for parks personnel to agree on the park's internal status and needs. Component tasks include:

1. Gather all past and current monitoring and research for evaluation.
2. Fit the existing measures into the current framework of the ecosystem indicators.
3. Assess measures in the context of the Park Management Plan.
4. Develop clear monitoring questions for each existing measure.
5. Review the current measures' suitability for reporting in the State of the Park Report.
6. Identify the measurement gaps for each ecosystem indicator using the ecosystem conceptual model.
7. Prioritize the next steps in measurement review and protocol development and testing, including aboriginal and stakeholder involvement.

The park-based forum should include:

- park personnel involved with monitoring,
- researchers closely associated with the park, and
- the monitoring ecologist.

Consider the entire monitoring program including potential measures of visitor experience and public education. Two recent examples of park-based consultations are found in Lee and Ouimet (2006) and Kehler and McLennan (2006).

## 6.3 Choosing EI Measures and Field Measurements

This section addresses selection of specific EI measures. This often involves many field measurements (e.g. species counts) that you will integrate in an EI measure. Various EI measures can be associated with any component of ecological integrity. For example, the ecological condition of moose may be a priority biodiversity measure. Specific measures may vary from coarse resolution descriptors, such as habitat distribution and area, to medium resolution descriptors, such as relative abundance. to very specific field measures such as physiological condition of individuals.

### 6.3.1 Selection Criteria

You should consider several criteria in selecting EI measures.

- *Appropriateness:* Most measures are selected based on a pre-conceived relationship with another measure usually demonstrated in the conceptual model. For ecosystem processes/function and stressors, there are features that are usually critical or greatly impact ecological systems. For example, dissolved oxygen (mg per l), a measure for water quality.

- *Sensitivity:* The EI measure should be sensitive to important changes in the environment. However, it should not be so sensitive that it prevents interpretation of trends because of noise created by natural variability.
- *Scale of management needs:* Managers will tend to be more interested in measures that match the size of the park and the frequency of the five year reporting cycle. EI measures whose trend detection requires sampling over areas larger than the park and greater park ecosystem are more difficult to interpret for park ecological integrity. EI measures whose changes are very rapid or very slow are also, in general, poor measures. Rapidly changing EI measures may require continuous monitoring and preset management actions at particular thresholds. Alternatively, measures with very slow changes would also be very difficult to assess in time for reporting and management actions.
- *Ease of Sampling:* EI measures should be easy to sample. The protocols should be reliable, well-tested, and have well-accepted methodologies. Ideally, the sample techniques should require limited training of personnel. The period of sampling within a year should be broad and the accessibility to sampling sites should be as efficient as possible, while allowing for a test of the effect of proximity to roads. You should weigh these logistic factors against the information gain from the EI measure.
- *Communication value for managers and public:* Although the selection of EI measures should be based on their technical merits, you must be able to explain their relevance to ecological integrity for a non-technical audience. All other features being equal, select EI measure that fit perceptions of that measure held by managers and the public. This aspect requires public consultation (see sections 6.2.1 and 14.2).
- *Resolution:* EI measures can be classified from coarse- to fine-filter measures (see Table 6.3). Coarse-filter measures generally provide relatively crude estimates of performance. In contrast, fine-filter measures focus on a more specific aspect of the performance such as reproductive success for biodiversity measures or rates for ecosystem processes. Begin considering measures from the coarsest scale then move to finer scales. The basic question is whether the coarsest scale of measurement provides a reasonable assessment of ecological integrity for that indicator while meeting all requirements of a good measure.

**Table 6.3: An example of measures chosen at different levels of resolution for forest songbirds.**

	<u>Metric</u>	<u>Cost</u>	<u>Coverage</u>	<u>Signal Strength</u>
Coarse-filter	% of mature and old forests	Low	High	Low
	Relative abundance of birds on transect counts			
Fine-filter	# fledgling per breeding pair of mature and old growth warblers	High	Low	High

### 6.3.2 Integrating Field Measurements

You may select field measurements to stand alone as EI measures or to combine with other field measurements in a model that better describes a component of the ecosystem. There are four basic models for this:

- *Population models* combine demographic characteristics of a population in an overall index of viability. Population Viability Analysis is a spatially explicit form of this approach.
- *Community models* summarize the relative abundances of species in a plant or animal community to track change in community composition.
- *Stress models* summarize combined effects of a variety of stressors according to their frequency and severity. The Canadian Council of Ministers of the Environment’s Water Quality Index takes this approach.
- *Productivity models* combine energy, nutrient and moisture considerations to predict biomass production for plant communities.

Other approaches are possible for defining complex aspects of ecosystems (e.g. food webs), but ultimately the measure that is generated must be worth the extra effort in taking multiple measurements. In many cases where a protocol calls for multiple measurements, you should choose the best of these (as described in the previous section) for threshold development and keep the other measurements as context. For efficiency, you may phase out these extra measurements if they do not assist the analysis over time.

## 6.4 Ongoing Changes and Periodic Review of Measures

Over time, changes in our understanding of ecosystems and changes in technology will necessitate reviewing our measures and protocols. However, to maintain continuity in monitoring, you should only update the measures in the case of major changes in our knowledge of ecosystems, the introduction of new, major, long-term stressors, and widespread acceptance of new protocols. New measures will usually require more resources or cutting back existing monitoring projects. This issue was partly responsible for the program's focus on measures for condition monitoring. The underlying premise is that "significant" measures for condition monitoring, particularly biodiversity and ecosystem processes and functions, would be less subject to change than other forms of monitoring such as management effectiveness monitoring.

The second issue involves applying a new protocol to a measure. Consider the following six factors before changing protocols:

- cost
- expertise
- precision
- accuracy
- invasiveness
- inherent biases

New protocols will enhance one or more of these factors. Regarding analysis, the two most problematic factors are changes, presumably increases, in accuracy and changes in the inherent biases. The former may shift previously statistically "insignificant" relationships to significance or change the values of measures themselves, if variation was part of the analysis, e.g. coefficients of variation. This is a problem. In this case, you might interpret changes in the results caused by changing protocols as a change in the trend for the measure. Leastwise, the trends could be confounded between those created by the new protocol and those resulting from real changes in the measure. One possible solution for changes in accuracy and bias caused by protocol changes is to apply a correction factor. If you understand the magnitude and direction of changes, you may be able to apply a correction factor to the older data. This will require a study to calibrate the previous data to blend them with the new data. Otherwise, you may need to treat the two datasets separately. You should also calculate the indicator with and without the new measure to examine the sensitivity of reporting to this new protocol.

While you may incorporate new measures and protocols anytime, you should thoroughly review the park monitoring program every three reporting cycles, i.e. ten to fifteen years. Sufficient data will have accumulated over this period to evaluate measures and indicators from the current program. Similarly, the long time period provides an opportunity to evaluate new potential measures and gauge the acceptance of new protocols by stakeholders, aboriginal partners and the scientific community.

## 7. COMBINING EI MEASURES IN INDICATORS

This section describes a methodology for integrating measures in EI indicators. This approach is mandatory for State of Park and State of Protected Heritage Area reporting.

### 7.1 Objectives

Various strategies exist for developing indicators - from strictly qualitative to quantitative methods. To develop the method presented here we evaluated a number of different methodologies. Because this document is a guide, it does not present the analyses of other methods. As with all monitoring systems, the replicability of the assessment of indicators and measures through time is a critical feature. Changes in the status of an indicator should be due to the changes in the constituent measures rather than changes in the methodology to determine its status. In this regard, the guide presents standardized methodologies for the derivation of the status and trends at the indicator-level.

### 7.2 Developing Composite Scores and Assessing Ecological Integrity Status for Indicator Ecosystems

Integrating EI measures in a composite score to assess and report an ecosystem's status is an increasingly common practice in reporting ecological condition. Indicators calculated this way are useful for managers in conveying the status and trends around complex issues to policy makers and the public. In this big picture context, environmental composite indicators are often easier to grasp than the individual constituent measures. Indicators explicitly do what a reader would do in attempting to synthesize the status and trends of a number of different measures. Indicators take the message further by providing an assessment, i.e., the author's interpretation of changes in the measures. Furthermore, a mathematical formulation is explicit and repeatable. This is an important feature, given monitoring programs' inherently long timeframe.

You should apply and interpret indicators judiciously and transparently. Table 7.1 summarizes potential benefits and pitfalls of indicators. A general pitfall is that indicators may lead to misleading policy messages, if the method of constructing indicators favours a particular policy directive or if the indicator is difficult to interpret. In particular, the aggregation of measures can weaken or mask signals from important individual measures. Also, the apparently simplistic nature of indicators may lead local managers or higher level policy makers to attempt to manage for the indicator itself, rather than more closely examining the root causes within the constituent measures. Indicators are most useful as a starting point for assessing and reporting status and trends, and for engaging higher level policy makers and the public in park ecological integrity.

**Table 7.1: Potential benefits and pitfalls of using indicators. Derived from Saisana and Tarantola (2002) and Nardo et al. (2005) with additions.**

<b>Potential Benefits</b>	<b>Potential Pitfalls</b>
<ul style="list-style-type: none"> <li>• Summarizes an array of complex and/or multidimensional measures into a few values.</li> <li>• Easier to determine trends than with multiple measures.</li> <li>• Balances conflicting status and trends among different measures.</li> <li>• Facilitates ranking different indicator ecosystems and measures.</li> <li>• Provides a transparent and repeatable method for synthesis.</li> <li>• Extends the interpretation by authors of multiple measures by providing a quantitative synthesis.</li> <li>• Provides a short summary of measures to fit size limits of reporting formats.</li> <li>• Facilitates communication with the public and promotes accountability.</li> </ul>	<ul style="list-style-type: none"> <li>• Invites simplistic conclusions about the ecosystem indicator.</li> <li>• May be misused, e.g. supporting a pre-determined position, if the construction of the indicator is not transparent and/or lacks sound conceptual and statistical principles.</li> <li>• Selection of measure weightings could be used to support a pre-determined position on the status of an indicator ecosystem or measure.</li> <li>• Construction methodology may disguise patterns in some constituent measures that lead to difficulties in identifying proper management action.</li> <li>• May lead to inappropriate management actions if the measures that are difficult to measure are ignored.</li> </ul>

The over-riding value of the indicator is that it provides an assessment of changes in park EI that can be conveyed to a wide audience - the park monitoring program's ultimate objective.

The methodology for integrating measures in an indicator varies from qualitative, to semi-quantitative, to fully quantitative formulations. Currently, there is no standardized methodology among parks for developing an indicator. This guide recommends a standardized method for determining the status and trend for each indicator. All parks within the agency should develop indicators and ecosystem assessments using the same formulation. In other words, a red signal of impaired ecological integrity for an indicator in British Columbia should mean the same thing as one in Newfoundland or the Arctic.

Parks, field units, and bioregions have a great deal of flexibility in:

- selecting measures,
- selecting field measurements,
- selecting targets and thresholds, and
- designing and interpreting the analysis.

Furthermore, parks and field units set the management priorities identified through the monitoring program. In summary, the PCA EI monitoring program is a mix of flexible park-driven activities that reflect park uniqueness, with an agency-wide standard for roll-up and reporting to ensure consistency of reporting across the system.

### 7.3 Indicator Status

This section provides a method to integrate the status of individual ecological integrity measures in a comprehensive assessment index for the ecosystem indicator. The scheme for representing ecological integrity indicators has the following colours (Parks Canada Agency 2005):

- green – good ecological integrity
- yellow – fair ecological integrity or at least some uncertainty about it
- red – poor ecological integrity
- no colour – insufficient information to evaluate ecological integrity

The no colour signal is a special case where there is insufficient information to make a statement about an indicator's ecological integrity. There are various reasons to leave an indicator blank, including:

- completeness of the selection process for the suite of measures within an indicator,
- development and implementation of suitable protocols for each measure,
- availability of data for measures, and
- interpretability of the current data for patterns of ecological integrity including the lack of thresholds for measures.

Individual parks decide if they can determine the status of their indicator. In general, you should only assign an undetermined status to an indicator one time. It is a sign that the park will make this indicator a priority for the following State of Park report. If you are unable to make substantial process towards an indicator in the following five years, the indicator should be dropped. If an indicator is missing data for one or two measures, a park may still decide there is sufficient basis to evaluate an indicator. If you add measures to an indicator over time, take care to evaluate the effect of these measures on the indicator's trend.

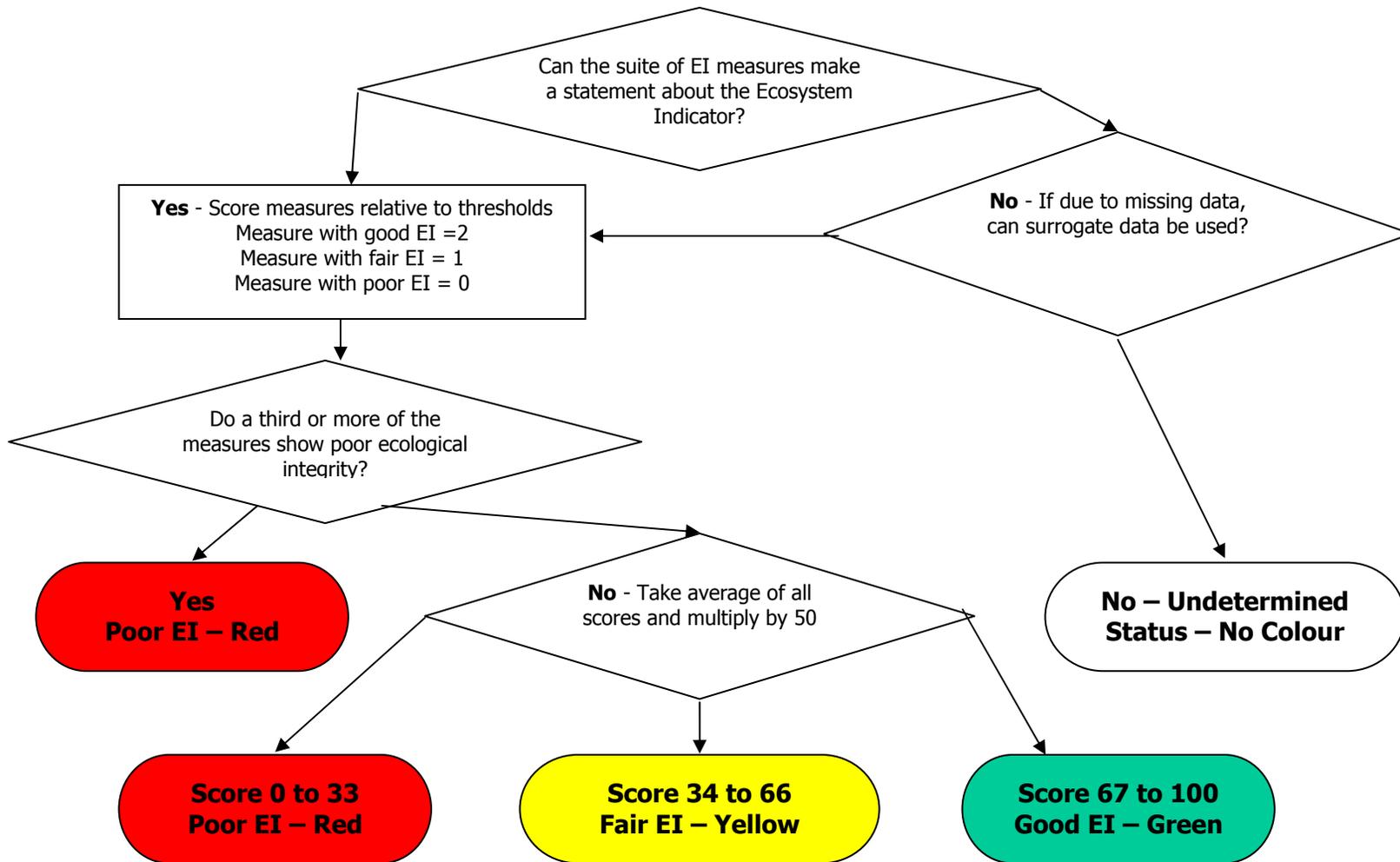
The general strategy is to convert ecological integrity measures into simple scores based on their thresholds. You then amalgamate scores in an overall score and colour signal that you convey to the public. To do this, you must standardize the results of different measures. There are various formulations for standardizing measures (reviewed in Ebert et al. 2004, Jacobs et al. 2004, and Nardo et al. 2005). These range from simple ranking schemes to more complex re-scoring formulations. In all cases, information is lost from the original data as values are expanded or contracted to fit a common, standardized range. Often the most affected data are extreme values, particularly from datasets compressed into a bounded scale such as 0 to 100. Development and application of comprehensive indices are as much art as science (Nardo et al. 2005). The main trade-off is the ability to capture the complexity of environmental state in a simple and transparent formulation, with the ability to track changes in the status back to the constituent measures. After reviewing a number of different formulations, we recommend a relatively simple, equally weighted formulation as a standard for all parks. Figure 7.1 is a flowchart of decisions for deriving an indicator.

The procedure is:

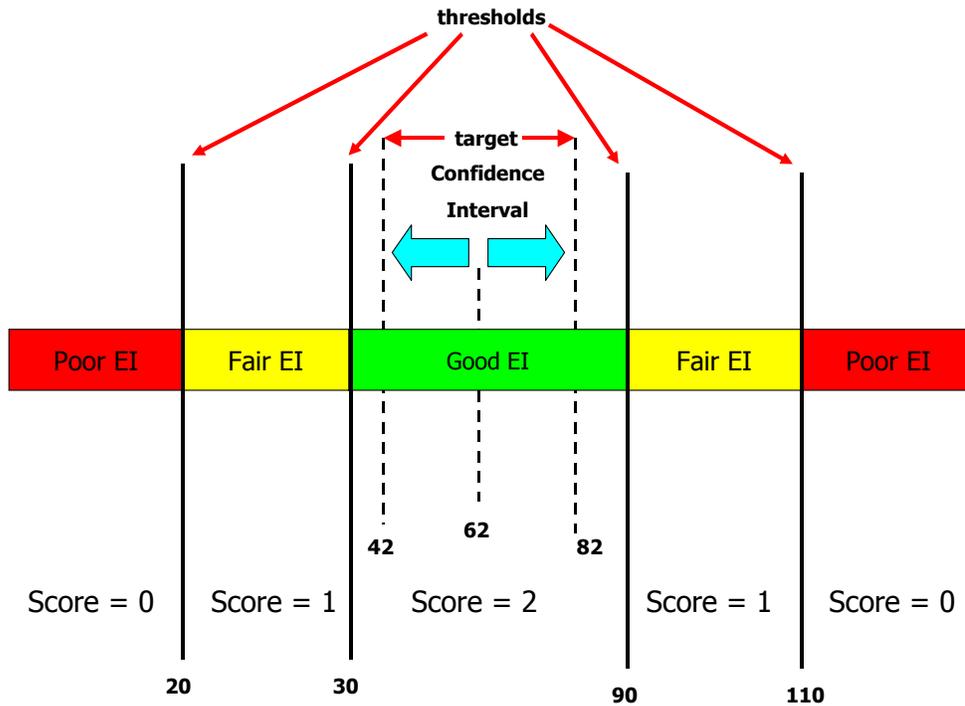
1. Determine whether the suite of ecological integrity measures and their associated data and analysis are sufficient to determine the indicator's ecological integrity. If not, the indicator receives no colour.
2. If data are sufficient to evaluate the indicator's ecological integrity, give ecological integrity measures a status based on their relationship to thresholds. Measures within thresholds (or above the upper threshold – see Figure 8.1) score two, while the measures in the intermediate areas score one, and those in the area with poor ecological integrity score zero (Figure 7.2).
3. If at least a third of the measures score zero, i.e. poor ecological integrity, then classify the indicator poor.
4. If less than a third of the measures score zero, then average the scores from each measure and re-scale them from 0 – 100.

$$\text{Indicator Score} = \frac{\sum \text{EI Measure scores}}{N} \times 50$$

Where N is the number of measures for that indicator. The indicator scores are translated into the colour system for ecological integrity (Table 7.2). In practice, this is only for distinguishing between indicators in fair or good condition. All indicators scoring 33 or less will have at least one third of their measures showing poor ecological integrity.



**Figure 7.1: Flowchart with decision rules for designating the ecological integrity status of the indicator ecosystem**



**Figure 7.2: The relationship between thresholds and scores for ecological integrity measures.**

**Table 7.2: The ranges of indicator scores for each ecological integrity colors.**

Scores (Samson <sup>1</sup> )	Colour
0 - 33	Red
34 - 66	Yellow
67 - 100	Green

Two aspects of this approach require explanation: equal weighting of measures and the use of the 1/3 measures rule. Equal weighting is the most transparent and readily justifiable approach for calculating indicator values. Without evidence of the relative

<sup>1</sup> Named after the inventor of the first formulation of the Parks Canada EI scale. Future generations of Parks Canada employees will have conversations such as, "Bones, I need more Samsons to raise the ecological integrity of this wetland."

"Damn it Jim, I'm an aquatic invertebrate specialist not a hydrologist!"

importance of all measures, it would be difficult to maintain a system of weighting that allowed some measures to have a greater impact on the indicator value than others. In the future we hope to derive a transparent and verifiable method for weighting measures according to their importance to the entire ecosystem, perhaps using the approaches outlined in section 5.3. Meanwhile, equal weighting ensures an unbiased, if somewhat coarse, summary of the state of the indicator.

One consequence of equal weighting is that a balance of good and poor measures receives the same indicator score as a set of measures in fair condition. Where a large proportion of measures are in poor condition you should report it. It does not matter if there is potential for good measures to offset the influence of the poor measures. This approach reflects the precautionary principle. Here, we designate all indicators with at least one third of their measures in poor condition as having poor ecological integrity. If these measures have, in fact, a greater influence on the ecosystem than the majority of measures that are in fair or good condition, the net effect on the ecosystem would be a loss of overall ecological integrity. This "one third rule" is necessary for warning stakeholders and managers of potentially serious problems for ecological integrity until we have a better sense of how measures work together in an ecosystem context.

## **7.4 Trends**

### **7.4.1 Background**

Trends mark the change in the ecological integrity status of an indicator since the last reporting cycle. Options for representing trends are:

- increasing,
- no change,
- declining, and
- insufficient information.

Unlike assessing status, which is based on the relationship between the current status and thresholds, assessing indicator trend is based on the change in the current indicator score/status from the previous score/status. It is not derived from a direct summary of trends from the constituent measures for an indicator. Combining trends from different measures within an indicator involves various complexities including:

- *Points of origin:* Measures that start from an impaired state are likely more important to managers than measures that start above or at the threshold. A comprehensive trend for an indicator must reflect the relative importance of these measures.
- *Crossing thresholds:* Measures that cross thresholds have a significant impact on the reporting of ecological integrity. Hence, you should weight these trends more than others. There are six possible transitions between threshold boundaries and another three where no change occurred (see Table 7.3). You will need a scoring system to highlight these transitions.

**Table 7.3: Categorization of trends based on a change of status of indicator.**

<b>Indicator Trend</b>	<b>Previous State</b>	<b>Current State</b>
Increasing	Red	Yellow
Increasing	Red	Green
Increasing	Yellow	Green
Decreasing	Green	Yellow
Decreasing	Green	Red
Decreasing	Yellow	Red

- *Magnitude of change:* Although a number of measures may exhibit significant trends, the magnitude of change may vary. You should recognize that the ecological significance for some measures might be very large despite relatively small change over time. A scoring system should consider both the size and significance of changes when combining different measures.
- *Differences in sampling intervals and time scales:* Measures differ in their sampling intervals. This is partly set by the underlying rate of change for each measure. Over the five-year reporting cycle of the State of the Park Report, different measures would accumulate different numbers of data points. For example, the sampling interval for water quality is quite short (~weeks) while the sampling interval for terrestrial vegetation is much longer (~years). Both are valuable measures of ecological integrity but it is easier to detect a trend in water quality because of the greater number of data points within a reporting cycle.
- *Discordance among measures:* It is difficult to account for discordance amongst measures within an indicator. For example, an indicator with five measures increasing, two measures with no change, and five decreasing measures could score as “no change” based on “averaging” of trends. Similarly, an indicator with one measure increasing, ten measures with no change, and one measure decreasing would produce the same score. This despite the underlying differences in trends for measures.

All these issues suggest that reporting an overall trend for an indicator based on rolling-up the trends of constituent measures is difficult. While formulations for a composite score on trends are mathematically possible, they are neither simple nor transparent. Therefore trends for indicators will be based primarily on the change of previous indicator score to the current indicator score. To provide added sensitivity, the proportion of declining measures and the balance of declining and increasing measures will also be considered. Section 7.4.3 discusses the assessment of trends in measures.

## 7.4.2 Determining Indicator Trend

Figure 7.3 outlines the decision rules for determining indicator trends. The flowchart's features include:

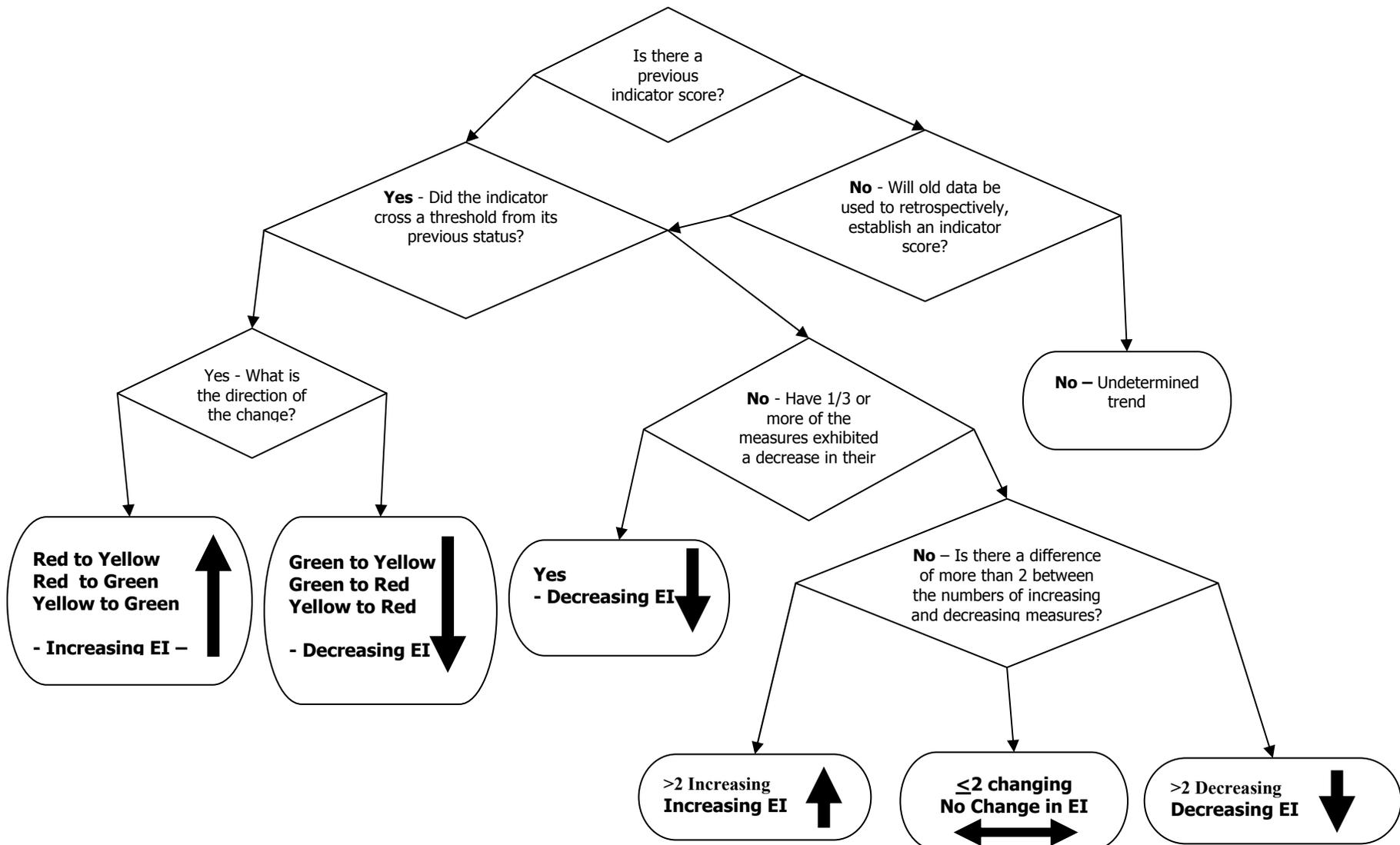
- There are three to five steps in classifying an indicator trend.
- It is a dichotomous key generally requiring yes or no answers.
- Decisions involve a hierarchical process reflecting ecological integrity monitoring program priorities and framework.
- Like the evaluation of status, the outcomes reflect a cautionary approach to classification in responding to downward trends more strongly, i.e. loss of ecological integrity.
- The decision tree provides a link in the chain of evidence from measures to assessment and reporting of an indicator trend.

The steps are:

1. If this is the first State of the Park Report using a quantitative indicator then you need not report the trend of your indicators. However, you can use archived data to generate retrospective indicator scores.
2. If there is a status from the previous indicator evaluation, determine whether the current status of the indicator has crossed a threshold. See Table 7.3. Above all other criteria, this will establish the trend for the indicator.
3. If the status of the indicator has not changed, then examine the measures. If one third or more of the measures are declining then mark the indicator as declining. This logic is similar to that for designating poor ecological integrity status. Since one of Parks Canada's primary goals is maintaining ecological integrity and parks' base condition should be a high level of ecological integrity, the scoring system is more sensitive to declines in the ecological integrity of measures than no change or increasing status.
4. The final level of evaluation is to subtract the number of declining measures from the number of increasing measures. If this net number of changing measures is greater than 2 or less than -2 then the indicator should be accorded a trend reflecting the more abundant group of changing measures. Otherwise, record the indicator as having no change.

Table 7.4 proposes a format for State of Park reporting. Note the use of text and color to indicate status. This helps convey the information in black and white copies of the document. The table also breaks down increases and decreases in the EI measures for each indicator.

**Figure 7.3: A decision tree of the steps in determining the trend for an indicator.**



**Table 7.4: A sample graphic for presenting status and trends on State of the Park Reports after the first or where previous indicator status/scores exist. The data presented are hypothetical. Fill colours represent the status of the indicator. An additional column on trend follows the status column. You can still report the pattern of trends for constituent measures as an optional feature.**

Indicators	Status	Trend	Trend (No. of Measures)			
			Increasing ↑	No change ↔	Decreasing ↓	Insufficient data
Forests/Woodlands	Good	↑	6	4	1	0
Non-forested	Good	↑	5	4	2	1
Lakes/Wetlands*	Fair	↓	2	4	1	0
Rivers/Streams	Fair	↔	2	6	0	0
Shorelines/Islets	Good	↑	4	1	1	0
Intertidal*	Fair	↑	2	4	3	1
Subtidal	Poor	↔	4	1	5	1

\* These indicators have had a change in status from the previous report.

### 7.4.3 Determining Measure Trend

Methods for evaluating a trend for a measure depend on characteristics of the EI measures. For measures based on change detection (Scenarios 1 & 4 in section 8) the measure is the trend. Determining trend for these measures is equivalent to examining the acceleration of change. You can use the same statistical techniques applied in sections 8 and 11 to the raw observations to identify trends in differences, moving window averages or slopes in the data.

Where you lack long time series of data, you must use a simpler approach. You could simply record all positive differences over the previous measure score as an increase. This, unfortunately, would pick up many minor fluctuations. It is better to proceed by defining a criterion that separates change from no change. It seems difficult to do this with so many different kinds of measures. However, each measure has an upper and lower threshold. The difference between these two represents a critical range, the difference between poor and good ecological integrity (see Figure 8.1).

Critical Range = Upper threshold-Lower threshold

We recommend a value of 1/3 of the critical range as the criterion for change in an EI measure (see Table 7.5). This value provides adequate resolution to warn of impending change in a measure's status.

**Table 7.5: Categorization of trends based on a comparison of previous and current EI measure scores. A criterion of 1/3 of the difference between upper and lower thresholds indicates significant change.**

<b>EI Measure Trend</b>	<b>Criteria</b>
Increasing	Current score > Previous score + 1/3*Critical range
No Change	Previous score + 1/3*Critical range ≥ Current score ≥ Previous score - 1/3 *Critical range
Decreasing	Current score < Previous score - 1/3 *Critical range

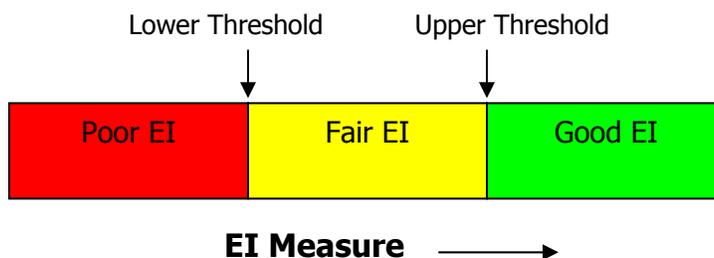
## 8. ESTABLISHING THRESHOLDS

This section describes various approaches for defining threshold values associated with measures of ecological integrity. You must identify interim thresholds for measures that you include in ecological integrity reporting.

Choosing threshold values is a key aspect for assessing and communicating monitoring results. Thresholds represent decision points in interpreting a continuous measure of ecological integrity. Groffman et al. (2006) reviewed the rising demand for ecological thresholds in environmental management. They concluded it is difficult or impossible to set precise thresholds based on scientific evidence. You should use such natural thresholds where available but not allow the search for these values to delay communication of monitoring results or effective management of ecosystems. This section establishes guidelines for selecting interim thresholds based on available information. Despite this focus on interim thresholds, the guidelines emphasize that you use the most biologically credible information on ecosystem function.

Figure 8.1 describes an EI measure that increases with ecological integrity. It is a simplified version of the left half of Figure 7.2 on page 33. Two decision points are required for all similar ranges of EI measures. One is the point where good ecological integrity can no longer be supported (upper threshold), and the second is the point where poor ecological integrity can no longer be denied (lower threshold). The range between these two values represents the critical zone referred to in section 7. It is a zone of moderate or uncertain ecological integrity. Identifying this zone is part of our commitment to the precautionary approach in ecosystem management.

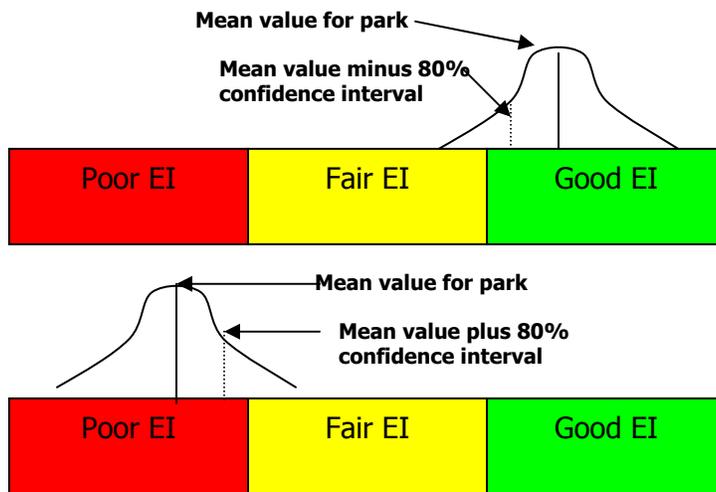
**Figure 8.1: Thresholds of Ecological Integrity**



Since there is often error in estimating a value for an EI measure, you should be careful in deciding when a threshold has been crossed. We recommend that you subtract a confidence interval when comparing your value to the upper threshold and add a confidence interval when comparing your value to the lower threshold (Figure 8.2). This will reduce the chance of misclassifying the ecological integrity of the measure. The rule of thumb is to make sure that

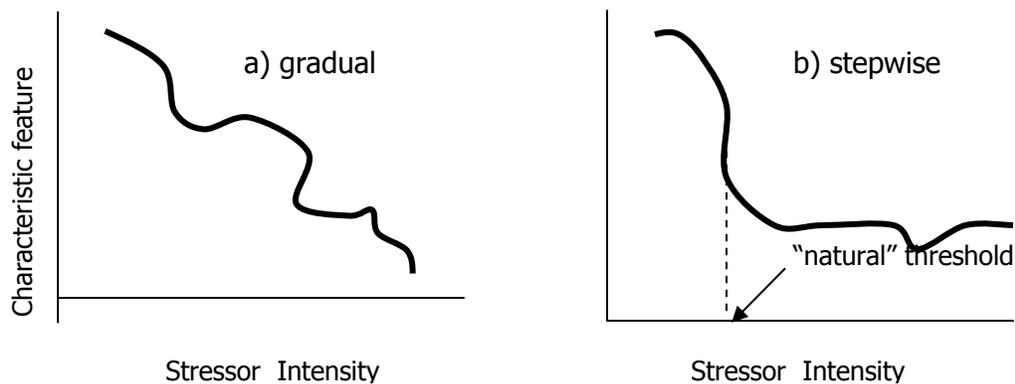
your estimated value is well below the lower threshold or well above the upper threshold before describing the measure as poor or good.

**Figure 8.2: Crossing Thresholds**



Ecological integrity declines with degradation or change of characteristic features (e.g. species or process rates) and remains stable when these features are persistent. Stressors are a type of ecological driver external to the natural region and having a negative correlation with the persistence of characteristic features (Figure 8.3).

**Figure 8.3: Types of relationships between stressors and characteristic features**



Stressors may arise:

- within the park (from our own infrastructure, operations and visitor effects),
- from directly outside the park in the greater park ecosystem (land use, pollution, human effects), or
- from a considerable distance, from regional to global (climate change, acid deposition, other pollutants).

Stressors help you identify the direction of a measure's relationship to ecological integrity. High levels of stress often correspond with low ecological integrity. Thus you can use negative or inverse values of stressor intensity as ecological integrity measures. Of course, many measures of human activity show no correlation with ecosystem characteristics and should not be identified as stressors.

You can use the slope of the relationship with a stressor to identify EI thresholds. Where there is a stepwise decline in ecological integrity for a small increase in a stressor (Figure 8.2 b), you can use the value of the stressor or the range of values of the ecosystem characteristic as natural thresholds (Walker and Meyers 2004). More often, there is a gradual or complex relationship between a stressor and an ecosystem characteristic (Figure 8.2a). It is more difficult to identify a natural threshold in the latter case. Still more frequently, you would lack any information about the slope of the relationship between ecosystem characteristics and stressors, and this information may only come from data collected over time through monitoring.

Apart from persuasive evidence of a stepwise decline in an EI measure at specific stress levels, there appear to be only four approaches for setting thresholds:

- *Persistence models*: Based on numerical modeling, this approach predicts a stepwise or irreversible change in the measure at a particular value. This approach assumes that the measure has values that are logically associated with a lower probability of persistence. This is the approach for assigning the population characteristics of species at risk. Knowing some life cycle and genetic characteristics, you can set a threshold at a specific population size. Until you observe the model predictions in a range of ecosystems, consider them interim thresholds.
- *Correlation with other measures*: Whenever two measures are correlated and one of them already has thresholds, you can use the corresponding values in the other measure as thresholds. This approach, though handy, limits the independent value of the measures when calculating an indicator.
- *Segmentation*: When you know the distribution of the measure at the site, you can simply divide it into three equal segments representing poor, fair and high ecological integrity. If you suspect an optimal value, as in Figure 7.2, divide the distribution into five sections including the optimal segment and equal bands of moderate and low ecological integrity on either side. This approach would yield a series of interim thresholds as your knowledge of the distribution increased.
- *Change detection*: This approach is a step back from treating EI measures as state variables. It uses the rate of change of field measurements over two or more observations

as the EI measure. This is legitimate because the legal definition of ecological integrity includes “rates of change” as an aspect characteristic of the natural region. The approach’s strength is that it can be applied to any data set. Thresholds set this way are interim, because they are based on statistical analyses rather than biological knowledge.

Though each of these threshold approaches produces values with reference to a single EI measure, its biological significance will depend on its contribution to large and irreversible changes in the characteristic aspects of the whole ecosystem. There are some initial approaches for developing whole ecosystem measures (Harte 1979; Brock and Carpenter 2006) you could use to calibrate your thresholds or else replace your system of using the average status of EI measures. These approaches will need extensive data over many years.

Figure 8.4 outlines a process for establishing thresholds. Begin by considering the ecology of the measure. Are thresholds already available for similar measures in the literature? If so, you should adapt these thresholds to ecological integrity in your park. One approach is to adapt the thresholds in view of differences between your park and the study site in the literature. Sometimes only one threshold value is given in the literature. Consider whether it is possible to convert this to upper and lower thresholds by using a confidence interval on either side of the published value to represent uncertainty about its effect on the rest of the ecosystem. It is important to avoid getting stuck at this stage of the process. Thresholds are quite specific and they are still uncommon in the literature.

The next step is to consider direct evidence of the persistence of characteristic features. Specifically, you are looking for a minimum population size, a rate of population decline or a critical surface area for an ecosystem type. These are all aspects of the ecosystem that could lead to large or irreversible change. You are not expected to conduct a population viability analysis for every species. The important thing is that you consider the values of these measures where loss of the characteristic feature becomes plausible.

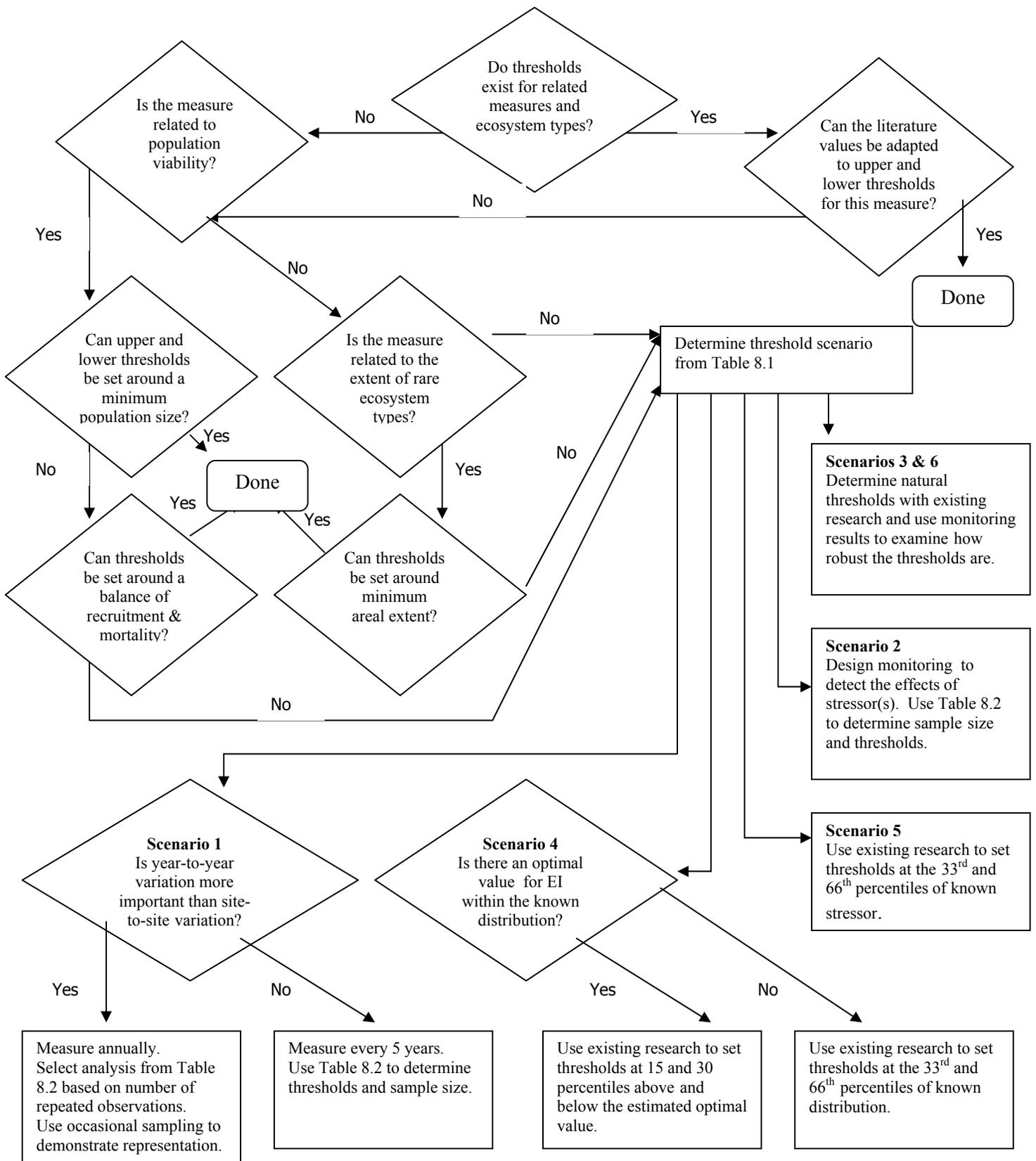
If neither of these approaches works, use table 8.1 to identify the threshold scenario that will be most informative for you.

Six scenarios are dealt with based on what is known about the distribution of the measure and its relationship with relevant stressors. Several options are available under each scenario. Generally, the scenarios on the bottom and to the right of Table 8.1 are preferable to those with less specific information on the top and to the left.

### **8.1 Scenario 1 – Unknown distribution, unknown stress relationships**

This scenario will be the most common as you begin ecological monitoring. The field measurements under this scenario are generally selected because they are characteristic of the ecosystem (e.g. % difference in plant species composition) and responsive to a wide range of stresses. However, the detailed response to any given stress is unknown. In this scenario, you derive an EI measure based on the difference or slope between several observations and use simple change detection to generate interim thresholds. If this EI measure changes beyond a pre-determined effect size, then a threshold has been crossed. This is a simple but rigorous response to the question: Is the ecosystem changing?

**Figure 8.4: A flow diagram for the process of threshold selection.**



It is difficult to combine both site-to-site variation and year-to-year variation in selecting a threshold effect size. So, generally, you will have to choose. If the ecosystem is fairly insensitive to annual fluctuations in a measure, then you should concentrate your monitoring efforts on measuring many sites once every five years. If, on the other hand, the year-to-year variation is much greater than site-to-site variation, it makes sense to collect data from few sites each year. The extreme case would be the single weather station representing the entire greater park ecosystem. For many parks, this is justifiable. Similar cases can be made for sampling well-mixed lakes, high-volume rivers and colonial bird populations. If you are using a small number of sites to make annual sampling logistically feasible, you should periodically (every 10 years?) check how representative they are.

**Table 8.1: Approaches to setting interim thresholds for EI measures.**

<b>Relationship with Stressor</b>			
	Unknown	Gradual	Stepwise
<b>Distribution Unknown</b>	1. Change Detection  a) Comparison with spatial variation b) Comparison with temporal variation <ul style="list-style-type: none"> <li>- Standard deviation</li> <li>- SE of slope</li> <li>- Statistical Process Control</li> </ul>	2. Stress Detection  Medium and large stress effects on the measure	3. Natural Threshold Detection  Identification of stress values with largest impact on the measure
<b>Distribution Known</b>	4. Distribution Segmentation  <b>Selection of thresholds at equal intervals</b> <ul style="list-style-type: none"> <li>- without optimum</li> <li>- with optimum</li> </ul> 4. Change Detection (temporal) <ul style="list-style-type: none"> <li>- % of distribution</li> <li>- ARIMA models</li> </ul>	5. Distribution Segmentation with Stressor  Selection of thresholds at equal intervals along stress gradient <ul style="list-style-type: none"> <li>- linear</li> <li>- non-linear</li> </ul>	6. Distribution Segmentation with Natural Thresholds  Identification of stress values with largest impact on the measure at approx. equal intervals

The first approach uses paired t-tests or repeated measure analysis of variance to test whether the average change in the measure between two State of Park reports is large relative to the variation in change within the park. This would indicate a potentially important change in this measure between the time periods.

Section 9 addresses study design. Here we use a number of default assumptions for the chosen analysis to set threshold effect sizes and appropriate sample sizes for upper and lower thresholds (Table 8.2). This guidance, based in part on rules of thumb from Cohen (1977), allows you to choose a defensible design whose rigor you can adjust by changing the power and confidence of the test or the effect size to be detected. Notice that the effect size is expressed in terms of the variability (either standard deviation or standard error) of the measure and does not require pilot studies to estimate variance or effect size. The Cohen (1977) rule of thumb allows you to avoid wasted effort looking for weak effects.

**Table 8.2: Default thresholds and sample sizes for selected analyses Both confidence and power are assumed to be 80%.**

<b>Scenario</b>	<b>Analysis</b>	<b>Effect Size Upper Threshold</b>	<b>Effect Size Lower Threshold</b>	<b>Type of replication</b>	<b>Minimum number of replicates</b>
1.Change detection	Paired t-test between repeated observations	0.5 sd	0.8 sd	Sample locations	19
1.Change detection	ANOVA among several repeated observations (3 or more)	0.25 sd	0.4 sd	Sample locations	32
1.Change detection	One sample t-test of difference from previous observations	1 sd	2 sd	Repeated observations	6
1.Change detection	Regression (t-test of slope)	2 se	4 se	Repeated observations	6
1.Change detection	Statistical Process Control	see text	3 se	Repeated observations	10 (at least 5 "in control")
2.Stress Detection	t-test between 2 stress levels	0.5 sd	0.8 sd	Sample locations	72
2.Stress detection	ANOVA among 3 levels of stress	0.25 sd	0.4 sd	Sample locations	96
4.Change Detection	% of distribution	1% per year	2% per year	Repeated observations	30
4.Change detection	Autoregressive Integrated Moving Average	1.5 se of slope	2.5 se of slope	Repeated observations	30

It also guards against overlooking commonly observed effects because of low sample sizes. Ultimately, you can adapt this default study design as you learn more about the relative size of the biologically significant effect size and the measure's variability.

The second approach for this scenario requires an established data set for the site of at least 6 previous observations and consequently is most appropriate for data collected on an annual (or more frequent) cycle. The "site" for this approach must be defined according to the scale of interest and usually represents a specific ecosystem type or population in the park by taking the sum or average of field measurements from several monitoring locations. Several analyses are appropriate:

*6-10 previous observations:* Use 1 standard deviation (upper) and 2 standard deviations (lower) of the temporal variation as thresholds for defining an unusual year (Table 8.2). Ensure you exclude current observations in calculating your standard deviation. This is not a very sensitive approach but you should be conservative given the limited information on variation over time. If you are specifically interested in trends, use 2 standard errors (upper) and 4 standard errors (lower) of the estimate of the slope as thresholds for possible and definite change during the observation period. That is, if the slope is less than 2 standard errors away from zero, there is no evidence for a change in the measure, and you should report it to reflect high ecological integrity. Choose the regression technique to suit the data's statistical distribution (see section 13.4).

*10-30 previous observations:* Use Statistical Process Control (SPC) to define thresholds of non-random fluctuations in the data. Dobbie et al. (2006) develop this quality assurance analysis for ecological integrity reporting. The approach is based on a three year running average of the EI measure as compared to six bands of values determined by the long-term mean and its standard error. Define EI status as follows:

1. A point is 3 standard errors from the mean (measure is "red").
2. Two of 3 points are 2 standard errors from the mean (measure is "red").
3. Four of 5 points are between 1 and 2 standard errors from the mean (measure is "red").
4. Fourteen consecutive points less than 1 standard error from the mean (measure is "yellow").
5. Fourteen consecutive points alternating above and below the mean (measure is "yellow").
6. Seven consecutive increasing or decreasing points (measure is "yellow").
7. Seven consecutive points above or below the mean (measure is "yellow").
8. None of the above (measure is "green").

If there are more than 30 previous observations over many years, you can generally assume that the distribution of the measure is known. See Scenario 4.

## **8.2 Scenario 2 – Unknown distribution, gradual relationship with stressor**

This scenario focuses on detecting an impact on the measure along a known stress gradient. For example, plots at different distances from the trail network can be examined for bird song. You can use any appropriate General Linear Model to detect differences in the measure at different levels of stress, including t-test, analysis of variance and regression. The experimental

design must choose similar ecosystem types exposed to different levels of stress. You set default thresholds similarly to the change detection analyses, except that the number of levels of stress sampled replaces the number of observations in the study design (Table 8.2). You should report the existence (or absence) of degraded ecological integrity in the park as the result of a known stressor. However, the tendency will be to focus on particularly stressed parts of the park. If you map levels of stress (e.g. road density, visitor use density), you can summarize the measure as a weighted average according to the area of different stress categories in the park. Thus the effects of a localized but intense stressor may be viewed as comparable to a minor but widespread stress. The approaches from Scenario 1 are also available for setting thresholds.

### **8.3 Scenario 3 – Unknown distribution, steep relationship with stressor**

Where a specific range of stress values has a greater effect on the measure than any other (Figure 8-2b), your task is to identify that range. The experimental design will be similar to Scenario 2 but there will be added emphasis on examining a broader range of stress levels and checking the robustness of the relationship with the measure through experimental variation in background conditions. Without a full awareness of the possible distribution of the measure, the thresholds become the two most precipitous declines in the measure for a small increase in the stressor. These thresholds should be relatively consistent under a range of environmental conditions. Thus they provide ecological information useful for park management. The approaches from Scenario 1 are also available for setting thresholds.

### **8.4 Scenario 4 – Known distribution- unknown relationship with stressor**

If you know the potential distribution of values for the EI measure in the park, then you can establish thresholds from this broader perspective. The intent is to divide the distribution into three equal segments, reflecting high, moderate and low values.. If you suspect an optimal value of the measure - one at which ecological integrity peaks and then declines – then you must divide the distribution among 5 segments, including sections reflecting a decrease in ecological integrity at values above the optimum value. Evidence for a measure increasing beyond an optimum value comes primarily from correlated measures, such as the lack of predators, a diminished prey base or a decline in decomposition. Like natural thresholds, optima are difficult to establish and may change with background conditions. If a measure has more than one local optimum within its potential distribution, then its relationship with ecological integrity is probably too complex for an EI measure.

Another approach involves establishing an effect size based on % change per year. This approach is not viable unless you know the distribution of the EI measure. Some variables naturally change by many units every year (e.g. grasshopper population densities) or have large absolute values. Without a known distribution to put these changes into perspective, it is impossible to set a threshold based on a percentage of the measure's initial value. You can calculate upper and lower thresholds of annual change as 2% and 4%, respectively, of the difference between the 90<sup>th</sup> and 10<sup>th</sup> percentiles. Sustained over periods of five years, these rates of change represent detectable or definitive differences in the measure.

Where the distribution of the measure has been established through 30 or more previous observations at the same site, you can use Autoregressive Integrated Moving Average (ARIMA) models to account for cycles in the data and estimate trends. Choose 2 (upper) and 4 (lower) standard errors of the estimate of the slope as thresholds for possible and definite change. The approaches used in Scenario 1 are also available.

### **8.5 Scenario 5 – Known distribution, gradual relationship with stressor**

This scenario assumes the potential distributions of both the ecosystem characteristic and its stressor are known and that there is at least a 75% correlation between them. You can identify potential distributions through data from sites with land uses that are or will be comparable to those of a national park. You can then simply set the thresholds at equal intervals along the stress gradient. Where you identify an optimum or minimum value of the ecosystem characteristic through non-linear regression, you need extra thresholds to interpret this relationship with ecological integrity. The approaches used in Scenarios 2 and 4 are also available.

### **8.6 Scenario 6 – Known distribution, steep relationship with stressor**

This combination of information allows you to situate thresholds where they have the greatest effect on the ecosystem characteristic and at approximately equal intervals along the entire distribution of the stressor. The stressor could act as a switch to remove the integrity of the ecosystem characteristic at a single threshold value. Here you will not need a moderate EI category. You must test the location of thresholds under a range of background conditions for them to have strong predictive power. All other approaches are available for setting thresholds in a data set of this type.

### **8.7 General approaches to thresholds**

As you replace interim thresholds with values that have a stronger grounding in the park's ecology it is important to backcast what the measure condition would have been with the new threshold values. This will allow you to report correctly the trend in the measure over time. Thresholds are ultimately a way to ensure clear reporting. Though you must always document your reasons for choosing a given value, you must report on the ecosystem with all but the most preliminary data sets. You must choose values that make the data understandable to a non-expert audience.

## 9.0 STUDY DESIGN & POWER ANALYSIS

You must have a clear monitoring question for each measure of ecological integrity. This section tells how to design a monitoring study to answer that question, including determining the sampling approach and conducting a power analysis (a tool that tells how likely you are to detect a real trend in the data). You must consider the relevant aspects of study design in planning each measure.

### 9.1 What is study design?

Study design is the careful selection of when and where you will collect data. For example, the study design for a stream fish community measure would include which streams to sample, which sections of each stream to sample, how often within a season sampling takes place, and in which years you sample each section of each stream.

### 9.2 Rationale for a good design selection

The choice of a study design is determined by the question your monitoring project needs to answer. Hence, you first need a good monitoring question. The more detailed the monitoring question, the clearer the choice of sampling design. Avoid a situation where you have collected data for years, and then realize you can't answer the question of interest because of a flawed design.

The ecological attributes of your chosen measure should direct the design of your study. Historic studies, modeling, or studies conducted on similar organisms or areas can generate target values, thresholds, estimates of variability or effect sizes that relate to the ecological integrity of the measure. Your ecological question then becomes whether observed conditions are consistent with EI - your statistical question and study design will follow.

### 9.3 When do you not need a sampling design?

In cases where you undertake a complete census with no measurement error (e.g. you count every individual of a species at risk in the park to determine abundance in the park) then you no longer have a sample, and have no need for a study design or for statistical analysis. This situation is very rare. Even then, there is merit in reviewing the ecological question to determine if you require true census. If you do not need a true census, you can determine an appropriate study design and sampling requirements using power analysis (see below). If previous census data exist, a simulation exercise using the historical data will yield very reliable estimates of required sampling effort to provide the required information for the least time and money.

## 9.4 What makes a good design?

A good design produces data that are free of biases. In other words, the study design accurately estimates the metric of interest (e.g. population abundance, average decomposition rate, average clam density per quadrat). To eliminate potential biases, we usually use some type of random choice of study sites/organisms. Keep in mind that, due to financial or logistical constraints, you are often not sampling the quantity of ultimate interest. For example, you might wish to monitor forest birds, but choose a protocol that samples only birds that are actively singing (e.g. point counts), and possibly you can only afford to sample within 1 km of access roads. Hence, you will choose a design that gives an unbiased (accurate) estimate of singing birds near roads, but probably a biased estimate of forest birds in general (unless information about singing birds near roads is equivalent to information about all birds throughout the forest). You will need to capture the latter bias in phrasing the monitoring question. The study design only seeks to avoid biases in the context of the restrictions set by the monitoring question.

### 9.4.1 Defining spatial and temporal extents

A study is always defined in time and space. Unless you need to conduct a complete census, you will be studying a fraction of the area or group of organisms of interest. However, you want to make an inference about the whole area or entire group of organisms. Statistically, this area or group of organisms is the "population". Thus, for each project you must define the population of interest and its spatial boundary. Is the park the study's spatial boundary? A portion of the park? An area occupied by a group of organisms? The answer defines the study area. Often, your true interest will be the entire park (e.g. all forests in the park), but for financial reasons, you limit monitoring to portions of the park (e.g. only hardwood forests, or only mature maple-oak-birch hardwood forests). The spatial extent is often called the sampling frame. The sampling frame defines the areas that you may select as study sites.

Although we are monitoring in perpetuity, we would like to report results at certain intervals. Do you need results every year? Every five years? Every ten years? This defines the study's temporal extent.

### 9.4.2 Sample selection strategies

You will select study sites or study organisms within the design's spatial and temporal extent. To avoid unintentional biases, we usually employ a random selection strategy. Again, the aim is to draw an inference about a large area or a group of organisms from a few samples. You may base this inference on a logical argument, but it will be greatly strengthened through rigorous application of statistical sampling theory. The assumptions of a simple logical argument are often less obvious and more easily challenged than those supported by a statistical process

where the assumptions are well known (e.g. independent sampling areas), and are often easily satisfied. Hence, you should use a sampling design that is ecologically and statistically sound.

- *Judgement or representative sampling:* uses logic or common sense to select study sites; for example, choosing sites that “look” typical. We do not recommend this because it prevents use of statistical theory to support your inferences.
- *Random or probability sampling:* the key element of random sampling is that every area/organism in the population of interest has a chance of being sampled. There are different kinds of random sampling:
  - *Simple random sampling:* all individuals or sampling sites have an equal probability of being sampled. Those to be sampled are drawn at random and the sample data are then used to make inferences about the entire population.
  - *Systematic sampling with a random start point:* Sampling sites are part of a regular grid with predetermined distances among points. This is easily achieved by overlaying a grid on a map. It is important to introduce randomness by choosing a random point to anchor the grid. This ensures good spatial coverage but can be problematic if the study area has a regular pattern (e.g. regularly spaced hills and valleys). As with simple random sampling, sample data are used to make inferences about the entire population.
  - *Stratified random sampling:* The study population is divided into one or more groups (strata) either by location or by other key ecological attributes. Within each stratum, a simple random sample is drawn. For example, a stream sampling program might stratify by stream order (1st, 2nd, 3rd). Hence, the study design might consist of ten randomly selected 1st order streams, ten randomly selected 2nd order streams and ten randomly selected 3rd order streams. This ensures that less common strata are adequately sampled. Stratified random sampling can also improve sampling efficiency by apportioning greater effort to strata with higher variances; increasing precision of estimates for a given cost and effort. Sample data are restricted to making inferences about the portion of the population within the stratum.
  - *Tesselation sampling:* Uses a regular pattern of geometrical shapes (e.g. squares) overlain on the study area. A sampling site is randomly chosen from within the area covered by each shape. This ensures randomness and good spatial coverage and avoids problems associated with systematic sampling.

#### **9.4.3 When is it OK to cut corners?**

Study design will always be a compromise between an optimal design, from a statistical perspective, and the logistical constraints and costs of field sampling. As a result, study design has often been a weakness of monitoring programs. Thus you must carefully analyse any

suboptimal design to determine whether the information lost by cutting corners still results in a design that is worth investing resources long term. A few common logistical issues:

- In many parks, access costs prohibit sampling remote areas. For example, it may cost 5-10 times as much to sample benthic invertebrates in alpine streams than in lowland areas. This might justify removing highland lakes from the sampling frame (they have no chance of being selected as study sites), but consequently you have restricted the monitoring study's spatial extent. You will lack information about highland areas' condition. In other words, you cannot make design-based statistical inferences for areas outside the sampling frame. You can justify this based on the information return on the investment of monitoring dollars. However, if a stressor is affecting highland lakes and not lowland lakes, or if highland lakes are more sensitive than lowland lakes, your monitoring program will miss this entirely.
- Another situation where access constraints affect the study design is when using an existing road or trail network to increase efficiency of sampling. Again, this has implications for the study design's spatial extent: what exactly is in the sampling frame? It is very important to be very clear what is the access constraint and then determine what is being sampled. For example, you might choose sample sites within 2 km of a trail or road. You must then determine what portion of the potential sampling sites falls within this 2 km envelope, and whether this captures the different types of sampling sites, as defined by a common sense stratification: geology, patch size (in the case of discrete sampling units such as forest stands, or lakes), elevation, etc... You might then need to reconsider the 2 km criterion to develop a logistically realistic study design that will still allow you to make a design-based inference about an important component of the park.
- Another constraint may be the desire to use historical sampling locations, or to augment historic sites with new sites. If you have information about how the historic sites were selected, then you can evaluate this information to determine whether sites were chosen with an element of randomness from a well-defined sampling frame. If so, you can determine the sampling frame's usefulness given the present goals of the monitoring program. For example, if historic forest plots were chosen only from highly productive areas, as defined by soil type, drainage and elevation, then these sites will give a very biased view of forests in general. However, you could add new sites to historic sites by stratifying according to soil type, drainage and elevation such that all types of forests are represented in proportion to their relative abundance in the new design. The final study design would permit inferences about forests in general. If you lack information how the historic sites were selected, you will be uncertain how to interpret the data they produce, and you may make mistakes. Unless the historic sites represent an important legacy data set, it is often better to start with a new design entirely.

#### **9.4.4 Autocorrelation**

A common assumption of statistical analyses is that sample units are independent. What this really means is that variability related to our sampling protocol or, more commonly, variability related to underlying ecological factors (geology, climate) is independent from one site the next. This is obviously not the case for many situations, where features at sampling points close in space or time will tend to be more similar than points farther apart in space or time.

You can use data from a pilot study to calculate an autocorrelation function, and determine at what distance or time points will be independent.

## **9.5 Sample size – how many, how often?**

Once you have determined how to choose sample sites/organisms, you need to determine how many sites to choose and how often to sample them. This is the question of sample size. The sample size needed depends on the study objectives and attributes of the data you will collect. Use a power analysis to determine sample size requirements.

### **9.5.1 Power analysis overview**

Statistical power analysis is the tool that tells how likely you are to detect a real trend in the data. It is usually defined on a scale of 0–100%. A related concept is confidence, which is the probability of any trend detected in the data being real and not a false alarm. Confidence can also be defined between 0 and 100%.

- High power & low confidence: you detect most real trends but often wrongly identify trends where none exist.
- Low power & high confidence: you detect few false alarms but often fail to detect real trends in the data.

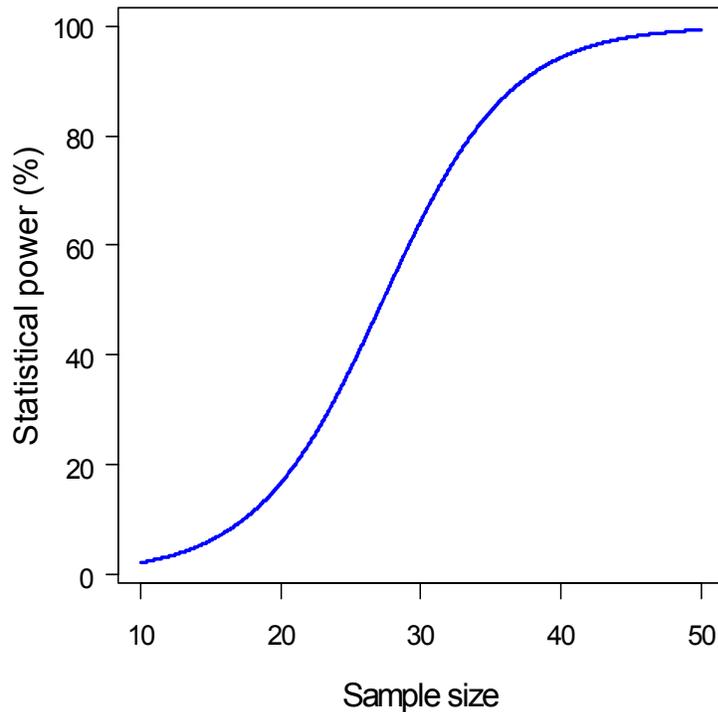
Though not practical, an ideal monitoring project could detect all real trends (100% power) without signalling any false alarms (100% confidence). The factors that influence statistical power are:

1. effect size: the magnitude of change you are trying to detect (it is easier to detect large changes than small changes),
2. variability of the data (noisier data lead to low power),
3. abundance: difficult to detect changes in rare species,
4. confidence: the more willing you are to accept false alarms, the less likely you will miss a real change,
5. time horizon: (e.g. reporting every 5 versus every 10 years; the effect of a persistent change will accumulate over time and, for any given sample size, will be easier to identify after a longer period),
6. the choice of statistical test to detect trends, and
7. sample size (Figure 9.1): the more data you have, the higher the power.

### **9.5.2 Choosing appropriate power & confidence levels**

The user determines the confidence level (you choose it). Power is a function of the elements in 7.4.1., and hence flows from decisions you make about effect size, confidence, and from elements outside your control (e.g. natural variability). There are no universally accepted values for acceptable power and confidence levels. Traditional research activities adopt a 95% confidence level, but this is not appropriate for most monitoring, where the consequences of missing an important change are graver than the consequences of detecting a false change. Hence, we aim to have a higher power than confidence. A notable exception is in the recovery

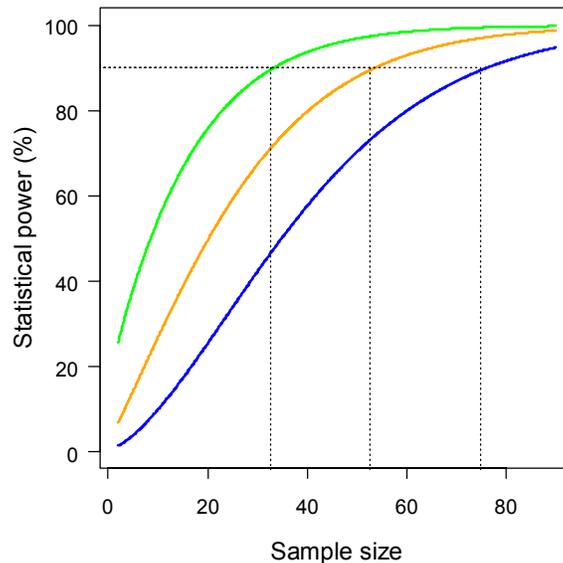
of species of risk, where it is worse to conclude falsely that a species has recovered when it hasn't than to miss an actual recovery. In this latter case, we would wish confidence levels to be higher than power. A realistic target for both confidence and power, given budgets is 80%. However, for some critical monitoring projects, you will need a higher power.



**Figure 9.1. Example of a power curve. Note that the increase in power with sample size is not linear (all other factors held constant). In this example, taking more than 40 samples yields little gain in power**

### 9.5.3 How to perform a power analysis

A power analysis requires training, and usually involves specialized software. The analysis involves many inputs and often requires a pilot study. With so many interacting variables it takes a skilled user to generate appropriate estimates of power. Keep in mind that power analysis gives us the future probability of detecting change. You cannot use it to determine how powerful a past analysis was (Hoenig & Heisey 2001). In many cases, most of the interacting variables will be fixed (e.g. confidence, effect size, abundance, variability), and you will use power analysis to determine the sample size necessary to achieve a certain power target.



**Figure 9-2.** Example of how changes in desired confidence affect power and required sample sizes. Three curves are shown corresponding to different levels of confidence (blue = 99%, orange = 95%, green = 80%). For each curve, the sample size corresponding to 90% power is indicated by dotted lines.

#### 9.5. 4 Tools for power analysis

There is various specialized software for power analysis, but you should consider some training before undertaking the analysis.

Training:

Websites:

- <http://power.education.uconn.edu/>
- <http://www.zoology.ubc.ca/%7Ekrebs/power.html>
- <http://www.statsoft.com/textbook/stpowan.html>

Books and articles:

- Lenth, R. V. (2001). Some Practical Guidelines for Effective Sample Size Determination, 'The American Statistician. **55**: 187-193.
- Thomas, L. and Krebs, C. J., 1997. A review of statistical power analysis software. Bulletin of the Ecological Society of America. **78**: 128-139.
- Hoenig, J.M. and Heisey, D.M. 2001. The abuse of power: the pervasive fallacy of power calculations for data analysis. American Statistician **55**(1):19-24.

Freeware:

- Monitor (<http://www.mbr-pwrc.usgs.gov/software/monitor.html>)
- Power Calculator (<http://calculators.stat.ucla.edu/powercalc>)
- R (<http://www.r-project.org/>)

Commercial software:

- NCCS (<http://www.ncss.com/>)
- Systat (<http://www.systat.com/>)
- SAS (<http://www.sas.com/>)
- S-Plus (<http://www.insightful.com/adwords/branded/default.asp>)

## **10. MONITORING PROGRAM IMPLEMENTATION – DEVELOPING A COSTED IMPLEMENTATION PLAN**

This section tells how and why to develop a costed monitoring program implementation plan. Your park must prepare and maintain such a plan to assure long term action on monitoring and reporting. The section includes directions for preparing a plan based on a sample Excel spreadsheet that accompanies this guide.

### **10.1 What is a Costed Implementation plan?**

A costed monitoring program implementation plan describes for all EI measures and EI indicators how you will implement park EI monitoring and reporting. It estimates and commits financial and human resources to carry out the program over the short and long term. By developing a monitoring plan, you will show how you will obtain all data for all monitoring measures. You will develop the plan within the five-year SOP reporting cycle, ensuring that the human and financial resources will be available to collect, analyze and report monitoring data for the next SOPR.

### **10.2 Why Do I Need a Costed Plan?**

A park EI monitoring program will comprise many EI measures collected over several years. It will be a complicated process to ensure the timely collection, analysis and reporting of all monitoring data to meet your needs for the SOPR. You must:

- integrate monitoring projects for different EI indicators over a five year period,
- commit or contract required expertise of in-park or external human resources,
- complete any training required for sampling and analyses,
- identify needs to capture and analyze the data, and
- identify program costs and work loads to obtain funding for sampling and analysis.

The costed implementation plan is the first step to ensure the park's proposed monitoring plan for the park is feasible. It demonstrates a serious management commitment to measure and report the state of park EI. The plan also demonstrates the long-term commitment to the EI monitoring and reporting required for program success. Thus a costed implementation plan is essential for success for all parks for the 2008 program deadline.

### **10.3 Developing the Plan**

The costed implementation plan follows a template (see Table 10.2 following page 60). Each monitoring project or measure is a row in the template. Template columns are your estimates of human and financial costs, five year scheduling of sampling for each measure or project, as well as data capture, analysis, and annual and five year reporting considerations. This template lays out, for your park, the integrated planning required to implement your park monitoring program, based on the EI measures you have selected. The plan thus also acts as a first filter for the overall feasibility of your proposed monitoring program. Through this process you will identify required human and financial resources and the year-by-year implementation of the monitoring for each measure.

#### **10.3.1 Plan Requirements**

The template will help you plan the EI monitoring and reporting program. It must be adapted to each national park. Should the language be changed to "a" park, rather than "your" park? Your park may also have other planning approaches or software more appropriate for this exercise, or you may develop your own template. You should use these other methods if they suit your program. However, the template and approach presented show the depth of preparation required for a successful monitoring program. Whatever the method, all costed implementation plans should address:

1. human and financial resource needs for each EI measure (human resource needs must differentiate between the use of park staff and external support),
2. required levels of sample replication for each EI measure in each year,
3. year-to-year human and financial costing within a five-year SOP reporting cycle,
4. extraordinary access needs such as boats and helicopters, and
5. the contribution of park partners.

#### **10.3.2 Human and Financial Resources for Monitoring**

The key to determining the proposed monitoring plan's feasibility is to ensure adequate human and financial resources are available to complete the tasks in a given year, and over the five-year cycle of the costed monitoring plan. Human resources can be divided into parks staff and external personnel, and into different levels of expertise, e.g., professional, technical and volunteer. Table 10-1 shows how you can use each of these human resource categories in the annual cycle of monitoring tasks.

**Table 10-1: Summary of human resources that could contribute to a typical annual cycle of park monitoring tasks.**

Task	Internal Staff		External Human Resources		
	Professional	Technical	Professional	Technical	Volunteer
1. Planning	*		*		
2. Training	*	*	*	*	*
3. Field sampling	*	*	*	*	*
4. Data capture/QA		*		*	
5. Data Analysis	*		*		
6. Reporting	*				

Professional staff involved in park monitoring may include a park monitoring biologist, wardens, data base/GIS specialist, interpreters, other science specialists, and the Resource Conservation Manager. Wardens or other technical staff may provide internal technical support. External professional assistance may be from:

- within Parks Canada including staff from other national parks, Service Centre, and National Office scientists,
- other government agencies,
- universities, or
- the private sector.

External technical staff will usually be university and technical institute summer students, technicians from other government agencies, or contracted private sector employees. Volunteers, local students, and park visitors may also be involved through volunteer programs, school programs, or the park interpretation program. The mix of personnel will vary among parks and will evolve with our experience in comprehensive park EI monitoring. Partners working in and around parks may also generate useful monitoring data for park programs.

You can also divide cost estimates into two categories – internal system costs, and goods and services costs. Costs of internal staff time will be based on the amount of time dedicated to monitoring, and good and service costs will be a combination of fixed costs and contracted human resource costs. Section 10.3.3 tells how to estimate project and program costs.

### 10.3.3 Template Key

This section tells how to develop estimates of financial and human resources for each EI measure or project displayed in the costed implementation plan template - Table 10-2.

1. **Monitoring Projects and EI Measures:** The elements you will use to calculate monitoring costs will be either monitoring projects or individual EI measures. For the calculation these are considered sampling units. They provide a logical process for estimating monitoring costs. These make up the template rows.
  - a. You can calculate EI measures together as a monitoring project when one field team collects information on a group of EI measures in the same place at the same time. Some elements of forest vegetation monitoring plots (tree, shrub, and ground vegetation sampling, coarse woody debris sampling), stream sampling sites (benthic invertebrates, water chemistry) and wetland sampling (water quality, vegetation) are considered monitoring 'projects'. We recommend this kind of sampling because of the human and financial resource savings.
  - b. In other cases you will need to calculate monitoring costs for individual EI measures, even if you collect them in the same location as the other measures for that indicator. You can sample decay sticks at the long-term forest monitoring plots, but collect them annually, or biannually, and in the fall before freeze up. Similarly, you may collect forest songbird point count data adjacent to forest plots, but must sample in early spring during the nesting season.
2. **Human and Financial Resource Factors:** The factors used to estimate the required human and financial resources for park EI monitoring make up the columns of the template. They are divided into three main categories (Number of Samples, Variable Costs and Fixed Costs) you will need to develop a costed monitoring plan, and are discussed in detail below.

The monitoring is planned for one full 5 year SOP reporting cycle. Complete all monitoring in the year before the SOPR is published to allow sufficient time for data analysis and reporting in the SOPR. This means that Year 1 of the 5-year sampling cycle is actually the year of publication of the SOPR from the previous reporting cycle.

- a. **Number of Samples:** A main driver of the monitoring cost is the number of samples required for a reliable estimate of the EI measure(s) sampled. The number of samples required is determined by the variability of the measure, and the amount of statistical power and precision you want for its estimation. Section 8 tells how to determine the number of samples for a particular measure. Another important cost driver is the locations of the samples. This is a product of project study design, also described in section 8.

**Table 10.2 Costed plan template**

			Number of samples					Variable Costs						Fixed Costs												
Indicator	Project/ measure	Components	Year 1	Year 2	Year 3	Year 4	Year 5	Person days per sample		Goods & Services per sample				Annual person days per project/measure		5-year Equipment Purchase Requirements					Comments					
			No. of samples	No. of samples	No. of samples	No. of samples	No. of samples	data acquisition, data entry, QA	Proportion internal (0 - 1)	External lab analysis	Extraordinary access (boats & helicopters)	Other external (salary, transport, accomodation, food)	Total variable G&S cost / sample	Data analysis, reporting, training	Proportion internal	5-year Fixed cost description	Year 1	Year 2	Year 3	Year 4		Year 5	5-year fixed cost			
<b>Forest</b>																										
	Vegetation plot (lowland)	Coarse woody debris, tree sampling, shrub sampling, ground vegetation					45	2	0					\$300	\$300	5	1	calipers, laser rangefinder			\$300				300	contracted out
	Vegetation plot (highland)	Coarse woody debris, tree sampling, shrub sampling, ground vegetation					10	2	0		1000		\$300	\$1,300												Equipment is covered off with the lowland sites.
	Forest songbirds			20			25							\$200	\$200	2	1								0	
	Decay sticks		20		25			1	1					\$0	\$0	3	1	drying oven, tongue depressors, scale, tags				600	600	1200		







- b. **Variable Costs:** The number of person days (external or internal), or the amount of goods and service dollars required for each sample for each measure/project are 'variable costs', because they vary with the number of replicates. The idea is to estimate, for each measure or project, human resources, and goods and service dollars required to complete one sample, and then multiply by the number of samples to estimate the cost of sampling for this measure (excluding Fixed Costs below) in a given year. You will estimate person days per sample and then multiply this value by a 'proportion internal' factor to identify whether costs will be internal or will come from goods and service funds. Typical per sample goods and service costs to consider include sample laboratory analysis (by external laboratories), extraordinary access costs (non-park vehicles), and the costs of labour such as fees, transportation, accommodation, and food.
  - c. **Fixed Costs:** Fixed Costs refer to two main considerations:
    - i. The number of person days required to analyze and report monitoring results, and for training to complete the sampling are estimated here as fixed costs. As for the variable costs, you can assign these fixed cost person days to internal or external workers.
    - ii. Equipment purchase requirements provide an estimate of the costs of sampling equipment, and any other expendable items required to complete the sampling for a given measure over the five-year sampling cycle. You can calculate these for the whole period, or break them down by year as we have done in the table. The yearly breakdown provides the flexibility to plan for equipment purchase during years with low overall sample costs, and in general, to maximize the use of available resources over the five-year sampling cycle.
3. **Estimating Annual Costs and Total Program Costs:** Once you fill in the required cells, estimating annual costs for each project/measure in the spreadsheet is a simple procedure. Multiply per sample variable costs by the number of samples for that year, and add fixed costs for that year to this product. The sheet can also be used to assess the cost implications of different replication or productivity (define productivity) estimates. Add costs for all measures in an indicator, and for all indicators to estimate yearly costs for the park program. The sheet also calculates the number of person days to be contributed by internal staff.

## 11. MANAGEMENT EFFECTIVENESS MONITORING

This section describes how to use management effectiveness monitoring (MEM) techniques to determine how management actions affect park EI. Your park must report on the ecological impact of key initiatives for maintaining or restoring ecological integrity. The section tells how MEM can apply to both active and passive management.

### 11.1 What is Management Effectiveness Monitoring?

Management effectiveness monitoring in protected areas is a means to evaluate whether management strategies actually help achieve their stated goals (Mezquida et al. 2005). Many aspects of protected areas management could be evaluated, and Hockings et al. (2000) defined three main components that could be assessed through evaluation and monitoring:

1. planning, which includes the appropriateness of legislation, policies and design (size, shape and links) of individual or networks of protected areas,
2. management system and processes, which include the efficiency of the amounts of resources invested, day-to-day maintenance, and adequacy of approaches to local community, and
3. delivery of objectives, which includes the effectiveness of national legislation and policies as well as management plans and actions.

Management effectiveness monitoring is targeted sampling and assessment to answer the second of the two major questions for park EI monitoring – “How do our management actions affect park EI?”. This corresponds with point 3 above, which is, according to Hockings et al. (2000), the “true test of management effectiveness” of protected areas, because it is centred on meaningful and concrete objectives. This kind of monitoring relates directly to the park management plan, because the goals and objectives for the proposed management activities are often described there. MEM is thus an accountability process for reporting results of management activities or ongoing park management policies and operations, in the context of ecological integrity objectives and project outcomes.

**Management effectiveness monitoring is monitoring that answers the question, “How do our management actions affect park EI?”**

Most management effectiveness monitoring will be short term to show direct consequences of our management actions in the context of park EI. MEM is not directly

equated with short term monitoring, however. In some cases MEM may be long term in relation to ongoing park management policies. These two kinds of MEM are distinguished below.

### **11.1.1 Management Effectiveness Monitoring in National Parks**

Park management activities, and MEM, fall in two broad categories;

- **active management:** directed park management actions, where a park makes a new investment in maintaining or restoring ecological integrity, or where an important ongoing park policy or operational procedure is changed:
  - ecological restoration: including restoring in-stream habitat and riparian function, prescribed fire, controlling invasive aliens, species introductions or maintaining habitat for species at risk, reducing footprint and infrastructure effects, and trail or road restoration or closure
  - environmental impact mitigation: including upgrading sewage facilities, right of way crossing facilities, infrastructure changes, stressors related to human activity, infrastructure developments
  - policy or operational procedure changes: including situations where new policies or operational procedures are initiated, e.g., closing a sensitive area to visitors, changes in harvesting regulations, or major operational changes to prevent proliferation of invasive species
  
- **passive management:** ongoing management activities related to park policies and operational systems from our mandate to present park EI to Canadians through memorable visitor experience and quality visitor education. This represents long-term mitigation of the environmental impacts of programs. Our objective is to maintain ecological function within a certain range or to restrict ecological stressors below a certain value. In addition, these monitoring projects will often be merged with measurement of other outcomes of the activity, including health and safety, visitor experience and visitor education. Typical examples are town site management, park facility effects, vehicle effects, recreational fishing and other in-park harvesting, road maintenance, and direct visitor use effects.

Management effectiveness monitoring is that component of these management projects and ongoing policies and operations that assesses effects of management activities in the context of park ecological integrity. That is, we must express results of management activities in terms of ecological integrity measures.

### **11.2 Management Effectiveness Monitoring and Environmental Assessments**

Management projects that trigger environmental assessments under the Canadian Environmental Assessment Act (CEAA) are a special subcategory of active management projects that may require MEM. The *Parks Canada Guide to Compliance with the*

*Canadian Environmental Assessment Act* (draft version, 2006) describes screening procedures for projects subject to CEAA

EAs often differ fundamentally from other park active management projects: Some EA projects may aim to minimize effects of the planned action on EI, or to maintain EI, rather than to enhance or restore EI. For MEM the difference is not significant, because the MEM objective in all cases is to select useful measures to represent EI, and then to follow the changes in the measures as a proxy for assessing potential affects of the management action on EI. These EI measures may include:

- maintaining low measured levels of sediment runoff and stream turbidity adjacent to a highways project,
- maintaining healthy ungulate populations where snowmobiling is being permitted or regulated, and
- preventing establishment of invasive alien species where buildings are being decommissioned.

### **11.3 Monitoring Active Management Projects**

The scientific approach is appropriate to MEM, because this type of monitoring aims to determine effects of management on EI status and trends of an ecosystem. Thus the management action is the 'treatment', and the monitoring measures we use to represent EI are the response variables of interest. Generally, the project components this guide describes for condition monitoring apply to MEM projects, e.g., principles of study design, power and significance, and developing clear monitoring questions.

Table 11.1 is an outline for a typical MEM project where active management is planned. The planned MEM will be part of a larger plan to carry out the active management, e.g., as an appendix or chapter in the active management plan.

The introduction should summarize management issues and actions, with a clear statement of the monitoring hypotheses, also known as the monitoring question. This should include short and long term goals used to evaluate and report success.

You will need to identify study sites for all projects . For some designs, you should select sites away from the site of active management to represent:

- an untreated but impaired condition for comparison, or
- a desired future condition for the site being treated.

Given this information, you will need to develop a study design that can clearly determine the management action's effectiveness in an EI context. You will select one or more monitoring measures to track. The changes in these measures, in relation to an *a priori* hypothesis, will act as a surrogate measure of the change in EI for the management action. You should measure as few aspects of the ecosystem as possible. The design must outline sampling methods and techniques, as well as the appropriate data analysis. It is also important to have a plan to phase out monitoring activities for individual active management projects. Otherwise, we will accumulate an unsustainable load of monitoring activities. Bioregional monitoring ecologists are trained to assist parks

staff with the design and analysis of MEM projects. The MEM report should end with a discussion of results in terms of expected targets and conclusions about the project's success.

### **Table 11.1: Content of a typical MEM report**

1. Executive summary
2. Introduction
  - a. Presentation of the management issue
  - b. Management actions implemented
  - c. Hypothesis and prediction
3. Study area
  - a. Description of the study sites
4. Methods
  - a. Study design, including phase-out of monitoring for active management projects
  - b. Sampling methods and techniques
  - c. Statistical analysis
5. Results
  - a. Effects of the management actions on the ecosystem
6. Discussion
  - a. Critical analysis of the design and results
  - b. Ecological interpretation of the results
7. Conclusion
8. References

### **11.3.1 General Management Effectiveness Monitoring Models**

Figures 11-1 and 11-2 present generalized monitoring models for the two kinds of management activities described above. The models can guide park MEM through a schematic representing the structured thinking for the two management types. You can visualize most MEM programs using these models.

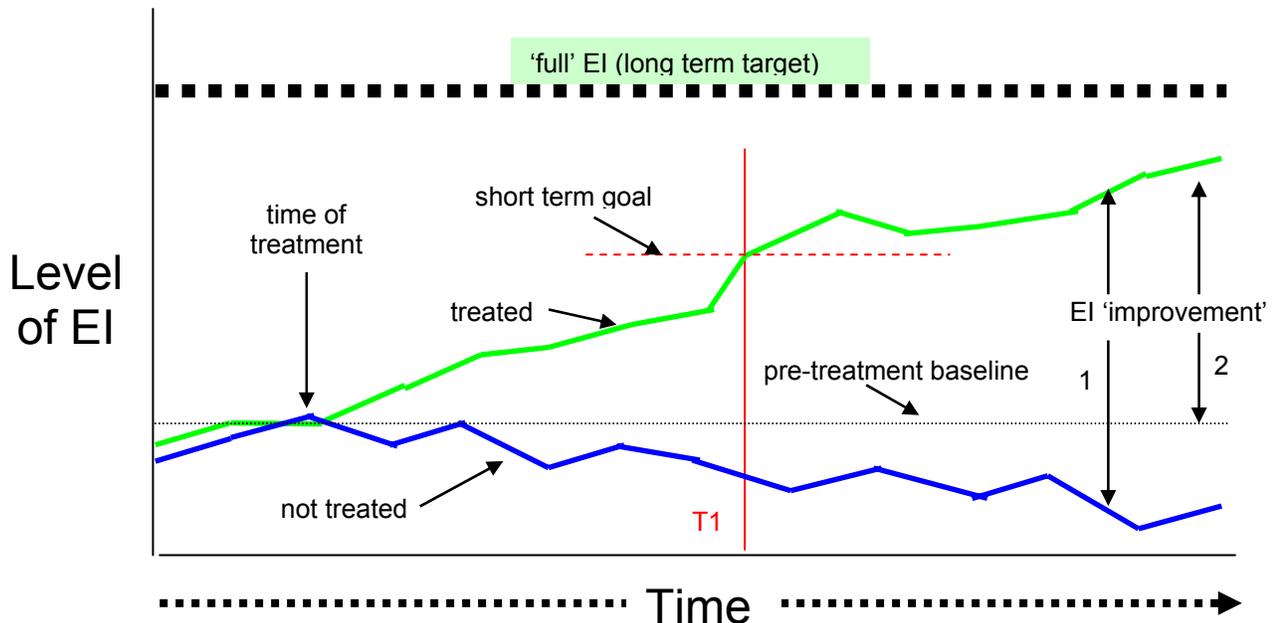
#### **11.3.1.1 Monitoring Active Management Projects**

The general model for monitoring active management projects (Figure 11-1) compares trends of EI measures for treated sites with untreated sites or with pre-treatment levels of the same measures. Differences in levels of the measures represent the improvement of park EI resulting from the active management project. Two scenarios are possible (1 and 2 in Figure 11-2):

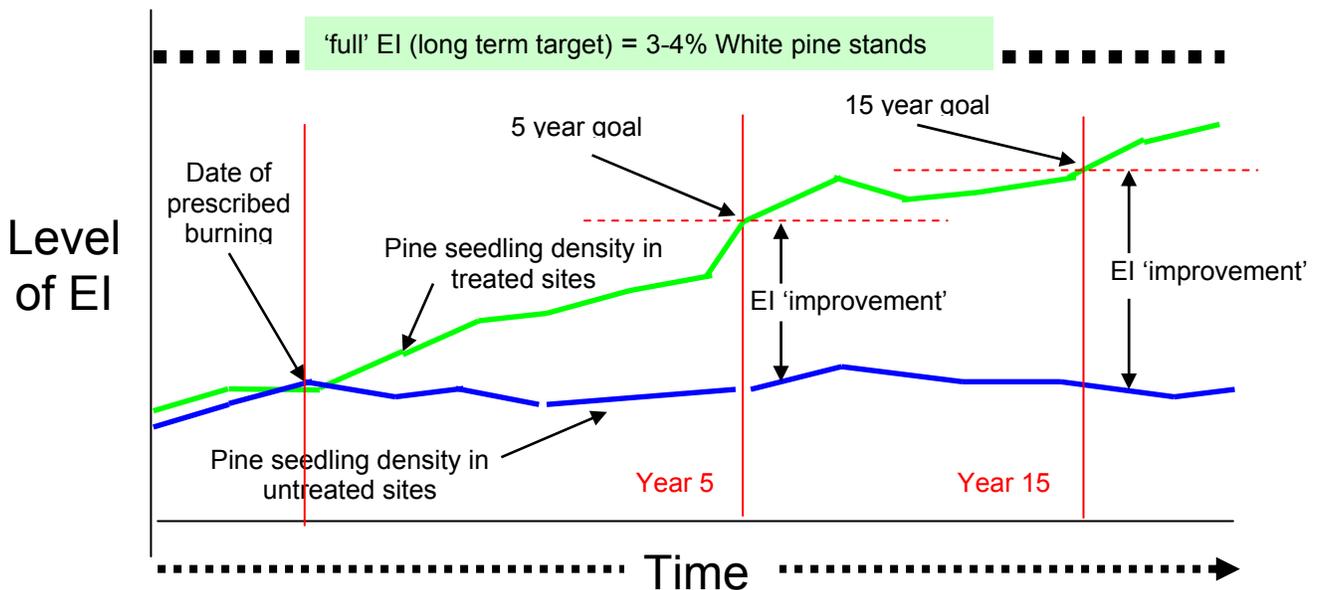
1. Levels of the measures (or trend lines for the measures) are compared between paired treated and untreated sites. This is an ideal scenario because the analysis accounts for trends for untreated sites. However, paired sites may not be

available, or the type of active management being assessed may not suit this kind of comparison.

2. Levels of the measures (or trend lines for the measures) are compared to a pre-treatment baseline, where paired untreated areas are not part of the study design. This type of assessment is less desirable because it assumes a constant trend in pre-treatment condition of the measures compared, if the management action had not been taken. In Figure 11-2 for example, the trend of the EI measure at untreated sites is negative, so that comparison with the pre-treatment baseline will underestimate the level of EI improvement resulting from the active management. That is, the real treatment effect is line 1, but the reported treatment effect is line 2. The trend for the untreated sites could also be positive, and this method could overestimate the effect.



**Figure 11-1: General model for management effectiveness monitoring of active management projects.**



**Figure 11-2: General model for management effectiveness monitoring of active management projects using the prescribed burning in La Mauricie National park as an example.**

Another important component of the general model for active management is the establishment of a level of the measure that will represent 'full EI', i.e. a long-range management target that establishes when full recovery of the EI measures is attained. This target will often be beyond the period of the study design for the active management project, or it may not be relevant to some projects.

One of the difficulties of showing positive results from active management interventions in ecosystems is the length of time it often takes for ecosystems to recover. A final aspect of the model shown in Figure 11-1 is the identification of short term goals, i.e., levels of the measure that will show progress of the active management in a shorter period than full ecological recovery. In Figure 11-1 this corresponds to targets set out in the study design for the desired level(s) of the measure(s) at Time 1 following the management action. These results can be reported in the short term (in the SOPR for example) to show the EI improvement resulting from the management action and a positive trend toward the long term EI goal.

### 11.3.1.2 Examples of Monitoring Active Management Projects

Example 1: La Mauricie National Park – Increasing the White Pine Component in Park Forests

#### 1. Identifying the management issue, and establishing desired condition

The Park Management Plan may describe active management issues and will present management actions, although usually not in the detail required to implement the action. For example, the PMP specified use of prescribed fire to achieve EI goals. Park science staff identified the under-representation of white pine stands in the park as a management issue for the park in the Fire Management Plan. Thériault and Quenneville (1998) prepared a white pine ecological restoration plan, and the MEM project is a component of this plan.

The desired condition for an active management plan may be difficult to establish precisely from the scientific literature, or from historic inventories or ecological reconstructions. At LMNP Thériault and Quenneville (1998) determined that pure white pine stands should cover at least 3-4% of La Mauricie National Park to reach the park's EI goal (minimum threshold of the desired condition). However, due to logging before park establishment, and long term fire suppression, this stand type presently covers <1% of the park surface area. The the management action's general objective was thus to increase representation of white pine in park forests to historical levels of 3-4%.

#### 2. Hypothesis and prediction statement related to proposed actions

A statement of hypothesis and prediction helps focus your attention on a management action's expected effects. For example, we can postulate that prescribed burning is an effective tool to stimulate white pine regeneration, and afterward increase representation of the species. One prediction related to this hypothesis is that treated stands, i.e., stands subjected to prescribed burning, will have a higher density of white pine seedlings following fire than untreated sites. Another prediction is that the dominance of white pine will increase or be maintained in treated stands, while the species will continue to be suppressed in untreated stands.

#### 3. Design of a controlled experiment able to detect the expected changes

The design for the management action was to select a number of suitable sites, burn some of them, leave others untreated, and compare white pine regeneration between the two sets of sites. In Figure 11-2 we show the model from Figure 11-1 using the LMNP prescribed burning as an example.

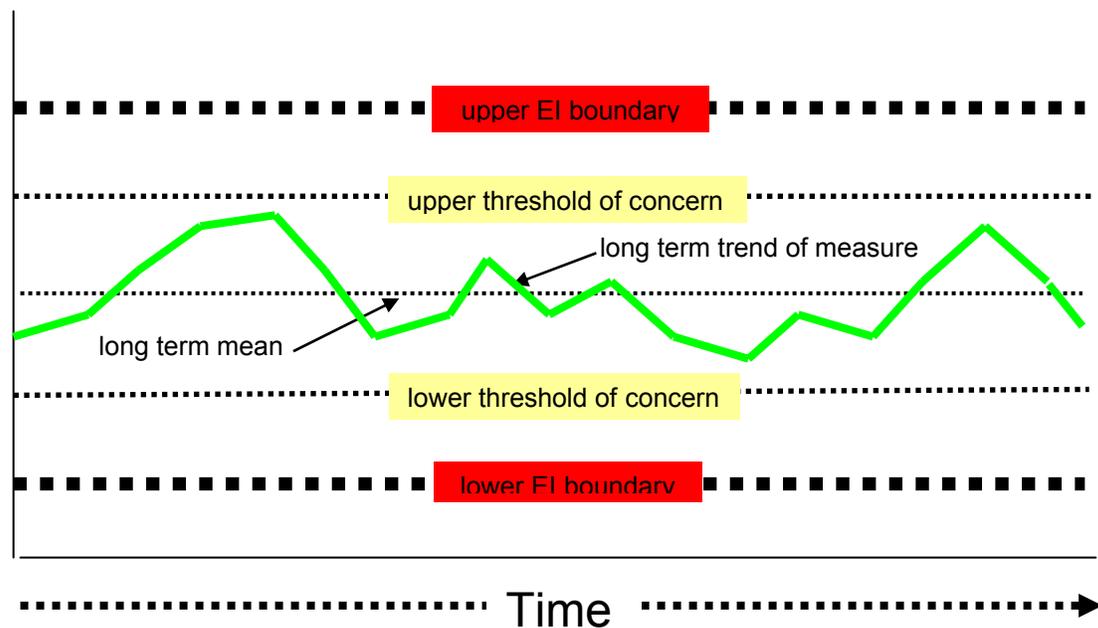
The EI measure in the management action is the density of white pine seedlings, and comparing densities between treated and untreated sites is a measure of the effectiveness of the management action in the context of park EI. Goals were set for 5, 10, 15 and 20 years following treatment to establish EI based targets for the prescribed burning. So, although it will take many years for LMNP to meet its long term goals of 3-

4% coverage of white pine dominated stands, these interim results can be reported (in the SOPR) as 'EI improvement', and we can infer that LMNP is progressing towards long term goals identified by Thériault and Quenneville (1998).

### 11.3.1.3 Monitoring as part of passive management

The general model for monitoring ongoing park policies and operations (Figure 11-2) shows the trend line for a monitoring measure relevant to a particular management activity or policy. For example the trend line may be for a measure of:

- fish population abundance from lakes or streams where recreational fishing is permitted,
- numbers of grizzly bears in a well used area of the park,
- numbers of a park focal herbivore population,
- values for a trail use index,
- levels of the Canadian Water Quality Index below a park town site, or
- the number of snowshoe hares where snaring is permitted.



**Figure 11-2: General model for management effectiveness monitoring of ongoing park management or operations.**

The role of MEM here is to assure park managers that ongoing management or policies do not threaten EI. We represent park EI through selected measures, and we monitor to ensure that levels of the measure do not exceed pre-established levels. This means that to monitor effectively we must establish management thresholds for the measure in question, and if levels exceed this threshold, then management action will be required (in these cases the general model outlined in Figure 11-1 would apply).

Following the precautionary principle, you must establish an upper and lower threshold of concern for the monitoring measure. In some cases either an upper or lower threshold will be sufficient, as for example the water quality index measure. We should mention as well that the threshold of concern here is the same principle as for the general model of assessing measure levels for EI condition monitoring (section 5). It is intended as an early warning to alert park managers of the need to assess the situation to determine what action may be required. For the lake example you could examine harvest levels, for the coliforms, you could evaluate local pollution sources, and for grizzly bears you could analyse visitor-bear interactions data.

Above and below the threshold of concern is that level of the monitoring measure that you determine to be outside the park's EI boundary. Regarding the threshold of concern, there may only be an upper or a lower EI boundary for the measure, and the concept is the same as for EI measures for condition monitoring. This level may correspond with an exceedence of the Canadian drinking water standard, local coliform standards, or levels of a park ungulate that you determine are either too low to sustain a long term population, or too high in relation to other park resources (hyperabundant population).

You will determine the scope and size of this component of the park EI monitoring program based on management needs and available resources. Parks will not have monitoring measures for every aspect of management and operations, and many EI stressors are little affected by park management efforts. However, park managers should at least be able to account for ongoing management and park policies in the context of ecological integrity. To meet Parks Canada's objective of 'protecting' EI as you 'present' it to Canadians, you should be able to show, for a key subset of these management policies and operations, that they are within acceptable bounds of park EI.

#### **11.3.1.4 Other Parks Canada MEM Projects**

Table 11-2 presents Parks Canada projects that apply the models for management effectiveness monitoring above. The table summarizes relevant background, management actions, measures used to represent EI, and study design information. References for project reports are given below the table. Full reports not available at other internet sites are listed on the PCA Intranet monitoring site: ([http://intranet/content/eco-re/monitoring-suivi-eng/HomePgAccueil\\_e.asp#TopOfPage](http://intranet/content/eco-re/monitoring-suivi-eng/HomePgAccueil_e.asp#TopOfPage))

**Table 11-2: Examples of management projects with management effective monitoring strategies that permit assessment of EI improvements that have resulted from the investment in park EI.**

Project	Background	Management	EI Measures	Study Design
Wolf corridor restoration (Jasper NP) <sup>1</sup>	Wolf-elk-human interactions are an ongoing management issue in mountain parks. Elk and deer tend to congregate in valley-bottom settled areas to exploit best habitats and reduce exposure to human-wary predators such as wolves. The park worked with a local golf course to modify fencing to create a corridor. An effective before and after monitoring plan was able to show the positive results of the investment.	<ul style="list-style-type: none"> <li>• Modify fence to permit travel of ungulates and predators through park golf course; wood-rail fence design restricts ungulates to corridor but is permeable to wolves</li> <li>• install gates to permit people to cross and use corridor</li> <li>• install counters on trails to assess human use of corridors</li> <li>• re-locate winter skiing and hayrides away from corridor</li> </ul>	<ul style="list-style-type: none"> <li>• relative abundance of elk, deer, and wolves from winter track transects</li> <li>• wolf movement paths from snow back-tracking</li> <li>• snow depth</li> <li>• human use counters</li> </ul>	<ol style="list-style-type: none"> <li>1. Establish levels of the measures before treatment</li> <li>2. Compare corridor use measures after fence construction with pre-construction use</li> <li>3. account for covariates such as snow depth and human use</li> </ol>
Stream restoration <sup>2</sup> (Pacific Rim NP)	Historical legacy of logging before park establishment has left important salmon-bearing streams full of decaying logs and disconnected through poor culvert maintenance. This has resulted in reduced flows, increased stream temperatures, deposition of organic material over spawning gravels, deterioration of water quality, and undesirable changes in biotic communities including benthics, fish and other vertebrates.	<ul style="list-style-type: none"> <li>• remove logs and debris to restore flows;</li> <li>• improve culverts to re-establish connectivity</li> <li>• add gravels as required</li> </ul>	<ul style="list-style-type: none"> <li>• water quality</li> <li>• water temperature</li> <li>• benthic invertebrates</li> <li>• salmon smolts</li> <li>• adult salmon returns</li> </ul>	<ol style="list-style-type: none"> <li>1. Establish levels of the measures before treatment</li> <li>2. Compare measures at treated sites with similar untreated sites</li> <li>3. Compare measures at all sites with similar pristine old forest sites to establish long range targets</li> </ol>

**Table 11-2 (cont.): Examples of management projects with management effective monitoring strategies that permit assessment of EI improvements that have resulted from the investment in park EI.**

Project	Background	Management	EI Measures	Study Design
Logging dam removal <sup>3</sup> (Kejimikujik NP)	Old logging dams constructed to permit log floating now reduce habitat quality and restrict fish and other aquatic organisms from accessing important fish habitats in lakes above the dam.	<ul style="list-style-type: none"> <li>• Three old logging dams were removed in 2004 and 2005</li> </ul>	<ul style="list-style-type: none"> <li>• Fish species abundance in fish traps</li> <li>• pH, conductivity, O<sub>2</sub>, and turbidity</li> </ul>	<ol style="list-style-type: none"> <li>1. Streams were sampled for fish while dams were in place in 2000</li> <li>2. water quality was tested in 2003 before dam removal</li> <li>3. fish abundance and diversity and water quality were sampled following dam removal</li> </ol>
Ski Hill Management <sup>4</sup> (LYYK)	Summer operations of ski hill area use in Lake Louise appeared to have a negative effect on a vulnerable grizzly population. As a condition of the business licence, management changes were implemented and effects are being assessed through a series of EI measures	<ul style="list-style-type: none"> <li>• electric fence constructed</li> <li>• alterations to human use patterns</li> <li>• control of human noise</li> <li>• strict adherence to NPA garbage regulations</li> <li>• education of lodge staff</li> <li>• staff education of park visitors</li> </ul>	<ul style="list-style-type: none"> <li>• tracking bears in area to determine spatial and temporal use patterns; assess 'bear jams'</li> <li>• birth and death data of local grizzly bears</li> <li>• measure levels, type, and timing of visitor use</li> <li>• measure noise with a sound detection metre</li> <li>• compliance monitoring of garbage regulations</li> <li>• counters to measure traffic abundance and timing</li> <li>• visitor surveys to assess awareness of bear issues</li> </ul>	<ol style="list-style-type: none"> <li>1. all measures were assessed at the onset of the management changes</li> <li>2. measures are assessed annually in an adaptive management approach to develop management regulations for the business licence that optimize bear survival and human use</li> </ol>

<sup>1</sup> Shepherd, B., and J. Whittington. 2006. Response of Wolves to Corridor Restoration and Human Use Management. *Ecology and Society* 11(2):1. [online] URL <http://www.ecologyandsociety.org/vol11/iss2/art1/>

<sup>2</sup> Wartig, W. 2006. Results of a workshop to establish a monitoring program for stream restoration projects in and around Pacific Rim National Park. Workshop results on the PCA monitoring website (URL)

<sup>3</sup> Dick, J.A., and M. Trudel. 2006. Survey of fish species following removal of old logging dams in Cobrielle Brook, Kejimikujik National Park and National Historic Site. Internal Report, Kejimikujik National Park and National Historic Site. 13 pp.

<sup>4</sup> Parks Canada Agency, Lake Louise, Yoho and Kootenay Field Unit, and Skiing Lake Louise. 2002. Research and Monitoring Framework, Skiing Lake Louise Summer Business Licence. Internal Report, Lake Louise, Yoho and Kootenay Field Unit.

## **11.4 Interactions between Management Effectiveness Monitoring and EI Condition Monitoring**

EI condition monitoring and MEM are distinct components of the park EI monitoring program. However you should explore opportunities for overlap to optimize program design and use of monitoring resources. Management effectiveness monitoring and EI condition monitoring address two different questions. Management effectiveness monitoring projects are generally smaller in area and briefer than EI condition monitoring. Typically, MEM projects focus on the areas where management actions apply, while EI condition monitoring covers the whole park. Management effectiveness monitoring projects are < 5 to 20 years duration, and will be normally discontinued, while EI condition monitoring projects are ongoing, and sampling is often only once in five years. Long term monitoring of park operations or policies focuses on the area of interest, addressing the MEM question about effects of management actions. Management effectiveness monitoring projects use more focussed experimental designs addressing specific questions for specific management actions, and often include treatments and controls. This is not possible for long term EI condition monitoring.

You may be able to integrate these two monitoring program components . Where the scale of the management intervention approaches the scale of the whole park, then monitoring established for EI condition assessments may inform specific management actions. For example, where a park has a management issue with hyperabundant ungulates, resulting management action for the whole park may involve long term forest or wetland plots. Similarly, prescribed burning to adjust the balance of forest ecosystem structural stages in a park will overlap with landscape scale targets for forest ecosystem representation, or for critical habitat for wide ranging species at risk such as woodland caribou. Clearly, overlap of MEM and EI condition monitoring will increase with the scale of the management action and will be more common in smaller parks.

Another opportunity for overlap of MEM and EI condition monitoring is in providing long-range EI targets from EI condition data for MEM projects. For example:

- plots in old forest stands on similar ecological sites can provide long term targets for forest structure and composition for restoration projects, or
- measures of aquatic EI in pristine streams can inform long-term targets for in-stream restoration.

You will find similar opportunities for program integration as EI condition and MEM mature in your park.

Finally, the project components this guide describes for EI condition monitoring generally apply to MEM projects, e.g., principles of study design, power and significance, developing clear monitoring questions. The main difference is in the question being asked. For EI condition monitoring the question is always 'What is the state of park EI?'. For MEM projects the monitoring question will be specific to the needs of the project being monitored.

## 12. INFORMATION MANAGEMENT FOR EI MONITORING

This section describes current practices for managing information and processing data for EI monitoring. You must record your methods and results in the Information Centre for Ecosystems using appropriate metadata (information about your data).

Information management (IM) refers to an interdisciplinary process that combines skills and resources from librarianship and information science, information technology, records management, archives and general management. Its focus is information as a resource itself, independent of the content of the information. Information management is a critical step in a park's EI monitoring program.

Information management is important for several reasons:

1. Effective IM adds value to Parks Canada's EI monitoring investment. EI monitoring continually collects data, adding to our knowledge of the behaviour of major park ecosystems. A key to success is that methods be as consistent as possible to assess trends accurately. Staff must be able to access long term datasets and associated metadata and program information. Analysts must also confirm that the sampling design, protocol, or other important aspects of the program remain consistent. Without these metadata you might mistakenly perceive a change in park EI that was in fact an artefact of a methodological change.
2. Effective IM is a valuable information source for EI monitoring staff. With staff turnover, new employees will require a consolidated reference on their park's monitoring program, including details of indicators, measures, protocols, sampling designs, equipment, data, analytical tools, and so on. Also, they need to know how the program has changed over time, especially if data for certain periods may be biased. (This could be due to staff vacancies, failed sampling equipment, or conflicting park operational priorities. Such program history, captured in a park's IM strategy, will maintain corporate memory.
3. By using recognized metadata standards (such as the Federal Geographic Data Committee (FGDC) and the National Biological Information Infrastructure (NBII)) that are used by other resource conservation organizations, Parks Canada will be able to share data more effectively with its partners. At all levels - park, field unit, bioregion, national - Parks Canada has data sharing agreements serving a wide range of programs, including EI monitoring. Parks Canada's national metadata working group developed metadata standards consistent with recognized, international standards (see description below).
4. Effective IM is an Agency requirement as described in the Ecological Data Management Bulletin 2.4.9 (<http://intranet/content/Pol-Dir/dir-eng/dir2-4-9-i.asp>). IM is a core part of all Parks Canada business, including EI. Thus a park's

EI monitoring program will be incomplete without an IM strategy consistent with the guidelines described here. IM is a fundamental component of EI monitoring, not an add-on. IM for EI monitoring will involve at least 10% of a monitoring project's total time and expense. Managers should be aware of this and budget accordingly.

Much of the IM program elements for EI monitoring are currently under development. Consult the following sources if the information here becomes dated.

- Parks Canada's national intranet site. In particular, these sections:
  - Information Management, Technology, and Services ([http://intranet/content/Imit-Giti/index\\_e.asp](http://intranet/content/Imit-Giti/index_e.asp))
  - Research, Collection and Monitoring in Heritage Areas ([http://intranet/content/eco-re/index\\_e.asp](http://intranet/content/eco-re/index_e.asp))
- Parks Canada EI Monitoring and Species at Risk Data Management Plans (draft). 2006. (Contact Ewen Eberhardt, National Office, Ecological Integrity Branch or your Bioregional Coordinator for a copy of the most recent version.)

From the National Ecological Integrity Monitoring Task Team (NEIMTT), the National Interdisciplinary Metadata Working Group, Ecological Integrity Metadata Profile Working Group, and the National Geospatial Metadata Working Group, IM for EI monitoring must contain these elements:

1. a park's EI monitoring plan,
2. monitoring project descriptors,
3. data files for individual monitoring measures,
4. standardized metadata records for each monitoring data file,
5. in-park file management systems,
6. bioregional archives of park monitoring plans, data and metadata, and
7. Parks Canada's national Information Centre for Ecosystems (ICE) and Biotics.

## **12.1 Park EI Monitoring Plan**

Every park requires an EI Monitoring Plan. This plan describes a park's conceptual ecosystem model(s), bioregional indicators, monitoring measures, protocols, and sampling designs. The ICE system will contain much of this information.

## **12.2 Monitoring Project Descriptors**

Every project in your EI monitoring program must be catalogued in ICE. The ICE system requires you to complete monitoring project descriptors – a standard for describing key elements of each project. A project may refer to a single monitoring measure, or a collection of measures in a common sampling unit (e.g., multiple measures monitored in 20x20m EMAN forest plots). Each monitoring project must catalogue the 23 descriptors listed below. For a definition of each descriptor and the online system for entering this

information, please visit ICE through the EI Monitoring and Reporting Program intranet site ([http://intranet/content/eco-re/monitoring-sui-ving/HomePgAccueil\\_e.asp#TopOfPage](http://intranet/content/eco-re/monitoring-sui-ving/HomePgAccueil_e.asp#TopOfPage)).

1. Park Name
2. Monitoring Measure
3. Indicator(s) that measure supports
4. Lead Agency
5. Measure Leader
6. Measure Rationale
7. Objective
8. Scope of sampling (single location to global network)
9. Dataset – data file name
10. Year of data
11. Data access and constraints
12. Funding and Person Time
13. Park Management Plan reference
14. Staff
15. Contacts
16. Comments
17. Category (Ecological, Cultural, Visitor Experience, Public Understanding)
18. Type (Condition Monitoring, Management Effectiveness Monitoring, Research)
19. Framework (Biodiversity, Process, Stressor)
20. Description
21. Active or Non-Active
22. Updated (when and by who)
23. Thresholds

### **12.3 Data Files for Individual Monitoring Measures**

Take care in managing data files for individual monitoring measures. Most errors involve data entry and data manipulation. You can waste a lot of time and money collecting monitoring data through inadequate attention to data file management. Common errors include:

- input error (e.g., typos),
- spreadsheet variable format errors (e.g., column formatted as a numeric field versus a data field),
- separate files created for the same monitoring measure sampled in different years (all the data are not present for analysis), and
- spreadsheet is not formatted as a “flat” file with unique variables as columns and unique observations as rows (data not in a format for export to statistical software packages).

Suggestions for avoiding these errors include:

- *Electronic Data Entry Forms:* You can create these forms using software such as MS Access or Excel. The forms can use standardized, controlled vocabulary involving drop down lists or check boxes that minimize typing to input data. You can also save electronic data forms on in-field data collection devices such as PDA's. Before you create databases with data entry forms, however, we suggest that you ensure each measure's protocol is well established. (Some national parks have developed protocol databases, and a protocol was changed or deleted soon afterwards.)
- *Password Protected Spreadsheets:* If several people will input monitoring data in spreadsheets, consider protecting the spreadsheet structure to prevent columns or formulae being reformatted accidentally. With a protected spreadsheet, only users with a password can change the file's structure. In Excel, you can access these protection functions through the Tools menu.
- *Collaboration with Bioregional Coordinator on Database Format:* Databases for some monitoring projects can become very complex, especially when you track several species, multiple variables, and different sites at various times. In such cases formatting a spreadsheet in a "flat" file for easy export to a statistical software package may not be straightforward. Here, staff should consult their bioregional coordinator. All bioregional coordinators have extensive experience with statistics.
- *In-Park Training:* Operational staff involved in monitoring are often students, term or seasonal employees, and a high turnover rate is common. Thus IM is an important, but often overlooked component of staff training in monitoring. staff learn monitoring protocols and sampling techniques but not how to use a database. We recommend regular IM training for all monitoring staff.
- *Quality Control Review:* Park monitoring ecologists' annual work plans should include time after each field season to review monitoring databases updated that year. This review will ensure the database is free of entry and formatting errors. A simple way to conduct such a review is to chart the data or do some simple descriptive analyses. This should highlight data outliers that may result from entry error.

## **12.4 Standardized Metadata Records for each Monitoring Data File**

Metadata refers to "data about data". Metadata describe origins and characteristics of a particular dataset. Every EI monitoring dataset requires specific, standardized metadata records. These records are similar in intent to monitoring program descriptors except they describe individual monitoring datasets versus individual monitoring projects.

Parks Canada has working groups to develop metadata standards for all functions within the Agency (e.g., EI, cultural resources management, archaeology). For EI monitoring, these are the National Interdisciplinary Metadata Working Group, Ecological Integrity Metadata Profile Working Group, and the National Geospatial Metadata Working Group. Parks Canada is still developing metadata standards. For an update, visit the Information

Management, Technology, and Services intranet site ([http://intranet/content/Imit-Giti/index\\_e.asp](http://intranet/content/Imit-Giti/index_e.asp)).

While the specifics are lacking as yet, these functions follow a consistent approach:

1. All data records follow the Parks Canada Agency Core metadata standard.
2. For data files (versus non-data files like written reports), a Structured Data Profile will apply with selected elements from the FGDC standard.
3. For EI data files (all EI data files, not just EI monitoring—will include Species at Risk, environmental assessment, etc.) an Ecological Integrity Profile will also apply that adds other specific metadata elements from NBII.
4. If applicable, a Geographic Information System Profile (e.g., projection, datum, coordinate system) will also be applied if a particular dataset is a GIS file. These profiles work together where applicable. For example, for an ArcGIS shape file of a sampling design for an EI monitoring measure, the required metadata records will include:  
PCA Core + Structured Data Profile + EI Profile + GIS Profile.

When the metadata elements are selected for the PCA core metadata standard and various metadata profiles, Parks Canada will provide customized ArcCatalogue and/or stand-alone metadata templates for staff to catalogue their metadata. In addition, customized metadata tools will be developed for non-Parks Canada staff, such as researchers and consultants, to use. (Non-Parks Canada staff often generate EI data. Metadata for these records will also be mandatory).

## **12.5 In-Park File Management Systems**

There are no national EI monitoring guidelines for in-park file management. However, professional IT, data management or GIS Specialist staff should manage IM at a park. EI monitoring staff should consult their IT and data management or GIS colleagues regarding the process for in-park file access and management.

## **12.6 Bioregional Archival of Park Monitoring Plans, Data and Metadata**

Annual updating of monitoring data for service centres should be a formal part of each national park's IM strategy. Parks should send copies of all updated monitoring plans, protocols, data and metadata to their bioregional coordinator by the end of each fiscal year. This serves several purposes:

- It provides redundant, off-site archives of information for security.
- It allows bioregional coordinators to respond centrally to multi-site data quests (from national office or partners),
- It ensures that data entry for all monitoring measures for each year is completed.
- It will facilitate updating ICE.

## 12.7 Parks Canada's National Information Centre for Ecosystems and Biotics

The Information Centre for Ecosystems and Biotics are centralized tools to help parks manage EI monitoring and species at risk related information. ICE is a web-based IM tool managed through the national office. The Information Centre for Ecosystems is an IM solution for Parks Canada's EI monitoring results, providing storage and access for:

- bioregions and the parks within them,
- park indicators and their annual levels and trends,
- park indicator measures and their levels and trends,
- metadata and protocols for each measure, and
- datasets, summary data, and links to datasets for each measure.

The Information Centre for Ecosystems is still being developed and tested. You can find updates (and eventual access into the ICE system) at the EI Monitoring and Reporting home page ([http://intranet/content/eco-re/monitoring-suivi-eng/HomePgAccueil\\_e.asp#TopOfPage](http://intranet/content/eco-re/monitoring-suivi-eng/HomePgAccueil_e.asp#TopOfPage)).

Biotics is IM software provided through a Parks Canada - NatureServ partnership. Biotics contains a suite of tools (Biotics Tracker, Biotics Mapper, Biotics Web Explorer, and Biotics Mapper Reader) to help parks manage species occurrence and element occurrence data. The main application of Biotics is for the Species at Risk program but there will be some overlap with EI monitoring, particularly where parks have identified species at risk as monitoring measures.

For more information on both ICE and Biotics, review *Parks Canada EI Monitoring and Species at Risk Data Management Plans* (draft, 2006) and the Information Management, Technology, and Services intranet site at [http://intranet/content/Imit-Giti/index\\_e.asp](http://intranet/content/Imit-Giti/index_e.asp).

When fully deployed, ICE and Biotics will be mandatory elements of each park's IM strategy for EI monitoring. This will provide Agency-wide standards, helping us better manage our EI data and share information (internally and externally).

## 13. DATA ANALYSIS

This section addresses statistical analysis related to status and trends in EI measures. It describes various complexities in analysing EI data and tells how to avoid common statistical errors.

### 13.1 Importance of good analysis

Statistical analysis goes hand in hand with study design and power analysis, helping determine a monitoring project's scientific credibility. The analysis step lets you derive useful information from field data. That information's quality depends on quality data and quality analysis. So make sure you use appropriate statistical tools.

### 13.2 How to interpret change

The values of our measures will change constantly. Your challenge is to interpret that change. First, you must determine whether the change is statistically real. Considering the variability of the data, your chosen confidence level, and the magnitude of change, your data analysis method will indicate whether the change is statistically significant. If so, then you ask a second question: is the statistically significant change ecologically relevant? Statistical significance can be misleading, since a significant change can be detected by increasing the sample size - remember that the standard error of the mean decreases with sample size ( $SE = s/\sqrt{n}$ , where  $s$  is the estimated standard deviation of the population, and  $n$  is the sample size.). Whether a change is ecologically significant will depend upon the change's effect on the underlying ecological system. Considering what constitutes an ecologically significant change in a measure is an important step in study design (See section 7.4.1).

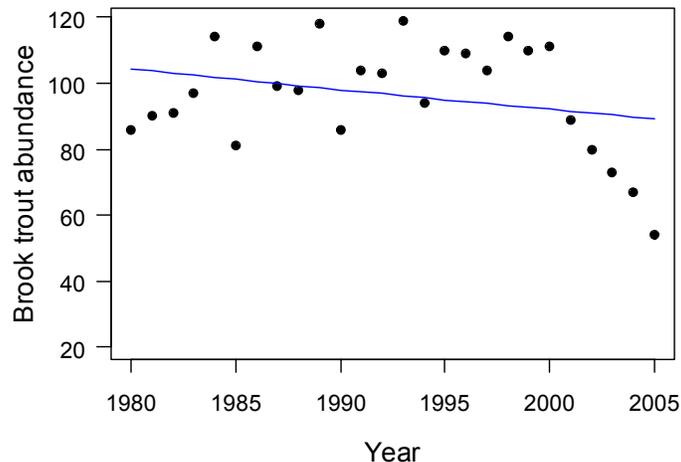
However, for a well designed measure, you will have conducted a power analysis and selected a study design and sampling regimen so that the threshold for statistical significance should correspond to the threshold for ecological significance. For example, if you determine that for a caribou population abundance, a decrease of 5% per year is ecologically significant, you will design your monitoring program to maximize the chances of detecting a statistically significant change of 5% per year or greater.

A further complication is that the final arbiter is not ecological relevance, but management relevance. For some measures not always, the management relevance will reflect ecological relevance.

### 13.3 Trend vs. status analysis

The monitoring program aims to deliver information on both **status** (the current value of your measure) and **trend** (how is your measure changing over time?). These two goals are not necessarily complementary. For example, status is often best determined using temporary sampling plots incorporating all measures in the same year, whereas trend is best determined using permanent sampling plots measured regularly and systematically. Moreover, determining trend and status will often require different kinds of analyses.

Detecting trends over time can involve different types of analysis. For example, we often use the generalized linear class of models (of which linear regression is a special case) when testing for a change over time in a single species attribute (e.g. abundance) or single environmental variable (e.g. temperature). When testing a community response (multiple species simultaneously) to change, you can use ordination methods or multivariate regression. An important consideration will be the time period over which a trend is analysed. As discussed in section 9.5 regarding power analysis, the more data you have over time, the more power you will have to detect a change. However, using the entire data set may not be relevant, especially if recently collected data are deviating from historical data, as recent data may be swamped by historical data (Figure 13-1).



**Figure 13-1. An example of a trend analysis where data in recent years do not fit the long term pattern.**

You can also determine your measure's status with different analysis techniques. The simplest involve calculating a mean or median over the period of interest (e.g. the last five years). However, if there is a strong trend in the data, the mean or median may give misleading status information. In this situation, it may more useful to use the estimated value from your trend analysis for the most recent year data were collected.

## 13.4 Analysis complexities

Because there will always be complexities in the analysis, there are no cookie-cutter solutions. You will need training and consultation with experts. The following sections describe certain complexities related to monitoring.

### 13.4.1 Sources of variability

Data analysis is hard because you are trying to determine status or a trend in the face of variability. Below we describe major sources of variability and some means to deal with them (See Urquhart et al. (1998) for details).

- *Variability among sites:* The value you measure at one site will not be the same as that at another site the same year. This is often called spatial variability, and is one reason why monitoring is often based on permanent sampling plots. With permanent sampling plots, you can account for the spatial variability by estimating a site-specific intercept (or mean) in your analysis.
- *Variability over years:* The average value for all sites may change from one year to the next. These are usually the changes that your monitoring program is attempting to detect, and hence these will be an explicit part of your analysis.
- *Variability in rates of change among sites:* Even though the mean among sites may change over time, individual sites may be changing in slightly different ways. This variability is what makes your estimate of how the overall level is changing uncertain. One possibility is to estimate a site-specific trend over time. However, this is rarely useful, since you wish to know how the overall mean is changing over time, not how individual sites are changing.
- *Measurement error:* In addition to uncontrollable sources of variability mentioned above is the variability resulting from the measurement process itself. For example, no measurement instrument is perfect (including humans) and repeated measurements of the exact same thing are usually slightly different. Other sources of measurement error may be related to slight changes in the timing of observations from year to year, or in the exact location of measurements from year to year. You can reduce this source of error by adhering carefully to the protocol methodology. You can also estimate and attempt to account for this type of error by repeated sampling sites within the same year, for example, as part of a quality assurance program that estimates observer error, or within-year variability.

Your analysis technique should account for these different sources of variability. You can do this either by adding additional variables describing site characteristics to your model, besides year, or by using random effects in your statistical model.

### 13.4.2 Random vs. fixed factors

In analysing status or change, you will often attempt to account for differences among sampling sites, or for lack of independence.

### 13.4.3 Avoiding common statistical errors

- *Identify the correct unit of analysis.* Often, we mistake the unit that is replicated in space and which we remeasure over time. The unit of analysis can be individual organisms (e.g. if you are measuring individual attributes such as growth or survival), but more commonly the unit of analysis will have a spatial component – a quadrat within which you count organisms, or measure decomposition.
- *Pseudoreplication.* Hurlbert (1984) first addressed this topic. Pseudoreplication occurs when you overestimate the number of independent sampling units. This leads to underestimates of the true variability, and an increasing chance of drawing false conclusions about pattern in the data. As an example, consider a study design where you measure forest decomposition using 4 decay sticks per forest plot. The design includes 40 forest plots. How many independent replicates are there of forest decomposition rate: 40 or  $40 \times 4 = 160$ ? The four decay sticks in the same forest plot are more likely to show similar results than decay sticks from other plots, and hence are likely not truly independent. Hence, you should not assume the sample size is 160, but since you don't know exactly how strong the plot effect is, you don't know the real sample size. The simplest solution is to average the decomposition rate from the four decay sticks to obtain a single estimate per plot. A more thorough treatment would involve estimating how correlated decay sticks within a plot are, using a random site effect in the statistical model. The latter approach will yield much more statistical power to detect a difference in decomposition rate over time.
- *Account for multiple testing error rate.* If you set your significance level at 0.1, then one in ten tests performed will be significant by random chance alone.
- *Inferring causality from correlation.* Monitoring is not a diagnostic tool. Most monitoring projects will be designed to correlate ecological measures with pertinent stressors, but even if a relationship exists, there is no statistical evidence to infer a causal relationship.
- *Matching conclusions to study design.* The study design will dictate the area of the park where you can make rigorous, defensible, statistical inferences from the analysis. If your sampling frame includes only bogs, you cannot make inferences about all wetlands in the park (see section 7 - Study Design).
- *Use appropriate "tailness" in your statistical test.* One-tailed tests are more powerful, but imply that you are only interested in detecting difference in a certain direction. For example, has mercury concentration in lake water increased from the

last observation period? Using a one-tailed test means that if mercury concentration hasn't increased, you won't know if that is because mercury concentration has stayed the same or decreased. That is, you will be unable to say whether mercury is decreasing. Generally, you will want to know about increases and decreases in the values of your measures, and hence will use two-tailed statistical tests.

- *Assuming a normal distribution:* Very few measures will generate data with normally distributed errors, which is an assumption of most simple statistical analyses. For example, count data (e.g., number of deer per transect or number of fecal coliform colonies in a water sample) will rarely follow a normal distribution, as counts have to be positive, and counts are discrete (you cannot count half a deer). Hence traditional methods like ANOVA and ordinary linear regression will not be appropriate tools. Instead, you must use other approaches such as
  - generalized linear models,
  - transformation of the dependent variable,
  - non-parametric test, and
  - randomization methods.
- 1. *Nonlinear trends:* Many changes over time will not follow a straight line. An exponential model is a great candidate for modeling curvilinear changes in time. Other nonlinear models can also be useful depending on the observed response.
- 2. *Temporal autocorrelation:* Most of the data you collect can be considered "time series", and often the value you record in one year will be similar to that recorded in the recent past. This is a form of statistical dependence that violates the assumption of independence of observations common to many statistical tests. Where temporal autocorrelation does exist, there are various methods to handle it.

## 13.5 Training

A good foundation in basic statistics and linear regression is essential. Linear regression is at the base of most techniques relevant to monitoring.

University/college classes

- Several universities offer correspondence courses in statistics

Online courses

- <http://www.statistics.com/>
- <http://training.creascience.com/>

Useful free information on the web

- Linear regression
  - [http://www.graphpad.com/curvefit/linear\\_regression.htm](http://www.graphpad.com/curvefit/linear_regression.htm)
  - [http://cs.gmu.edu/cne/modules/dau/stat/regression/linregsn/nreg\\_3\\_frm.html](http://cs.gmu.edu/cne/modules/dau/stat/regression/linregsn/nreg_3_frm.html)
  - <http://www.itl.nist.gov/div898/handbook/pmd/section1/pmd141.htm>

- Generalized linear models  
<http://www.statsci.org/glm/>  
<http://www.statsoft.com/textbook/stglz.html>  
<http://www.sfu.ca/sasdoc/sashtml/insight/chap39/sect3.htm>
- Ordination  
<http://ordination.okstate.edu/index.html#topics>

## 14. PUBLIC ENGAGEMENT AND COMMUNICATION

This section summarizes communication needs and challenges for the EI program. Your State of Park Report must convey assessments of ecological integrity, visitor experience and public understanding.

Section 1 stated that the central motivation for monitoring park EI is to show Canadians that their national parks are being protected, as mandated in our legislation. In fact, if you cannot convey your monitoring results, you probably cannot justify the cost of data collection. We are also strongly motivated to engage Canadians in park monitoring. This includes park visitors, neighbours, First Nations and Inuit, partners, and other stakeholders. The third volume in our PCA EI monitoring series of publications will prescribe communication and engagement approaches for EI monitoring and reporting.

This section summarizes program communication needs and challenges.

### 14.1 Engaging Canadians

Parks Canada has an Engaging Canadians strategy to ensure we:

- raise awareness of our management goals,
- promote visitors understanding and enjoyment of parks, and
- foster Canadians' sense of ownership in national parks (Parks Canada Agency 2001).

The park EI monitoring and reporting program can support all of these goals. The work can raise awareness of management goals by showing how we measure and report our success. When neighbours, visitors and stakeholders are aware of the program and understand its relevance, they will use the results to hold parks accountable for accomplishing EI objectives. A park-specific public engagement strategy should be an important component of your monitoring program.

## 14.2 Communication

As emphasized throughout this volume, communicating about park monitoring objectives, approaches and results is a key component of program development, and of its long-term success and sustainability. The park EI monitoring and reporting program will use various communication tools to ensure we engage park visitors, partners and stakeholders. These will apply at different levels:

- corporate reporting through various media opportunities,
- direct communication with visitors through the park interpretation program, and
- through targeted education and outreach initiatives.

To succeed we must also communicate internally in the park, in the bioregion, and among national parks. Therefore we have a program-wide intranet site, web server and newsletter. Frequent bioregional meetings and communication with bioregional ecologists will also be important. Methods for dialogue within a park or field unit, such as newsletters, presentations, and reports, will also promote discussion and understanding of program objectives.

We should also enhance communication with our science peers locally and regionally. This may include university staff, government employees and consultants. Here we aim to develop local or bioregional communities of interest in ecosystem monitoring and reporting. Most parks will have a science advisory board to address technical questions, review proposed projects and protocols, and connect park biologists with the wider science community. Monitoring is ongoing and contact with science peers will be critical to keep up with scientific developments.

## 14.3 Monitoring Protocols

The park EI condition program is to be in place indefinitely, so you can expect that park staff who will implement the program will change with time. A basic assumption of monitoring is that methods for measuring and assessing park EI will be repeated using the same methods for a very long time. Thus it is essential that project rationale, sampling, analysis and assessment methods, logistics and responsibilities, and standard operating procedures are documented and updated as required in the monitoring protocols developed for the program.

Another important component of developing clear protocols is to ensure the scientific credibility of the park EI monitoring and reporting program. You must be able to describe very clearly how you monitor a particular measure, or group of measures, so that science peers can assess your approach, suggest improvements where needed, and provide their 'stamp of approval' on the approach outlined in the protocol. The program's scientific credibility will be very important when, for example, park superintendents must support or defend controversial management decisions.

To ensure uniformity among national parks, the EI monitoring and reporting program has developed a protocol standard that outlines key steps in planning, implementing, and reporting on a particular EI measure or group of measures. Adapted from Oakley et

al. (2003), the protocol standard is provided in Appendix 2. Ongoing park EI monitoring should be upgraded to this standard and new measures designed following this outline.

#### **14.4 The State of the Park Report**

The SOPR is an important component of Parks Canada's results based performance framework, and every national park, national historic site and national marine conservation area prepares one. While the document originally focused on ecological integrity, it has been expanded to include all elements of the mandate (cultural resources, visitor experience and public education). The expanded document continues as an assessment and reporting tool relying heavily on information from monitoring programs described in this guide, and information developed simultaneously for cultural resources, visitor experience and public education. It also utilizes information from short term monitoring to assess management actions' effectiveness, and from park management plan Annual Implementation Reports.

The SOPR is key to the park management planning cycle (Figure 4-1 on page 9). Its assessment:

- underlies our understanding of the current 'state' of the park,
- helps assess the appropriateness of direction within the current management plan, and
- helps determine issues and priorities to address in the next management plan or five-year management plan review.

These reports form the basis of scoping documents. A copy of the completed SOPR must be attached to the scoping document when submitted to the CEO for discussion with the Field Unit Superintendent (FUS) and director general.

The SOPR also contributes to the State of Protected Heritage Areas Report, and it will be important information source for Parks Canada staff, stakeholders and the public.

In summary, the SOPR has these purposes:

- Clearly convey the state of, and long-term trends of a national park's ecological and cultural resources, visitor experience and public education, and their integration, to a wide public audience.
- Report on management actions' effectiveness in achieving results in mandate areas.
- Measure how well a park fulfilling its management plan vision and objectives related to these mandate elements.
- Help establish the scope of the next management plan review by considering the current plan's effectiveness in addressing existing and emerging issues.
- Provide a tool for informed decision making for issues associated with each of the mandate components and their relationships.

Central elements of the "state of" report are:

- a framework describing key indicators for the Agency's mandate,
- an assessment of conditions and trends for the key indicators and their associated measures,

- an assessment of the effectiveness of management actions, and
- an analysis of the key issues facing the heritage place in achieving desired results.

The following are current expectations for completing the SOPR. These will evolve as the Agency continues to integrate monitoring, analysis and reporting for all elements of the mandate.

- produced every five years - in the year before initiating the management plan or plan review
- public document based on science, but written in non-technical language
  - science to be subjected to peer or third party review
- based on an indicator/measure and target/threshold framework
  - typically, the first "state of" report will be limited by the availability of existing data and ongoing monitoring results.
  - the reporting approach will use a system of green/yellow/red markers to rate the condition of indicators/measures and a system of arrows to indicate whether the trend in the condition of the indicator is stable, declining or improving
  - for each mandate component (such as EI) we will develop a description of key issues and challenges relative to the condition and trend of indicators/measures
- will focus on the key indicators/measures and the relationships between mandate components
- is objective and represents all the relevant professional groups in the park
- will include a conceptual model to explain selection and integration of indicators and measures
- concise (< 30 pages) but supported by a compendium addressing technical issues of data quality, analysis and interpretation
- reports on state of the park and, to the extent possible, the greater park ecosystem
- uses available traditional ecological knowledge where possible
- The FUS is expected to consult the National Office Directorates for National Parks, National Historic Sites and External Relations and Visitor Experience. Currently the Executive Director – EI Branch must review and endorse the EI component of the report. The process for review and endorsement by the other National Office Directorates has yet to be defined.
- for cooperatively managed parks, the park management board would probably be involved in preparing the SOPR, and would agree to its content before final review and approval
- Reports should be highly visual, using graphs, tables, charts and photos with short text explanations.
- The first "state of" report for national parks and national marine conservation areas must reflect the commitments made in the establishment agreements.

A major challenge for the park monitoring and reporting program will be the need to complete data collection, analysis and assessment and presentation of results through the park SOPR within the five year reporting time.

A set of guidelines, tools and templates exist to help parks prepare SOPRs ([http://intranet/content/eco-prot/report-rapport-eng/HD\\_Ecosystemreporting\\_lb.asp](http://intranet/content/eco-prot/report-rapport-eng/HD_Ecosystemreporting_lb.asp)). While currently focused on EI, they will be updated to reflect all elements of the

mandate and their integration, and to ensure consistency with the new Guide to Management Planning.

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## GLOSSARY

**abiotic:** non-living; usually applied to the physical and chemical aspects of an organism's environment (Begon et al. 1990)

**adaptive management:** Adaptive management is done whenever the dual goals of achieving management objectives and gaining reliable knowledge are accomplished simultaneously; it is a scientifically defensible means of learning while doing

**alien species:** a species that was not originally found in a given area but is now found there as a direct or indirect consequence of human activity (Parks Canada terminology Bulletin 236)

**autocorrelation:** correlation of the error terms from different observations of the same variable; also called serial correlation. Source: Institute of Education Sciences, United States Department of Education:

[http://nces.ed.gov/programs/projections/projections2014/app\\_d.asp#stat](http://nces.ed.gov/programs/projections/projections2014/app_d.asp#stat)

**baseline:** level of an EI indicator or EI measure at the onset of monitoring

**biodiversity:** The variety of life, from genes and species to communities, ecosystems, functions and processes (from Protecting Canada's Endangered Spaces, Hummel, 1995)

**biotic:** living; usually applied to the biological aspects of an organism's environment, i.e., the influences of other organisms

**community model:** a mathematical model that summarizes the relative abundance of species in a plant or animal community to track change in community composition

**correlation:** an expression indicating the degree of association or mutual relationship between the value of two attributes, not necessarily a causal or dependent relationship

**conservation:** The implementation of measures for the rational use, maintenance and rehabilitation or restoration of natural resources (Parks Canada terminology bulletin 236)

**EI indicator:** one of 6-8 indices, comprised of an internal suite of EI measures, that are combined through semi-quantitative models to provide a clear message on a key park EI element

**ecological integrity:** The EI Panel's detailed and specific definition of ecological integrity is contained in section 2, Volume II of this report. In short, the Panel defines ecological integrity as follows:

"An ecosystem has integrity when it is deemed characteristic for its natural region, including the composition and abundance of native species and biological communities, rates of change and supporting processes."

In plain language, ecosystems have integrity when they have their native components (plants, animals and other organisms) and processes (such as growth and reproduction) intact.

**EI measures:** monitoring data that contribute to an EI indicator, that are collected over time following a strict protocol, to measure present condition and change since the last measurement date; an EI measure may be a single ecological field measurement, or may combine several field measurements into an index

**ecosystem:** An interdependent system of living organisms with their physical and geographical environment (Parks Canada terminology bulletin 236).

**ecosystem process:** any of a wide number of energy, biologic, and material flows between ecosystem components such as plant recruitment and survival, flooding, deposition and erosion, soil decomposition, pollination, soil weathering, and predation

**EMAN:** Ecological Monitoring and Assessment Network. EMAN comprises a network of approximately 100 research and monitoring sites in Canada which are organized in 14 terrestrial Ecological Science Cooperatives. EMAN provides a national perspective on the impacts of environmental changes on ecosystems, an early warning system that identifies new ecosystem changes as they emerge and reports on their distribution (EMAN website).

**field measurements:** The fundamental data collected through a monitoring project which contributes to an EI measure

**greater park ecosystem:** That area around a park where human activities directly affect the ability of the park to meet its mandated objectives.

**habitat:** The particular environment or place where an organism or species tends to live (Parks Canada terminology bulletin 236)

**impair:** To change the ecological structure or function of a given area so it no longer performs at an ecological optimum (Parks Canada terminology bulletin 236).

**Information Centre on Ecosystems (ICE):** a web-based information system containing all relevant monitoring information including park indicators and measures with levels and trends, as well as datasets, protocols, summary data, links between EI measures and indicators, and relevant geospatial data

**information management (IM):** an interdisciplinary process that combines skills and resources from librarianship and information science, information technology, records management, archives and general management

**infrastructure:** the basic structural foundations of a society or enterprise; a substructure or foundation such as roads, bridges, sewers (Concise Oxford Dictionary)

**interpretation:** an educational activity whose objective is to reveal meanings and relationships through the use of artefacts, illustrative media and first-hand experiences rather than by simply communicating factual information (Parks Canada terminology bulletin 236)

**judgment or representative sampling:** using logic or common sense to select to study sites; for example, choosing sites that “look” typical

**management effectiveness monitoring (MEM):** a means to evaluate whether management strategies actually help achieve their stated goals

**metadata:** Metadata sets include facts describing the nature of the data (e.g. sampling units) and circumstances (e.g. where, how and when the data was sampled) of the data at the time of recording.

**Monitoring:** the process of checking, observing, or keeping track of the presence or absence of any particular factor; allows for regular surveillance and quantification of how much of the factor is present (Soil Conservation Society of America 1982)

**multidimensional scaling:** a method for putting objects (individuals, sites, ecosystem components) in order that conveys as much information as possible about their measured differences in a few summary dimensions

**native species:** organisms that occurred in a North America before 17 century colonization

**national park:** An area of land and/or sea, designated to (a) protect the ecological integrity of one or more ecosystems for present and future generations; (b) exclude exploitation or occupation inimical to the purposes of designation of the area; and (c) provide a foundation for spiritual, scientific, educational, recreational and visitor opportunities, all of which must be environmentally and culturally compatible. Source: “Guidelines for Protected Areas Management Categories” – IUCN – The World Conservation Union (1994): [http://www.unep-wcmc.org/protected\\_areas/categories/eng/index.html](http://www.unep-wcmc.org/protected_areas/categories/eng/index.html).

In Canada, the word also means a national park as described in Schedule 1 of the *Canada National Parks Act*. It is an area which has been identified as a natural area of Canadian significance, which has been acquired by Canada and designated by Parliament as a national park, and over which Parks Canada has been given administration and control under the authority of the *Canada National Parks Act*. It is managed for the benefit, education and enjoyment of Canadians so as to leave it unimpaired for future generations.

**natural region (terrestrial):** Canada is subdivided in 39 distinct natural terrestrial regions based on geology, physiography and vegetation. The system of Canadian national parks is designed to protect representative natural areas of national significance in each of these 39 natural regions.

**Park EI condition monitoring:** monitoring that addresses the question, “What is the state of park EI?”

**park management plan:** Each park management plan contains a statement of park purpose and objectives that reflects the role of the park in the system of national parks,

and in the natural region in which the park is located. The plan provides the framework for further detailed sub-plans concerning ecosystem management, interpretation, visitor services and visitor risk management. Park Management Plans are required to be tabled in Parliament every five years.

**park visitor:** any person who does not reside within a national park, who travels to a national park for purposes of recreation, business, education or other activities. Parks visitors may be tourists or recreationists.

**Parks Canada Agency:** The Parks Canada Agency (PCA) is a public agency created by an Act of Parliament dated February 1998 (Bill C-29). The Agency has the mandate to conserve, protect and present nationally significant natural and cultural heritage. The Agency reports directly to the Minister of Canadian Heritage.

**path analysis:** an approach for extending the results of correlation analysis to model components that are not measured in the monitoring program

**population model:** a mathematical model that combines demographic characteristics of a population in an overall index of viability. Population Viability Analysis is a spatially explicit form of this approach

**power analysis; statistical power analysis:** tool that tells how likely you are to detect a real trend in data. It is usually defined on a scale of 0 –100%. A related concept is confidence, which is the probability of any trend detected in the data being real and not a false alarm.

**productivity model:** a mathematical model that combines energy, nutrient and moisture considerations to predict biomass production for plant communities

**random or probability sampling:** sampling where every area/organism in the population of interest has a chance of being sampled. The kinds of random sampling include:

- **simple random sampling:** All individuals or sites have an equal probability of being sampled.
- **systematic sampling with a random start point:** Sampling sites are part of a regular grid with predetermined distances among points.
- **stratified random sampling:** The study population is divided into one or more groups (strata) either by location or by other key ecological attributes.
- **tesselation sampling:** A sampling site is randomly chosen from within a regular pattern of geometrical shapes (e.g. squares) overlain on the study area.

**restoration:** the process of restoring an area, a natural resource or an ecosystem to a specified state or condition; accomplished passively through natural processes or actively by human manipulation (Parks Canada terminology bulletin 236)

**service centres:** Parks Canada service bureaus, which offer support to Field Units in terms of professional and technical services. Service centres are located in Halifax, Quebec City, Cornwall, Winnipeg, Calgary and Vancouver.

**State of the Parks Report:** Following the 1988 amendment to the federal National Parks Act, the State of the Parks Report is intended to be a historical record of the parks' and historic sites' state. Produced by Parks Canada, this report is to be presented to Parliament every two years.

**State of the Parks and Heritage Areas report:** a national report tabled in parliament every two years

**status:** the current value of a measure

**stress model:** a mathematical model that summarizes combined effects of a variety of stressors according to their frequency and severity. The Canadian Council of Ministers of the Environment's Water Quality Index takes this approach.

**stressor:** any factor that directly affects ecosystem processes or components and moves ecosystems away from a state of ecological integrity

**target:** the desired condition of an EI indicator or EI measure, i.e., the level of the EI indicator or EI measure that represents high EI

**threshold:** levels of an EI indicator or EI measure that represent high, medium and low ecological integrity. Trends that cross thresholds invoke a pre-described management response

**topology:** the pattern of connections in a network without reference to the size or strength of those connections

**traditional ecological knowledge (TEK):** knowledge of the conservation and sustainable use of an environment gained from generations of living and working within that environment. Knowledge may relate, among other things, to the harvest of resources, the planting of agricultural crops or the use of natural herbs and other material for medicinal purposes. Source: Canadian Biodiversity Strategy

**trend:** how a measure changes over time

**trophic:** related to nourishment or feeding

## **ACRONYMS USED IN THE GUIDE**

**ARIMA:** Autoregressive Integrated Moving Average

**EA:** environmental assessment

**EI:** ecological integrity

**FGDC:** Federal Geographic Data Committee

**ICE:** Information Centre on Ecosystems

**IM:** information management

**NBII:** National Biological Information Infrastructure

**NEIMTT:** National Ecological Integrity Monitoring Task Team

**PMP:** Park Management Plan

**SOP:** state of the park

**SOPR:** State of the Park report

## **Appendix 1: Criteria for Evaluating Parks as They Complete Their Monitoring Programs**

<b>Criteria</b> The criteria are calculated as the average of sub-criteria scores	<b>Sub-criteria</b> The sub-criteria are calculated as <i>either</i> <ol style="list-style-type: none"> <li>a) the average of program ratings by three reviewers or</li> <li>b) the average of project ratings for the park on a scale from 0-100.</li> </ol>	<b>Program questions</b> These questions will be addressed in the park's work plan and used to rate the park's program for a given sub-criterion from 0-100.	<b>Project questions</b> These questions will be rated by the park for each monitoring project – or measure –according to the levels of excellence in the next column. Questions are numbered as in Table 1B in the workplan.	<b>Project levels of excellence</b>
Scientific Credibility	Ecological comprehensiveness	a) Are biodiversity, ecological processes and stressors measured in co-located permanent sites in your park's major ecosystems?		
		b) Are remote sensing and other landscape measures made for these ecosystems?		
		c) Are the most abundant, threatened or otherwise important examples of these ecosystems sampled?		
	Credible thresholds and methodology	2) Is there a monitoring question? Is it well formulated, including thresholds and targets?		0 – No monitoring question , thresholds, or targets. 1 - A specific monitoring question has been formulated (including explicit spatial and temporal scales and an explicit effect size) , however there are no thresholds or targets with which to interpret the data. 2 – Tentative thresholds and targets 3 – Well established thresholds and a target for which the park is adapting its management actions
		3) Has the methodology been reviewed?		0 - No review of methodology 1 - Methodology accepted by internal experts 2 - Methodology has been published or accepted by external experts 3 - Methodology has been published in the primary literature or is a widely accepted and applied practice
		4) Is the methodology available?		0 - No draft methodology 1 - Draft methodology exists but is not ready for distribution 2 - Methodology is posted on Parks Canada's national database 3 - Methodology is on national database and is available in external publications

<b>Criteria</b> The criteria are calculated as the average of sub-criteria scores	<b>Sub-criteria</b> The sub-criteria are calculated as <i>either</i> <ol style="list-style-type: none"> <li>a) the average of program ratings by three reviewers or</li> <li>b) the average of project ratings for the park on a scale from 0-100.</li> </ol>	<b>Program questions</b> These questions will be addressed in the park's work plan and used to rate the park's program for a given sub-criterion from 0-100.	<b>Project questions</b> These questions will be rated by the park for each monitoring project – or measure – according to the levels of excellence in the next column. Questions are numbered as in Table 1B in the workplan.	<b>Project levels of excellence</b>
<b>Data Management and Statistical Design</b>	Credible data management and statistical design	6) Are data available electronically and are metadata files set up to describe and help manage the data?	0 - Data is not available in an electronic format 1 - Data is partly available in an electronic format 2 - Data is available but metadata is not available (or is incomplete) 3 - Complete data and metadata are available on Parks Canada's national database	
		7) Is the sample size sufficiently large to assure acceptable levels of confidence and power?	0 - No justification has been given for the sample size 1 - An informal justification has been given for the sample size OR acceptable levels of power or confidence cannot be reached for logistical reasons 2 - The methodology is being evaluated for power and confidence 3 - The methodology has enough power and confidence to detect statistical and biological change within a reasonable timeframe.	
		8) Does the sampling design account for bias, sources of variation, levels of ecological stress and confounding factors?	0 - Sample plots or individuals are selected without consideration of bias. 1 - Sample plots or individuals are chosen at random from an incomplete sampling frame (e.g. without an inventory of all similar plots or individuals) 2 - Sample plots or individuals are chosen from a complete sample frame 3 - A detailed sampling design accounts for major sources of variation, confounding factors and levels of ecological stress	
<b>Bioregional Cooperation</b>	Coordination among national parks in a bioregion	d) What is the percentage of measures that are common to all parks in the bioregion? (Full score for 50% or higher)	5) Are the results linked to the greater park ecosystem and bioregion?	0 - The measures in this project are unique to the park 1 - The measures are being considered for use in the greater park ecosystem OR in parks throughout the bioregion 2 - The measures are taken using the same protocol as partners in the greater park ecosystem OR as in several other parks. 3 - The measures are taken using the same protocol as all other parks in the bioregion
	Coordination within the greater park ecosystem	e) What is the percentage of measures that are common to Parks Canada and greater park ecosystem neighbours? (Full score for 30% or higher)		

<b>Criteria</b> The criteria are calculated as the average of sub-criteria scores	<b>Sub-criteria</b> The sub-criteria are calculated as <i>either</i> <ol style="list-style-type: none"> <li>a) the average of program ratings by three reviewers or</li> <li>b) the average of project ratings for the park on a scale from 0-100.</li> </ol>	<b>Program questions</b> These questions will be addressed in the park's work plan and used to rate the park's program for a given sub-criterion from 0-100.	<b>Project questions</b> These questions will be rated by the park for each monitoring project – or measure –according to the levels of excellence in the next column. Questions are numbered as in Table 1B in the workplan.	<b>Project levels of excellence</b>
<b>Stakeholder Involvement</b>	Stakeholder involvement in monitoring design	f) Has your park produced a State of the Park report?		
		g) Has your monitoring program been presented to a cooperative management or advisory board?		
		h) Do staff present messages to the public based on recent monitoring in your park?		
		i) Has monitoring been the subject of management plan consultations?		
		j) Has feedback regarding any of the above communications been used to modify your monitoring program?		
<b>Linkage to Plans</b>	Monitoring management objectives	1) Are the measures produced in this project highlighted in an ecological conceptual model, State of Park Report or Park Management Plan?	0 - Measures are not referenced in models, State of Park reports or Park Management Plans 1 - Measures are referenced in models but not SOP reports or PMP's 2 - Measures are highlighted in a conceptual model and will be used to develop one of the 6-8 indicators 3 - PMP makes specific reference to the measures and their use in calculating an indicator is strongly recommended on the basis of conceptual modelling and other considerations	

<b>Criteria</b> The criteria are calculated as the average of sub-criteria scores	<b>Sub-criteria</b> The sub-criteria are calculated as <i>either</i> <ol style="list-style-type: none"> <li>a) the average of program ratings by three reviewers or</li> <li>b) the average of project ratings for the park on a scale from 0-100.</li> </ol>	<b>Program questions</b> These questions will be addressed in the park's work plan and used to rate the park's program for a given sub-criterion from 0-100.	<b>Project questions</b> These questions will be rated by the park for each monitoring project – or measure – according to the levels of excellence in the next column. Questions are numbered as in Table 1B in the workplan.	<b>Project levels of excellence</b>
<b>Feasible Strategy</b>	Performance on the previous work plan	k) What percentage of allocated funds were spent?		
		l) What percentage of milestones were met?		
	Strategy for assembling monitoring program	m) Does the strategy ensure that each indicator will have a set of well-established measures?		
		n) Does the strategy ensure that tentative thresholds will be in place and that indicators can be calculated?		
* The following sub-criteria are not used in reporting. They are combined with Feasible Strategy scores to calculate the Severity of Gaps or the Needs of the program	Feasibility of projects		9) Is the project feasible to implement given costs and staff time?	0 – No funds or staff time have been committed to this project and significant increases in resourcing would be necessary to make it feasible 1 – Capacity and resources are being developed at the Park level and the park has committed some funds to the project producing these measures, however, significantly more funds are necessary to make it feasible 2 – The park is contributing existing capacity and resources to this measure, and requested funds will allow this project to be fully implemented 3 – The project is fully implemented with existing capacity and resources.
	Indicator development	p) What percentage of EI indicators have mostly developing or preliminary projects?		
	Conservation funding	q) What percentage of park funding is committed to all other service lines besides service line 2?		

## **Appendix 2: Draft Protocol Layout**

# **EI Monitoring and Reporting Program**

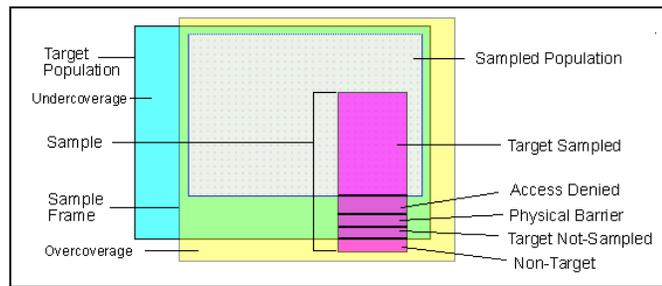
## **Monitoring-Protocol Layout - DRAFT**

### **I. Background and Objectives**

- (1) Introduction and general background - brief background on natural history of measure for which the protocol is being developed.
- (2) Objectives
  - (i) Overall scope and aim of the measure (e.g., link to Park Management Plan, link to provincial monitoring program, EMAN protocol).
  - (ii) Importance of monitoring measure for the applicable parks. Link the measure to the bioregional indicators and identify ecological significance or justification for choosing the measure (e.g., trophic significance, stakeholder significance, keystone species)
  - (iii) Applications of protocol and derived results in a greater context. If possible, detail the relationship between this protocol and other similar monitoring efforts (e.g., the same monitoring happening in other bioregions or provincial jurisdictions or by other federal partners).

### **II. Sampling Design**

- (3) Monitoring question(s) – The detailed monitoring question should guide all aspects of the monitoring methodology. This question includes how long the monitoring is planned for, over what area, and what effect size is expected.
- (4) Sampling frame
  - (i) Describe what is being monitored in the context of the sampling frame.
  - (ii) Power analysis and ideal sample size – This subsection should detail the sample size estimation conducted and how the sampling effort was identified.
  - (iii) Other sampling considerations – This section should explicitly identify other considerations, such as the spatial extent of monitoring, the number and distribution of sampling sites; site selection; frequency, duration, replication, controls; procedures for archiving of design development and changes. This previous list likely contains elements that do not fit with all protocols. Remember the intent of this section is to provide the detail around the sampling design to ensure program sustainability and scientific rigour.



### III. Field Methodology

- (5) Equipment – Required equipment, forms, permits and applications made. Detail equipment location(s), condition and replacement schedule if necessary.
- (6) Field Methods – The intent of this sub section is to provide, in as much detail as possible the field sampling methodology. Detail should sufficient for an ecologist unfamiliar with that protocol to replicate the protocol at that park. Some suggestions are
  - (i) Monitoring locations (e.g., spatial coverages with current georeferenced locations)
  - (ii) Field methods – this subsection should contain the recipe for conducting the monitoring and should be detailed enough to allow replication. If the methodology is extracted from another source (e.g., EMAN, BC RIC standards), then that source should be referenced. As a contingency, methods from other sources should be duplicated here. Any changes to methods should also be included here.
  - (iii) Data collection - Details of field measurements and sample collection; post-collection processing of samples / sample cataloguing and storage; end of season procedures.
  - (iv) Schedule - Timing and sequence of events.

### IV. Data Handling, Analyses, Reporting

- (7) Data entry and management
  - (i) Software to use (e.g., Excel, Access, GIS)
  - (ii) How to enter data – data format(s), QA/QC issues. Data entry, verification, editing; metadata procedures; database design.
  - (iii) Language of data (English/French, special computer language, etc.)
  - (iv) Where to enter data – systems (e.g., protocol database), data trustee(s).  
Data archive procedures for maintaining data and reports.
- (8) Data analysis – Identify the recommended data summary, statistical analysis to detect change and limitations of the analysis.

- (9) Interpretation of results (for instance, thresholds).
- (10) Frequency of reporting (if applicable). Recommended reporting schedule.
- (11) Recommended reporting format.

## **V. Personnel Requirements and Training**

- (12) Operational Requirements
  - (i) Personnel required and necessary minimum qualifications.
  - (ii) Budget - Anticipated or known project costs (includes training). Start-up costs and operational budget.
  - (iii) Minimum training required and suggested options for training
  - (iv) Roles and responsibilities for each phase of program.
  - (v) Schedule – annual schedule and schedule for the duration of the period identified in the monitoring question, at a minimum.
  - (vi) Data storage and access – Identify location of data (e.g., ICE) and access rules for data.
  - (vii) Partnerships – Identify any partnerships or Memorandum of Understanding that either govern or limit the monitoring identified in the protocol.

## **VI. Program Review – Quality Assurance / Quality Control**

- (13) QA / QC – Has the protocol received a peer edit and/or review. Detail that review and any resulting changes in the protocol.
  - (i) Results leading to protocol revision.
  - (ii) Recommended steps for revising protocol.
  - (iii) Results leading to protocol retirement, if the protocol is limited to a time period, as governed by the monitoring question.
  - (iv) End of protocol procedures.

## **VII. Additional Reference Material**

- (14) Recent publications (if applicable)
- (15) Other references
- (16) Appendices (if needed)