Consolidated Guidelines for Ecological Integrity Monitoring in Canada's National Parks

Parks Canada Agency

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APPROVAL

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Introduction

This document provides an update of key concepts and management direction to support Field Unit Superintendent accountabilities related to maintaining or improving ecological integrity in national parks.

Ecological integrity monitoring is a key tool in national parks management is . Parks Canada has achieved internationally recognized success in maintaining ecological integrity across the national parks system and remains committed to improving ecological integrity in targeted parks.

The guidance presented in this updated document replaces both the *2005 Monitoring and Reporting Ecological Integrity in Canada's National Parks Volume I: Guiding Principles* (2005) and the compendium document, *Volume 2: A Park-Level Guide to Establishing EI Monitoring (2007).* The technical appendices in this consolidated document may be updated as more innovative monitoring approaches and technologies emerge.

Key changes from past versions of this document include

- a greater emphasis on developing sustainable, credible Ecological Integrity (EI) monitoring activities that support the Parks Canada Vision, Strategic Outcome and Performance Management Framework within the context of specific field unit management objectives and fiscal realities;
- clear management direction on the expected number of core EI indicators and measures; and
- the introduction of voluntary Operational Reviews of park EI monitoring activities to enhance managers' understanding of how Agency resources are contributing to the integrated delivery of expected outcomes.

Field Unit Superintendents and Resource Conservation Managers are expected to update their present monitoring programs to reflect the direction presented in this document and to align with the level of A-base resources allocated in the field unit. This should include an assessment of the normal range of variation and a predetermination of thresholds for each measure to confirm the stage at which we would report an indicator as Good, Fair or Poor. Doing this assessment after the fact places the usefulness and credibility of the monitoring activities at risk. Indicators that are not included in a park's updated, core suite of EI indicators should generally be discontinued unless otherwise approved by the operational Director General, in consultation with the Director General, National Parks. Where valid local reasons exist for continuing to monitor non-core indicators and appropriate approvals have been granted to do so, these indicators will not normally be coded for EI monitoring and will not be included in the Agency's (State of Protected Heritage Areas) SOPHA reports. Purpose of EI Monitoring Guidelines

Parks Canada conducts ecological integrity[1] (EI) monitoring and reporting activities in national parks to provide managers with the necessary information to make informed decisions in support of Agency objectives and to communicate the ecological state of national parks to decision makers and Canadians.

The Agency's Corporate Plan, tabled in Parliament annually, presents the Agency's Strategic Outcome:

> "Canadians have a strong sense of connection, through meaningful experiences, to their national parks, national historic sites and national marine conservation areas, and these protected places are enjoyed in ways that leave them unimpaired for present and future generations."

A clear understanding of the intent of these Guidelines will support managers in achieving expected outcomes and ensure that the Agency can report on our successes and challenges related to delivering on the Strategic Outcome and expected results.

EI reporting is done in parallel with reporting on cultural resources and on the quality of visitor experience and public appreciation within the context of integrated park and site management activities. State of Parks Report (SOPR) assessments inform park and site management planning activities and provide input to the Agency's Departmental Performance Report, the Corporate Plan and SOPHA reports.

What is Ecological Integrity Monitoring?

Parks Canada uses the definition for monitoring in protected areas put forward by Elzinga et al. (1998):

> "…the collection and analysis of repeated observations or measurements to evaluate changes in condition, and progress towards meeting a management objective".

Ecosystems in national parks are dynamic and change over time in response to environmental and anthropogenic drivers and stressors. We assess the relevance of these changes to our management objectives through repeated measurements of the state of selected ecological measures (e.g., wildlife populations, rates of tree growth, rates of soil decomposition, water quality) (Figure 1) in relation to reference thresholds for each monitoring measure, or through observations of significant change from historical norms as informed by traditional or local knowledge.

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[1] Ecological integrity as defined in the Canada National Parks Act (2001) means ", with respect to a park, a condition that is determined to be characteristic of its natural region and likely to persist, including abiotic components and the composition and abundance of native species and biological communities, rates of change, and supporting processes".

Within Parks Canada, EI monitoring activities are undertaken to support the Agency's commitment to maintain or restore ecological integrity in national parks. Managers need credible information to understand and communicate the condition of park ecosystems and to assess progress in achieving active management objectives within the ecosystem. Park monitoring activities allow for the collection, analysis, and assessment of data for an approved suite of park EI indicators, supporting measures and scientific thresholds (see Technical Appendix 1 for a Glossary of Terms) within the context of approved management targets, performance expectations and available resources. Parks Canada administered lands, waters and sites that are outside of national parks are managed to respect environmental assessment and species at risk requirements but are not managed for ecological integrity. As such, ecological integrity monitoring activities are conducted only in national parks.

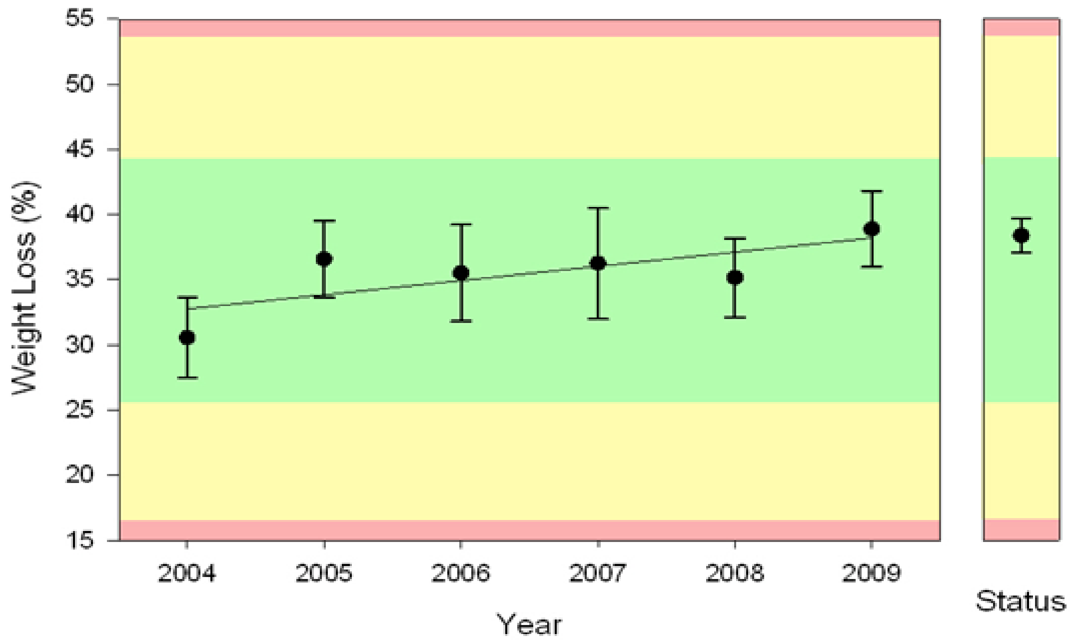


Figure 1: An example of the results of monitoring and assessing the condition and trend of an EI measure – index of soil decomposition (part of the "Forest" EI Indicator). The graph shows average annual rates of dry mass loss of buried wood standards from 39 forest plots in St. Lawrence Islands National Park. The change in colour represents the thresholds between good and fair (yellow), and fair and poor (red) EI. The EI of this measure was assessed as "Good".

Why Monitor Ecological Integrity?

The Canada National Parks Act (2000) requires the development of ecological indicators as part of management planning:

> "11. (1) The Minister shall, within five years after a park is established, prepare a management plan for the park containing a long-term ecological vision for the park, <u>a</u>

set of ecological integrity objectives and indicators and provisions for resource protection and restoration, zoning, visitor use, public awareness and performance evaluation, which shall be tabled in each House of Parliament."

For Parks Canada, EI monitoring is a park management tool that supports conservation objectives. We use the results of park EI monitoring to provide a knowledge-based rationale:

- to assist managers in identifying and prioritizing evolving EI issues that may require management action;
- to assess the outcomes of our management actions and investments against conservation objectives, and
- to support Agency reporting requirements respecting the state of Canada's national parks.

To serve these management goals, EI monitoring at Parks Canada is focussed on answering two questions:

- What is the state of park EI, and how is it changing?;,and;
- What are the results of our management actions to improve EI?

These Guidelines describe a two-level, integrated monitoring approach that seeks to provide an unbiased assessment of the ecological condition of a park (condition monitoring), and of the success of active ecosystem management projects, in terms of EI (effectiveness monitoring).

Condition monitoring ensures the Agency is able to assess and report the state of natural heritage in each of Canada's national parks. Condition monitoring provides medium and long-term data for assessing and reporting overall park EI. It is summarized in a small suite of approved EI indicators and supporting measures that are carefully selected to represent the biodiversity and biophysical processes of park ecosystems in the context of the larger scale natural processes.

Sustainable and credible EI condition monitoring alerts park managers to potential new or evolving ecological issues that may require management attention or action. Analysis of condition monitoring results can identify those issues that can be proactively addressed through management actions by the park without leading to costly restoration efforts in the future and can identify important contextual issues that may affect park management. For example, individual parks cannot alter ongoing changes in the regional climate but an understanding of the most immediate impacts of climate change on the park may be important for the management of other ecological issues that the park can manage.

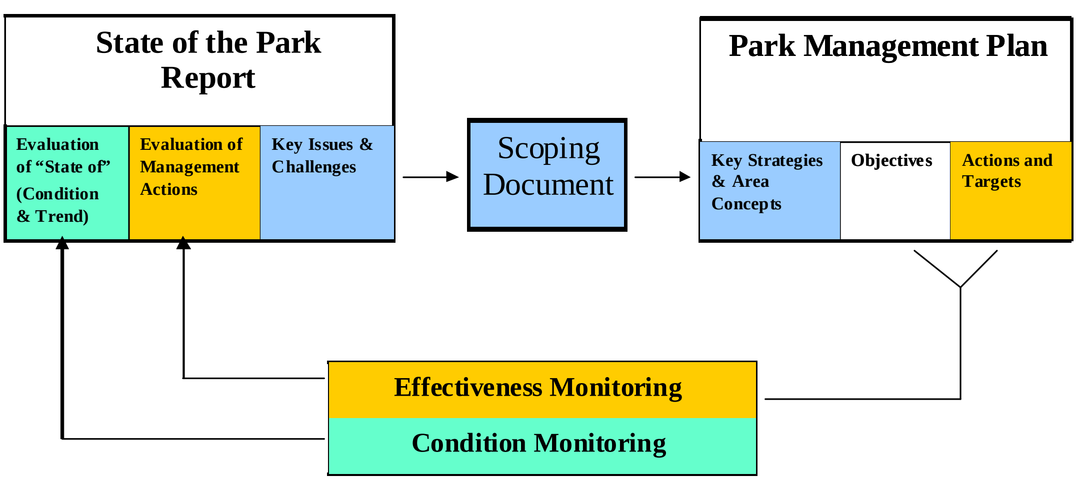
From a park management perspective, the most important function of park condition monitoring is to identify potential EI issues as they emerge and to provide the context to prioritize those identified issues that can be most effectively influenced through park management activities.

This knowledge empowers managers to consider options for addressing potential ecosystem threats within the broader dialogue of park management decisions, priorities and investments.

Effectiveness monitoring is designed to assess the ecological outcomes of specific management actions (e.g., Action on the Ground projects), and provides information to report on the ecological effectiveness of these actions and investments. It is thus carried out on a project-by-project basis, usually covering parts of an important ecosystem of the park. The key challenge for useful effectiveness monitoring is to identify and implement relevant and cost-effective EI measures at a scale appropriate to the project, so that we can measure and report the impact of the management action in achieving expected conservation outcomes. Technical guidance for designing and implementing effectiveness monitoring projects is found in Technical Appendix 10.

The condition and effectiveness components of park EI monitoring activities contribute to management planning processes through SOPR (Figure 2) processes. Based on information reported in the SOPR, EI issues are identified and can be prioritized for potential management action in the Management Plan Scoping Document. Approved management actions are formalized into Key Strategies in the Park Management Plan and the outcomes of our actions are assessed through effectiveness monitoring in subsequent SOPR processes.

Figure 2: EI monitoring and reporting activities and Parks Canada management planning cycle



Park EI monitoring activities inform management actions in the full range of PA 2 accountabilities in national parks and should complement and support PA3 (Public Appreciation and Understanding) and PA4 (Visitors Experience) objectives as well. Effectiveness monitoring information also supports assessments of several resource conservation activities, including protecting species at risk, conducting and participating in environmental assessments, managing fire, implementing active management and ecological restoration projects, and remediating contaminated sites.

Key Concepts

These Guiding Principles identify the general expectations of EI monitoring activities and provide guidance to park and field unit management teams for the manner in which EI monitoring activities should be applied within the broader park management context. The accompanying technical appendices provide the monitoring practitioner with details on the many aspects of planning, establishing, conducting and communicating EI monitoring in a park and should be consulted for technical details of park monitoring. This section provides a brief summary of the key concepts used in this document.

Assessment of park EI condition and trend are at the heart of EI monitoring and reporting, and both are reported through SOPR processes. Park EI condition is reported based on an assessment of the condition of a small number of core, FUS-approved park **EI Indicators** (Technical Appendix 2), that represent the major ecosystems that occur in a park, (e.g., park forests, streams, tundra, wetlands). Each EI indicator is a composite index of a small suite of carefully chosen, FUS-approved **EI Measures** (Technical Appendix 3) within each major park ecosystem, (e.g., water quality, moose density, soil decomposition, landscape connectivity), and are selected to track the key biodiversity and ecological processes for the major park ecosystems. The **condition** of each EI indicator (Good EI, Fair EI, Poor EI, or undetermined) is derived from a rule-based assessment of the suite of EI measures (Technical Appendix 5) that comprise the EI Indicator. Table 1 provides a qualitative description of ecosystems with Good, Fair and Poor EI, and is useful for establishing monitoring thresholds and communicating EI condition.

Table 1: Interpreting the condition of EI Indicators

Indicator Condition	Description
Good EI	The ecosystem is presently secure, is likely to persist, and contains a healthy composition and abundance of native species and biological communities, rates of change and supporting processes. No major active management actions are required.
Fair EI	The ecosystem is presently vulnerable and does not contain a completely healthy composition and abundance of native species and biological communities, rates of change and supporting processes. There may or may not be an opportunity to use active management to improve the EI of the indicator.
Poor EI	The ecosystem is presently impaired and does not contain a healthy composition and abundance of native species and biological communities, rates of change and supporting processes. There may or may not be an opportunity to use active management to improve the EI of the indicator.
EI undetermined	There is presently not enough information available to provide a condition rating for the indicator.

A **trend** is a change, over time, of the ecological integrity of an EI indicator or EI measure (e.g. ‘the Forest EI Indicator has improved’, or ‘the Forest Connectivity EI Measure has declined’, since the last SOPR.) Trends may be positive, negative or stable, based on directional movement toward or away from a defined threshold, and are calculated using a procedure outlined in Technical Appendix 5.

For each EI measure, monitoring **thresholds** are established to assess and report the condition of the measure (Technical Appendix 4). Monitoring thresholds are levels of an EI measure that represent Good, Fair, or Poor EI for that EI measure (Figure 3). They should not be confused with ‘ecological thresholds’ - a biological term that describes an ecosystem condition that leads to irreversible changes in ecosystem condition.

Lastly, a **target** is defined as an ecologically-based management goal, for a particular EI indicator, or for a particular management action, established by the Field Unit Superintendent, with advice from park Resource Conservation Specialists.

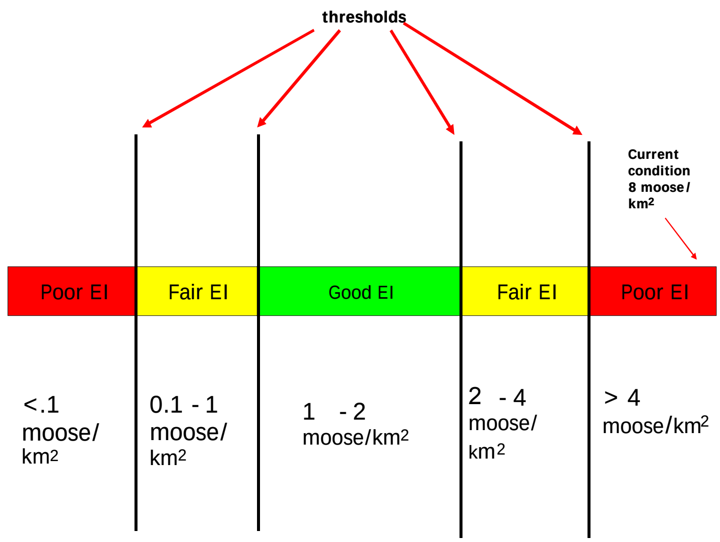


Figure 3: Biologically-based thresholds for an EI measure – moose density in Gros Morne NP.

Guiding Principles and Management Direction for EI Monitoring

Sustainable and Credible EI Monitoring

The Field Unit Superintendent, in conjunction with Resource Conservation Manager and Specialists, has the considerable challenge of designing and implementing park EI monitoring programs that are sustainable and credible. Sustainable programs are those that can be realistically supported over the long term through the use of human and financial resources provided for within the field unit's A-base budget. Supplementary funds may be sought and provided for Action on the Ground or other field unit initiatives, but approved, core monitoring activities should be sustainable within the A-base. As EI monitoring identifies issues requiring park management attention, A-base financial resources will be the primary source of funds for proactive actions to correct the situation or for ecological restoration initiatives (e.g. Action on the Ground).

It will take a number of years to determine the most cost-effective sampling, analysis, and assessment procedures to develop mature programs that are credible, but the criteria of sustainability must remain at the centre of planning in order to ensure the success and usefulness of park monitoring activities over the long term.

To ensure the sustainability of EI monitoring activities across the entire Agency and to ensure the credibility of the information we gather, the following general direction is provided concerning the identification of core EI indicators, measures and thresholds.

Please note that the direction provided in this document is intended to apply to the vast majority of parks. Field Unit Superintendents who believe their park circumstances may warrant varying from this direction should consult the Director General, National Parks. For example, an exception to the number of measures may be warranted when field efforts or "projects" enable park staff to measure several measures with a single effort and investment. Consider water sampling, where the most significant expense is often the gathering of the sample. In this case, the cost of analyzing several additional measures from the sample may be marginal and therefore warranted. Similarly, it is possible that additional indicators can be monitored with little or no Agency investment if innovative approaches are identified to obtaining the required information to assess those indicators.

Criteria for Selecting EI Indicators

Field Unit Superintendent will select the number of indicators that they determine to be essential to understanding the ecological integrity in the park, taking into account ecological and fiscal realities; parks will select 3-4 key indicators from the national suite of indicators presented in Appendix 2, focussing on those that are most essential to inform management decisions and support State of the Park Reporting processes while working within approved resourcing levels. The following direction is also provided:

- Select major park ecosystems as EI indicators if they represent a significant proportion (generally > 5%) of the park.
- Select major park ecosystems as EI indicators that are small in area (< 5%), only if they have conservation values important to specific, established park management objectives.
- Where feasible, each EI indicator to be assessed should include measures of biodiversity, ecological process, and stressor(s)/driver(s) acting on the major park ecosystem.
- Parks currently using different indicators are expected to find an appropriate method to align with those identified in Appendix 2 and seek advice from the Director General, National Parks as required.

Criteria for Selecting EI Measures

Select the number of supporting measures required for each EI indicator, taking into account the degree of scientific confidence required by management for each indicator, the complexity of the ecosystem, park management needs, opportunities for leveraging investments to serve other Performance Activity functions such as public appreciation/understanding and visitor experience and ability to contribute to the Agency’s vision. 5 measures per indicator are recommended to ensure credibility of scientific monitoring activities and to mitigate the risk of false findings. The following direction is also provided:

- EI measures will be associated with a specific monitoring question that includes appropriate thresholds and targets and sampling size will be consistent with the level of confidence required by managers.

- Where feasible, EI measures should be able to provide information at 2 spatial scales – local ground-based measures, and landscape-scale measures (often using remote sensing tools).

- Results, methodologies, protocols, analysis and supporting information for EI measures will be documented factually in the Information Centre on Ecosystems (ICE) in a timely manner by field units to facilitate annual Agency reporting requirements and the ability of parks to share annual data with partners and stakeholders; conclusions and recommendations can be addressed through established SOPR processes and timelines

It is important to focus on monitoring as a means to inform management decisions about resource conservation priorities, investments, and activities, with a view to ultimately effecting positive ecological integrity change on the ground. It is critical that Field Unit Superintendents and Resource Conservation Managers play a leadership role in the process to identify the appropriate level of information needed to make sound decisions, and to do so in the most cost-effective manner within an approved level of resourcing. For example, parks may consider taking advantage of co-location of sampling by combining related field measurements to form indexes as EI condition measures (e.g., a forest songbird index, a tundra vegetation health index, or a land cover change index).

The real key to success will be the effective management of scarce resources, and the selection of cost-effective approaches for developing a sustainable monitoring program that provides a credible assessment of park EI condition and acts as a mechanism for alerting park managers to new ecological change that may impact park EI, leading to proactive active management actions. The use of credible third party data from other federal departments and other orders of temporal adjustments in specific activities (e.g., in the frequency of sampling), and the development of common EI measure protocols are all examples of potential sources of efficiency (Technical Appendix 3).

Criteria for the Use of Aboriginal Traditional Knowledge in Monitoring Activities and Assessing the "State of the Land"

Many national parks are cooperatively managed with Aboriginal communities, while others have developed relationships where Aboriginal communities have advisory roles for park management.

Park managers are responsible for ensuring that traditional Aboriginal knowledge is part of the knowledge base used to inform decision-making, and for reporting park condition. SOPRs include the local Aboriginal perspective on the state of the land in the park, as well as the state of their connection to the land. The inclusion of Aboriginal traditional knowledge in ecological assessments reported in SOPRs is evolving and different parks may utilize different levels of knowledge integration. For example, Aboriginal knowledge of caribou abundance or condition may be used as assessment information for a caribou EI measure as a component of the Tundra EI Indicator for a northern park, or it may stand alone in the State of the Land section of the SOPR.

Measures that incorporate species of cultural importance or that are premised on historically monitored, culturally based ecological observations will serve to engage Aboriginal peoples in the cooperative management of these traditionally used lands and is to be encouraged wherever possible.

Voluntary Operational Reviews

All national parks are expected to establish and implement monitoring and reporting programs. As previously noted, developing sustainable and credible approaches to assessing park condition within the context of broader park management realities and limitations of available resources is a challenging task. A key to success for developing quality programs is to work together with other field units and other Agency specialists to benefit from best practices. To this end, a voluntary operational review process for park monitoring and reporting programs will be implemented to advise and assist Field Unit Superintendents and Resource Conservation Managers with program development. An operational review will be initiated at the request of the Field Unit Superintendent and will follow the approach currently in place for the Parks Canada Environmental Assessment Operational Review. Program criteria will be drafted and applied to a number of pilot parks. This will provide the opportunity for field staff to provide ongoing input into the procedures, objectives and assessment priorities of the operational review process and to ensure that the process is directly relevant to park needs.

The Operational Review process will support field units in implementing their monitoring program by

- assessing the ability of the park EI monitoring activities to provide relevant and timely information for park managers;
- assessing the ability of the park EI monitoring activities to understand and report the EI condition of the park and how it is changing;
- assessing the use of effectiveness monitoring as a tool for decision-makers to report EI achievements that result from direct management actions to improve EI, and to ‘learn by doing’ through an adaptive management process, and;

- assessing the roll up of monitoring information for Agency reporting purposes, including measures, thresholds and monitoring questions

Operational reviews will be initiated at the request of a Field Unit Superintendent and conducted by a small team of managers and ecologists. Using structured interviews and analyses of documents, the team will work in collaboration with the Resource Conservation manager and staff to conduct a review of the factors critical to the success of the field unit's EI monitoring and reporting requirements. The objective will be to utilize the expertise of monitoring peers to improve program quality by building on ongoing program strengths and recommending potential improvements to reduce or mitigate risks. The review and associated recommendations will address the following:

- the ability of park managers to provide a credible assessment of the state of the park and how it is changing;
- the ability of park managers to assess the results of management actions on EI;
- the extent to which park EI condition and management data and successes are recorded in the Information Centre for Ecosystems (ICE) to support information management and reporting requirements;
- the potential for park managers to reduce costs and improve effectiveness through integration and cooperation with other park/site planning processes.

Following an operational review, the Field Unit Superintendent will receive a report on the results of the review, and has the discretion to distribute it further within the field unit management team as appropriate. Information about innovative best practices being conducted by parks under review is collected to share nationally, thereby contributing to the overall improvement of Parks Canada's EI monitoring activities, but individual reports are not distributed externally by the review team and there is no intent or mandate to roll individual park results up nationally.

Field unit superintendents have the option to request a follow-up review to confirm the implementation of recommendations and the effectiveness of any changes made.

Making Assessments of Park EI Condition

An assessment of the EI condition of each EI indicator in a park is reported through SOPR processes and through the SOPHA report. These assessments are based on a roll-up of the condition ratings of each of the EI measures that are monitored for an EI indicator (Technical Appendix 5). The target for a mature park monitoring system is that each EI indicator will generally have 5 sustainable EI measures which, taken together, provide the Field Unit Superintendent with a credible assessment of that EI indicator.

Scientific rationale for the EI condition assessments will be documented in ICE so that they can be accessible for Agency analysis and reporting purposes. The information recorded in ICE will include information such as the monitoring question, rationale for the measure, the metrics used and a clear presentation of the most important analyses conducted. For detailed guidance see Technical Appendix 11. This is intended to ensure the maintenance, sharing and transmission of information between Parks Canada employees over the long term, reduce field unit reporting demands, and streamline Agency planning and reporting functions. Field Unit Superintendents and Resource Conservation Managers are accountable for ensuring the integrity and timeliness of data that their field units are documenting in ICE.

Sharing science knowledge and leveraging Agency investments

Park EI monitoring and reporting programs will use the best available science and knowledge to establish its sustainable and credible EI monitoring activities. Designing and implementing the sampling, analysis and assessment of a number of EI measures across EI indicators will typically require expertise in several ecosystem types, such as forest, tundra, grassland, wetland, freshwater, and marine. Given the broad ecological scope of park monitoring, it is recommended that park teams find cost effective means to collaborate with other field units and Agency specialists to share expertise, identify optimal and common approaches, provide national data-sharing and management, and ensure links and cross-functional synergies with other activities (e.g., with EA, SARA, ecological restoration, fire). This will ensure that technical information clearly supports management, facilitates reporting, and is auditable.

A bioregional collaborative approach provides one potential opportunity for taking advantage of ecological similarities among parks in a given biological region, and for achieving further efficiencies by providing access to a broader range of expertise and experience, ensuring a regional context for ecological observations, and minimizing duplication of protocols, data management and other work. This approach also allows for greater opportunities to increase sample size, whereas an individual park may not have the resources or species population size to achieve or sustain a sufficient sample size. In addition to facilitating cost efficiencies, this approach encourages more effective communication and interaction with other agencies and regional partners. Please note, while bioregions provide a useful means for potentially sharing information and developing more cost-effective programs, they in no way constitute administrative or reporting units, and do not impact in any way upon field unit accountability structures.

Leveraging Investments and Building Partnerships to Support Expected Outcomes

Establishing and sustaining comprehensive, credible park EI monitoring and reporting activities requires a considerable investment of human and financial resources and every effort should be made to leverage these investments to contribute to a broad range of Agency objectives. Two key areas for leveraging monitoring investments are the direct engagement and participation of Aboriginal communities and park visitors in monitoring activities. Credible monitoring results also play a broad communication role by providing the data to communicate park condition and conservation to managers and to external audiences, thus supporting a ‘culture of conservation’ among Canadians. EI monitoring can contribute as well to other park EI initiatives including environmental assessments, species at risk management, and ecological restoration initiatives such as prescribed fire and Action on the Ground objectives.

Credible, sustainable monitoring activities have the potential to act as knowledge-based magnets, attracting investments in applied science and research partnerships with other government agencies and universities. Successful partnerships should serve the purposes of all partners, and will require ongoing management attention to maintain and evaluate. Within the context of field unit objectives and fiscal realities, careful consideration should be given to the scope and duration of potential partnership arrangements where Parks Canada financial investments are concerned. While it may often be most useful to consider multi-year agreements in order to effect meaningful change over a specific time horizon, Field Unit Superintendents should also consider the proposed Agency investment over the life of the agreement, relative to potential new or emerging priorities. Where public funds are proposed for transfer to third parties for the delivery of monitoring information or services to Parks Canada, responsible managers will ensure compliance with relevant policies and with direction provided under the Financial Administration Act.

Citizen science

Citizen science groups (school classes, visitors, special park interpretation programs, or volunteers) can effectively participate in some of the activities that relate to EI monitoring in a park, while contributing to public awareness and appreciation and facilitating memorable visitor experiences. The keys to success with citizen science activities are to design the monitoring so that the information to be collected matches the level of training of those conducting the sampling, to provide sufficient supervision to ensure data quality, and to report back to the participants showing how their efforts have been incorporated into park condition assessments. The benefit is that useful monitoring data are collected for park programs, while also achieving PA3 and PA4 outreach, public appreciation and visitor experience objectives. These programs should not be perceived as inexpensive or *ad hoc* - a considerable effort by park staff is required to design and successfully deliver citizen science programs.

Other Considerations

National consistency in choice of EI Indicators

Each national park ecosystem will generally be monitored with a core suite of 2-4 EI indicators that are reflective of the major ecosystem types found within the park (e.g., forest, streams, tundra, wetlands) as selected from the national list of indicators identified in Appendix 2. Field Unit Superintendents of larger, more complex parks that feel they may require more than four indicators should consult the Director General, National Parks. Furthermore, additional indicators for which incremental costs are clearly marginal may also be considered, in consultation with the Director General, National Parks. Parks are expected to work to implement the ecosystem-based approach for selecting EI indicators as described in Appendix 2. This will provide for consistency in park and system level reporting, will reduce establishment costs, and will provide a consistent ecosystem-based approach to assessing and reporting park condition.

Measuring and reporting EI within national park boundaries

While it is understood that regional-scale ecological factors often influence park condition, and that Parks Canada regularly works with park neighbours to positively influence conditions near or adjacent to national parks, Agency investments and performance reporting will focus on Parks Canada accountabilities and key areas of responsibility within the boundaries of national parks.

Information management

Data, metadata, protocols, analysis and ancillary information will be carefully managed and stored, in order to contribute to effective decision-making, and to ensure the long-term value of Agency investments in EI monitoring. EI measures require protocols that are clearly and consistently described and applied, and that describe key aspects of the measurements taken. This ensures that long-term monitoring datasets remain credible and accessible and that they reflect changes and trends, irrespective of the staff conducting the monitoring at a given time. Monitoring data must also be effectively and reliably managed and stored. The national Information Centre on Ecosystems (ICE) provides an information management, storage and retrieval tool for data. ICE also provides managers and practitioners with a “dashboard” for reviewing the overall state of EI across all national parks. Field Unit Superintendents and Resource Conservation managers play key leadership roles in ensuring that staff use ICE and maintain up-to-date information related to their respective national parks. (http://intranet/apps/ice/PhaListing.aspx).

EI monitoring in Northern Parks

In Parks Canada, "northern parks" refers to Torngat Mountains, Ukkusiksalik, Auyuittuq, Sirmilik, Quttinirpaaq, Ivvavik, Tuktut Nogait, Aulavik, Vuntut, Kluane, Wapusk, and Nahanni National Parks

Guiding Principles for northern national parks were approved by the CEO in March 2011 and remain a relevant reference for northern field units. They reflect the uniqueness of working in the North and provide a clear sense of direction for the development of northern monitoring activities. Further guidance is also included in the document "Ecological Integrity Monitoring in Canada's Northern National Parks – A Path Forward". Following is a brief summary of the direction provided in the Guiding Principles.

EI monitoring activities in the north are based on the same ecological principles for monitoring in southern parks. The core program must be credible and sustainable and indicators and measures will be developed so as to engage Aboriginal communities while supporting the Agency Vision, promoting citizen science and contributing to the delivery of visitor experience and public education objectives.

Given the large size of northern parks and associated access challenges, a well-designed remote-sensing program will be the cornerstone for monitoring park EI. This approach will most effectively address the challenges associated with logistics, park size, staff capacity, and the unique socio-political environment for northern parks. A core suite of carefully selected ground sampling measures, associated with two approved indicators that are located in focal watersheds and, where feasible, based on common protocols and measures, will be implemented to support remote sensing activities. Where appropriate, one indicator will be common to all northern parks and ground work should be largely focussed in a focal watershed. All methods, protocols, data and analysis will be documented in ICE.

Roles and Responsibilities

The Field Unit Superintendent (FUS) is accountable for ensuring the maintenance or improvement of the ecological integrity of the national park, for the identification of park EI indicators and measures and for timely corporate reporting through the park management planning cycle. FUSs are encouraged to engage their staff and management teams in a dialogue about risks, relative priorities, and other management objectives when planning monitoring activities to achieve the best possible results within approved resourcing levels.

Ecological integrity monitoring and reporting is a key area of work for the resource conservation function and the Resource Conservation Manager (RCM) is accountable to the FUS for the delivery of expected results. The RCM is responsible for applying these Guidelines and for delivering a sustainable, credible suite of monitoring activities that will support both the long-term monitoring and reporting of EI condition, as well as the monitoring and reporting of major active management projects. The RCM is responsible for scientific, technical, and operational considerations, and is supported by resource conservation staff and other staff specialists, with functional direction and support from the National Parks Directorate.

The Director General National Parks, supported by the Executive Director of Ecological Integrity and the Chief Ecosystem Scientist, is responsible to the Chief Executive Officer for the policy framework for knowledge-based EI monitoring, liaising with other directorates and supporting the roll up of park-level data to meet national, Agency reporting requirements.

The Chief Administrative Officer (Strategies and Plans) is responsible to the Chief Executive Officer for establishing guidelines for Management Planning and State of Park Reporting, as well as for reporting ecological integrity information and results on behalf of the Agency.

TECHNICAL APPENDIX 1: Glossary

The following definitions should be applied consistently in Parks Canada documents.

EI Indicator

A nationally consistent summary statement that provides a clear assessment of the condition of an important element of park EI (i.e., a major park ecosystem), and it is based on a combination of EI Measures. Field Unit Superintendents will approve selected EI Indicators from the national suite of indicators identified in Appendix 2.

Examples: *Aquatic EI Indicator, Forest EI Indicator, Tundra EI Indicator*

EI Measure

Monitoring data that contribute to a specific EI indicator, that are collected over time following a strict protocol, and that measure current 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.

Example: *A Forest Ecosystem Indicator may be comprised of several EI measures such as interior songbird diversity, soil decomposition index, fire cycle, and salamander abundance. The songbird diversity measure is comprised of several field measurements of different songbird species abundances.*

EI Condition

The current assessment of the level of EI of an indicator or measure, Good, Fair or Poor (e.g., *The Wetland Indicator is in Fair condition; The Forest songbird measure, part of the Forest Indicator, has a Good condition*).

Condition is evaluated based on the Agency’s definition of ecological integrity. Good, Fair, and Poor descriptors are based on scientifically defined thresholds for EI Measures. Overall, the assessment of condition of the EI Indicator should be consistent with Table APP 1.1

Table APP 1.1: Interpretation of the condition of EI Indicators

Indicator Condition	Description
Good EI	The ecosystem is presently secure, is likely to persist, and contains a healthy composition and abundance of native species and biological communities, rates of change and supporting processes. No major active management actions are required.
Fair EI	The ecosystem is presently vulnerable and does not contain a completely healthy composition and abundance of native species and biological communities, rates of change and supporting processes. Active management actions may be required but may not be feasible.
Poor EI	The ecosystem is presently impaired and does not contain a healthy composition and abundance of native species and biological communities, rates of change and supporting processes. Significant and ongoing management actions are required but may not be feasible.
N/R	There is presently not enough information available to provide a condition rating for the indicator

Threshold

A threshold is a level of an indicator or measure that represents the point at which the condition changes (e.g., between good and fair, or fair and poor) (Figure APP 1.1). Thresholds are science-based and are determined independently of management targets, and irrespective of our ability to influence their condition.

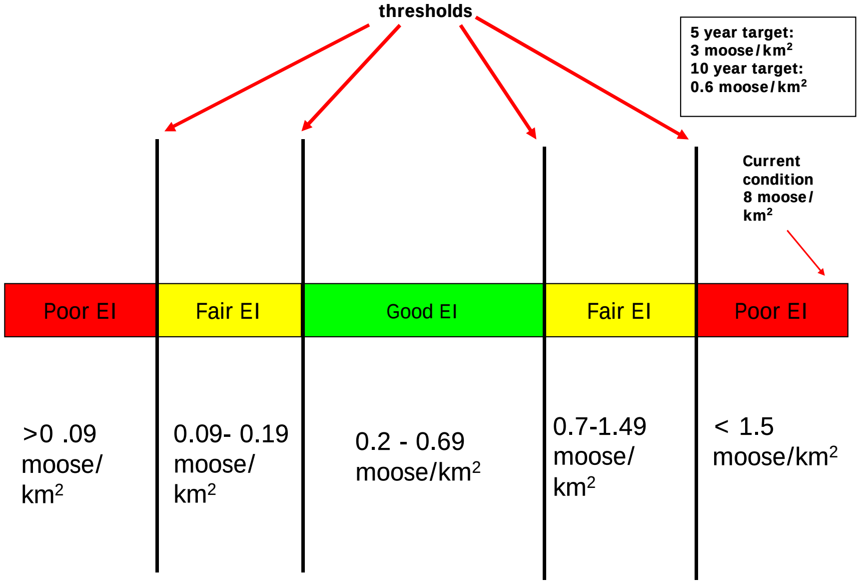


Figure APP 1.1: Thresholds for moose population density

All EI measures must have thresholds, in order to be scientifically useful and credible. Biologically significant thresholds for a particular EI measure may already be available, they may be developed through consensus, or they may require time to establish through monitoring. A measure with no threshold is not an acceptable component of an EI monitoring program. Thresholds based on statistical assessments of change can serve as interim thresholds until reliable, biologically significant thresholds can be established. Developing useful thresholds takes time, so it is recognized that the first SOPR for a park may contain and report on only a few thresholds.

Trend

A trend (Table 1.2) is a specific measurable change, over time, of the ecological integrity of a measure or an indicator (e.g., the Forest indicator has improved since the last SOPR; the water quality measure demonstrates deteriorating EI). It is worth noting that the trends describe changes in ecological condition, and the assessment of condition depends on what is being measured. The decreasing change in condition may be the result of either an increasing trend (towards ungulate hyperabundance or pond eutrophication) or a decreasing trend (decreasing SAR populations or forest connectivity.

Table APP 1.2: Types of trends for EI Indicators

Trend of Indicator Condition	Description
Improving ↑	The condition of the Indicator has improved since the last assessment / State of the Park Report
Stable ↔	The condition of the Indicator has remained stable since the last assessment / State of the Park Report
Declining ↓	The condition of the indicator has deteriorated since the last assessment / State of the Park Report
N/R	There is not enough information available to report a trend for the indicator

Target

A Target is a defined management goal for a particular indicator, or for measures associated with a particular management action, approved by the Field Unit Superintendent, with advice from resource conservation staff. A target sets what level of EI result is possible, desirable and feasible.

Active Management Target

A time-bound, specific, desired ecological outcome of a management action that acts as a surrogate for changes in EI as a result of management actions. Targets in this context are park-specific management targets, identified through Park Management Plans or specified through active management activities. Targets should be realistic and achievable and are approved by the Field Unit Superintendent.

Example: By 2010, the fire cycle in the White Pine forest will be restored to 20 percent of its historic level

TECHNICAL APPENDIX 2: Park and National EI Indicators

EI indicators are a key tool in our approach to assessing and conveying the results of park EI monitoring to park managers and a wide audience of Canadians. Overall park EI is measured, synthesized, and assessed based on a core suite of approved EI Indicators that credibly summarize and communicate park condition (Figure APP 2.1). The model for the EI Indicator mirrors the Canadian Forest Fire Danger Rating System (CFS 1987) – a widely-known index of fire danger communicated to a wide audience, and based on strong science. Following a similar approach, complex results and analyses from the monitoring of EI measures are synthesized in an 'iceberg' model to assess and communicate EI condition for each EI Indicator in a park. Public communication of park EI represents the 'tip of the iceberg', while the more detailed data and methodology that support the assessment is out of sight, but available in ICE.

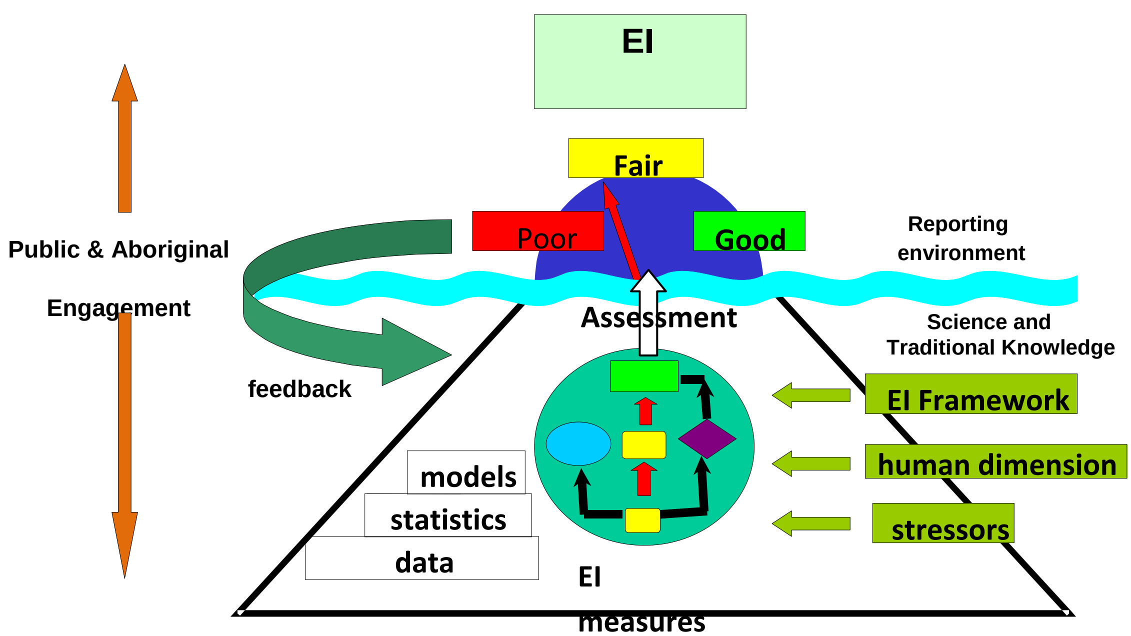


Figure APP 2.1: Iceberg model for an EI Indicator

Parks Canada's approach is that each selected EI indicator represents a major park ecosystem, e.g., park forests, streams, lakes, wetlands, tundra. Taken together, assessments of park indicators provide a credible synopsis of park EI condition. Each indicator is generally based on a set of measures covering, to the extent feasible, biodiversity, the ecological processes that support and determine that biodiversity, and the stressors and drivers that affect both. These factors are visualized in simple conceptual ecosystem models for each indicator. The models provide an ecological frame for selecting EI measures and also provide a strong communication tool for summarizing ecosystem complexity.

Selecting EI Indicators for Park Monitoring

The Guidelines that precede this Appendix provide guidance to Field Unit Superintendents and Resource Conservation Managers regarding which of the parks' major ecosystems should be selected for EI monitoring and reporting. One of the key challenges for any type of monitoring is the long term sustainability of the program and the ability to mitigate the risk of future failure. For this reason, appropriate leadership is required to design and implement monitoring activities that are credible, yet sustainable in the long term. The direction provided here emphasizes that the key park ecosystems that contribute in a significant way to understanding park EI will be prioritized for investment. In some cases, major park ecosystems will occur in a park but may occupy a very small area of the park, or conservation issues in that ecosystem may not be considered necessary for maintaining or restoring park EI. In the interests of program sustainability, Field Unit Superintendent may determine that monitoring a suite of measures in these ecosystems is not justified.

To ensure that programs are sustainable in the long term and that condition assessments of EI indicators are credible, parks focus their monitoring efforts on 3-4 EI indicators. In some cases, the field unit may decide that additional EI indicators are required to capture park complexity, **and in these cases parks should discuss their rationale with the Director General, National Parks**. In all cases the goal is to develop a sustainable program that captures the key components of park EI and to ensure that each approved EI indicator has a sufficient number of well-selected measures to provide a credible assessment of EI for that EI indicator. To create EI indicators for park monitoring, major park ecosystems in Table APP2.1 can be grouped to provide a more cost-effective synopsis. For example, in some parks the Forest and Woodland Indicators may be combined into an overall Forest Indicator, the Stream and Lake Indicators can be combined into an overall Freshwater Indicator, or Coastal and Marine Indicators can be collapsed into a single Coastal/Marine Indicator for monitoring and reporting. It is recommended that parks combine EI indicators where appropriate to ensure a credible but sustainable number of EI measures to develop a reliable assessment.

Providing a National Synopsis of Park EI in the SoPHA

Table APP 2.1 presents a matrix of major park ecosystems for all national parks, grouped under 8 SOPHA EI indicators that will be used for national reporting.

To make an assessment of park EI where the SOPHA indicator for that park is comprised of more than one EI Indicator, all EI measures across the relevant EI indicator are assessed as a group, following the same rules for determining condition and trend as for an individual EI indicator. This analysis will be done by the ICE team in the National Parks directorate in support of the national roll up that is subsequently prepared by the Chief Administrative Officer on behalf of the Agency.

Table APP2.1: PCA Ecological Integrity Indicators (Page 1)

SoPHA Indicator		1.FORESTS		2.TUNDRA		3.SHRUBLANDS[2]				4.WETLANDS			5.GRASSLANDS		6.FRESHWATER		7.COASTAL/MARINE					8.GLACIERS
PARK	**Park Indicator**	Forest	Woodlands[1]	Arctic Tundra	Alpine Tundra	Shrublands	Alvars	Barrens	Landres	Wetlands	Floodplains	Deltas	Grasslands	Badlands	Streams	Lakes	Marine[4]	Coastal[3]	Inter-tidal	Islets	Sub-tidal	Glaciers
Quebec-Atlantic																						
Cape Breton																						
Forillon																						
Fundy																						
Gros Morne																						
Kejimkujik																						
Kouchibouguac																						
La Mauricie																						
Terra Nova																						
Mingan																						
Prince Edward Island																						
Interior Plains																						
Elk Island																						
Grasslands																						
Prince Albert																						
Riding Mountain																						
Wood Buffalo																						
Pacific Coastal																						
Gulf Island																						
Gwaii Haanas																						
Pacific Rim																						

1. Woodlands: includes open-canopy forested ecosystems where ecological drivers do not permit complete forest coverage, e.g., subalpine parkland, sub-arctic, and semi-arid woodlands.
2. Shrublands: Non-arctic shrub ecosystems maintained at a shrub disclimax stage by fire, drought, or other drivers. 'Barrens' or 'Landres' are local names for shrub-dominated ecosystems maintained either historically or presently by persistent fire. Alpine ecosystems referred to as 'Barrens' in Gros Morne NP have been moved to 'Alpine Tundra'.
3. Coastal: Otherwise terrestrial ecosystems (including estuaries and lagoons) located adjacent to marine or large freshwater systems where the ecology of the system is strongly affected by its proximity to the coast.
4. Marine: Pelagic marine ecosystems deeper than Sub-tidal ecosystems.

Table APP2.1: PCA Ecological Integrity Indicators (Page 2)

SoPHA Indicator		1.FORESTS		TUNDRA		3.SHRUBLANDS[2]				4.WETLANDS			5.GRASSLANDS		6.FRESHWATER		7.COASTAL/MARINE					8.GLACIERS
PARK	**Park Indicator**	Forest	Woodlands[1]	Arctic Tundra	Alpine Tundra	Shrublands	Alvars	Barrens	Landres	Wetlands	Floodplains	Deltas	Grasslands	Badlands	Streams	Lakes	Marine[4]	Coastal[3]	Inter-tidal	Islets	Sub-tidal	Glaciers
The North																						
Auyuittuq				■						■					■	■		■				■
Ukkusiksalik				■						■					■	■		■				
Quttinirpaaq				■						■					■	■		■				■
Sirmilik				■						■					■	■		■				■
Torngat Mountains				■						■					■	■		■				■
Wapusk		■		■						■					■	■		■				
Aulavik				■						■					■	■	■	■				
Ivvavik			■	■						■					■	■		■				
Tuktut Nogait				■						■					■	■						
Vuntut			■	■						■	■				■	■						
Kluane		■	■		■					■					■	■						■
Nahanni		■	■		■					■					■	■						■
Southern Mountains																						
Banff		■	■		■					■			■		■	■						■
Jasper		■	■		■					■			■		■	■						■
Kootenay		■	■		■					■					■	■						
Mt Revelstoke & Glacier		■	■		■					■					■	■						■
Waterton Lakes		■	■		■					■			■		■	■						■
Yoho		■	■		■					■					■	■						
Great Lakes																						
Bruce Peninsula		■					■			■					■	■		■				
Georgian Bay Island		■					■			■					■	■		■				
Point Pelee		■								■					■	■		■				
Pukaskwa		■								■					■	■		■				
St. Lawrence Islands		■								■					■	■		■				

TECHNICAL APPENDIX 3: Ecological Integrity Measures

Objectives

Selecting a core suite of scientific and traditional knowledge-based indicators, supported by approved EI measures, to represent complex ecological systems, is the cornerstone of effective park EI monitoring. 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 and drivers is long and growing. However, capacity and finances will restrict parks to a few measures for each indicator. The challenge is to select those that, together, provide a credible understanding of the ecological integrity of that indicator ecosystem to alert park managers to potential evolving ecological issues and to assist managers in delivering on expected outcomes and the Agency vision. Traditional knowledge, citizen science and other sources of information and understanding remain key components of park monitoring and reporting activities and should be incorporated into the early stages of monitoring plan development.

Processes for Selecting Measures

Selecting measures includes two choices:

- choosing the ecosystem component for measurement (e.g., forest songbirds, invasive plants, climate change; see Section 5), and
- choosing the specific EI measure and its field measurement(s) (e.g., abundance of forest songbirds, percentage change in element occurrence of noxious weeds, number of frost free days).

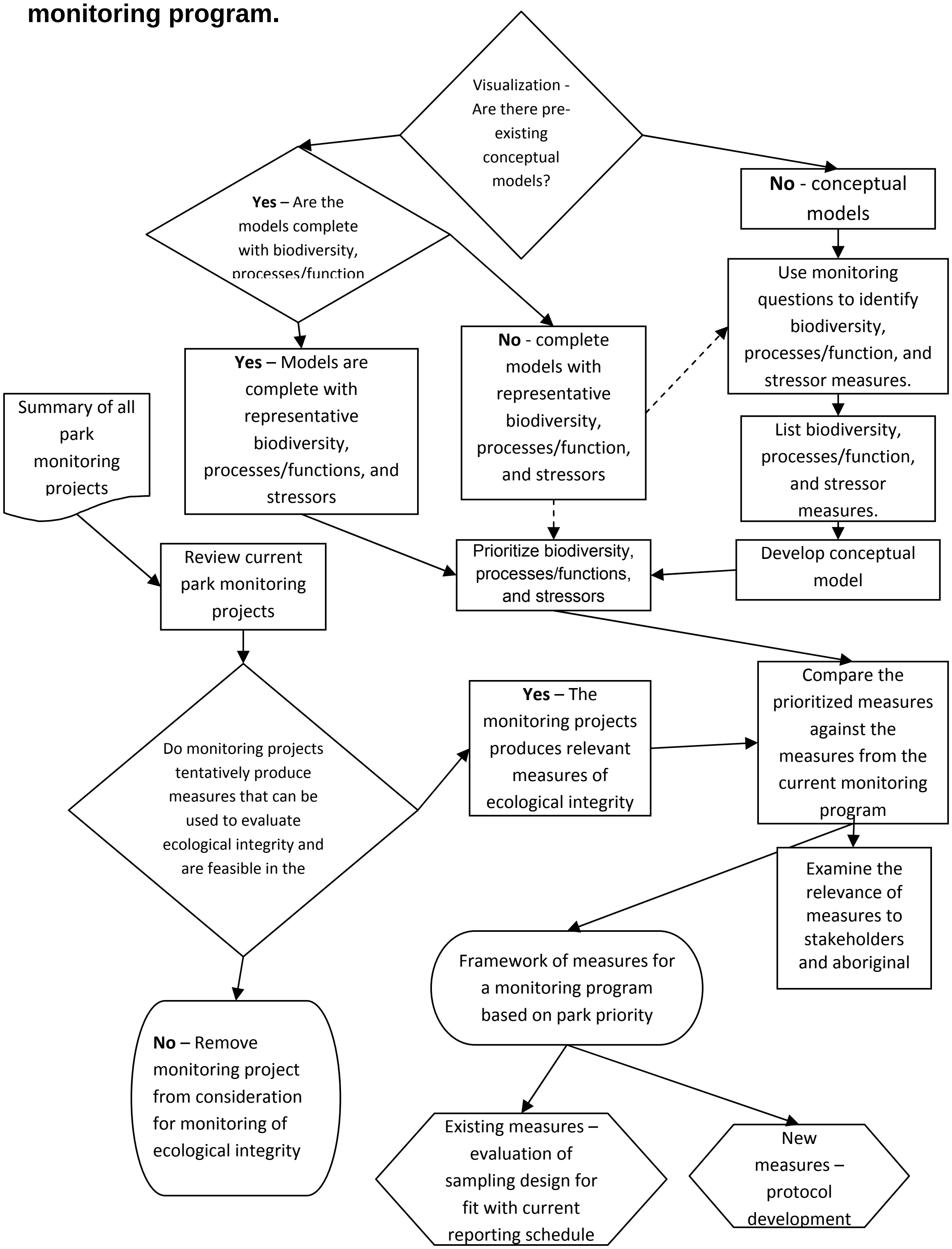
The process normally starts with a large list of potential measures, and these are filtered to generate a smaller list of prioritized measures. Figure APP 2.1 describes a process for measure selection.

Groups to Consult

The following groups may be engaged in designing a monitoring plan:

- park-based groups,
- aboriginal communities and elders,
- science advisory groups,
- stakeholder groups, and
- bioregional groups (when applicable).

Figure APP 3.1: Flowchart of the process for reviewing the existing park monitoring projects and identifying new measures for a completed park monitoring program.



Parks Canada consults these groups for various purposes. You should integrate the consultation needs of the monitoring activities with those of the park generally and use existing committees and processes (e.g., Park Management Planning). Advice may also be sought from the Aboriginal Affairs Secretariat regarding the engagement of Aboriginal peoples in park monitoring activities. 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,
- chapters in State of Park Reports prepared in collaboration with Aboriginal communities that describe the “State of the Land”, and
- the Guide to Consulting Aboriginal People, which addresses principles and stages of consultation in terms of our legal obligation to consult http://intranet/content/aborig-autoch/orig/consultation_doc_EN.pdf).

Bioregional Groups

Bioregions are geographically related groups of parks that work together to develop common measures and protocols. It is not a mechanism for rolling up monitoring at the national level and does not affect field unit accountabilities.

Bioregional measures are shared by two or more parks within a common bioregion. Bioregional cooperation can vary from minimal, such as periodic consultation on the park’s 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 success of the monitoring program 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 APP 2.1). 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 APP 2.1.

With the approval of the implicated Field Unit Superintendents, a working group of biologists and park ecologists from each participating park can be established to develop and recommend bioregional measures.

Table APP 3.1: Levels of co-operation in the integration of bioregional measures, i.e., measures shared by two or more parks.

Increasing integration	↓	• Consultation on measures • Agreement on measure • Agreement on metrics • Application of similar protocols • Data input into single, shared database • Common analysis to all data • Common integration and reporting format for data

Park-Based Groups

Work plans generally arise from a park-based forum. The forum's main objective is for park personnel to agree on the park's internal EI status and monitoring needs.

Typical tasks of a park-based forum::

- gather past and current monitoring and research data for evaluation;
- fit the existing measures into the national framework of the ecosystem indicators identified in Appendix 2;
- assess measures in the context of the Park Management Plan;
- develop clear monitoring questions for each existing measure;
- review the suitability of current measures for State of the Park reporting requirements;
- identify measurement gaps for each ecosystem indicator using the ecosystem conceptual model, and;
- prioritize the next steps in measurement review and protocol development and testing, including aboriginal and stakeholder involvement.

The park-based forum should include:

- park resource conservation staff,
- researchers closely associated with the park, and
- Agency functional experts.

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).

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 a condition index of individuals.

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 to or greatly affect 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 high natural variability.

- *Scale of management needs:* Managers will 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 and cost-effective 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.

- *Cultural Relevance:* Managers should identify opportunities to consider culturally relevant species or historical ecosystem observations when developing EI measures. This requires the meaningful engagement of Aboriginal communities.

- *Resolution:* EI measures can be classified from coarse- to fine-filter measures (see Table APP 3.2). 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 APP 3.2: An example of measures chosen at different levels of resolution for forest songbirds.

	Metric	Cost	Coverage	Signal Strength
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

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 common models:

- *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 the 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.

Program Criteria for EI Measures

The selection and implementation of monitoring measures is at the heart of all park EI monitoring programs. It is important to set minimum criteria for a credible and sustainable program so that we can ensure a comparable level of rigour across field units. What follows are general criteria for selecting and implementing EI measures.

The measures and assessments of ecological condition collected and reported by park EI monitoring programs must be credible to ensure that park managers have reliable and defensible information for decision-making. The following criteria are recommended to support Field Unit Superintendents and Resource Conservation Managers in this work:

- Approved EI measures will be relevant to assessing the condition of the EI indicator, and to a specific monitoring question that includes appropriate thresholds and targets.
- Sample size for an EI measure will be sufficient to achieve levels of confidence and power that are acceptable to the Field Unit Superintendent.
- The sample design for an EI measure will, to the extent feasible, account for bias, sources of variation, levels of ecological stress, and confounding factors.
- Methods, protocols, data, and analyses for EI measures will be documented in ICE.

Ongoing Changes and Periodic Review of Measures

Over time, changes in our understanding of ecosystems and changes in technology will necessitate reviewing measures and protocols. To maintain continuity in monitoring over the longer term, however, parks will generally only update EI measures in the case of major changes in our knowledge of ecosystems, the introduction of new, major, long-term stressors, and/or widespread acceptance of new protocols.

To reduce the risk of data loss and unintended upward financial pressures, parks should consider the following six factors before considering whether to change measures or protocols:

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

Potential new protocols should enhance several 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.

TECHNICAL APPENDIX 4: Establishing Monitoring Thresholds for EI Measures

Background

Choosing monitoring threshold values is a key aspect of assessing and communicating monitoring results. Monitoring 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 available.

Figure APP 4.1 describes an EI measure that is a simplified version of the left half of Figure APP 5.2 in Appendix 5. 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 a zone of fair ecological integrity. Identifying this zone is part of our commitment to the precautionary approach in ecosystem management.

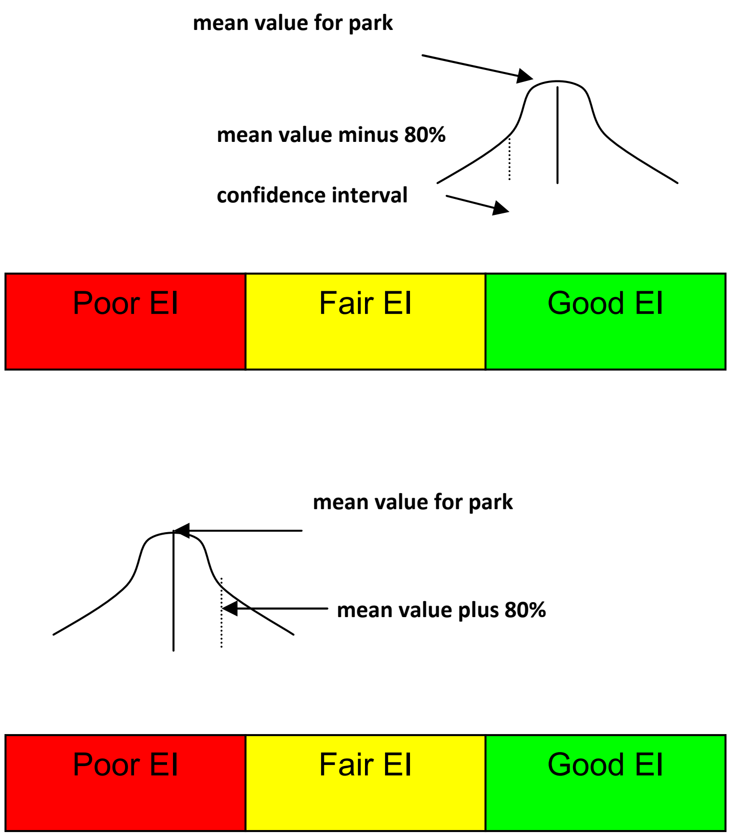
Figure APP 4.1: Thresholds of Ecological Integrity

Lower ThresholdUpper Threshold

EI Measure

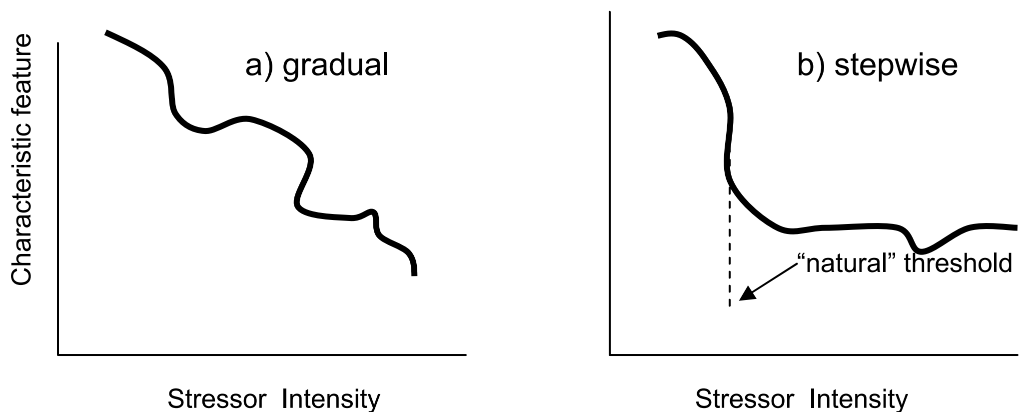
Since there is often error in estimating a value for an EI measure, you should be careful in deciding when a threshold has been crossed. It is recommended that you subtract a confidence interval when comparing your value to the upper threshold and add a confidence interval when comparing your value to the lower threshold (Figure APP 4.2). 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. A word of caution is warranted here. Depending how this approach is applied in specific instances, it may be more difficult to show improvement and may potentially obscure the fact that something is worsening, particularly where the interval between measures is long. Attention should be paid to address these potential risks when establishing thresholds.

Figure APP 4.2: 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 that have a negative correlation with the persistence of characteristic features (Figure APP 4.3).

Figure APP 4.3: Types of relationships between stressors and characteristic features



Stressors may arise from a variety of sources:

- 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, e.g., forest fragmentation is a stressor, but its inverse, forest connectivity is an EI measure. 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 APP 4.2 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 APP 4.2a). It is more difficult to identify a natural threshold in the latter case. Still more frequently, you will 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.

Setting Monitoring Thresholds

Apart from persuasive evidence of a stepwise decline in an EI measure at specific stress levels, the following are four useful 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, 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.

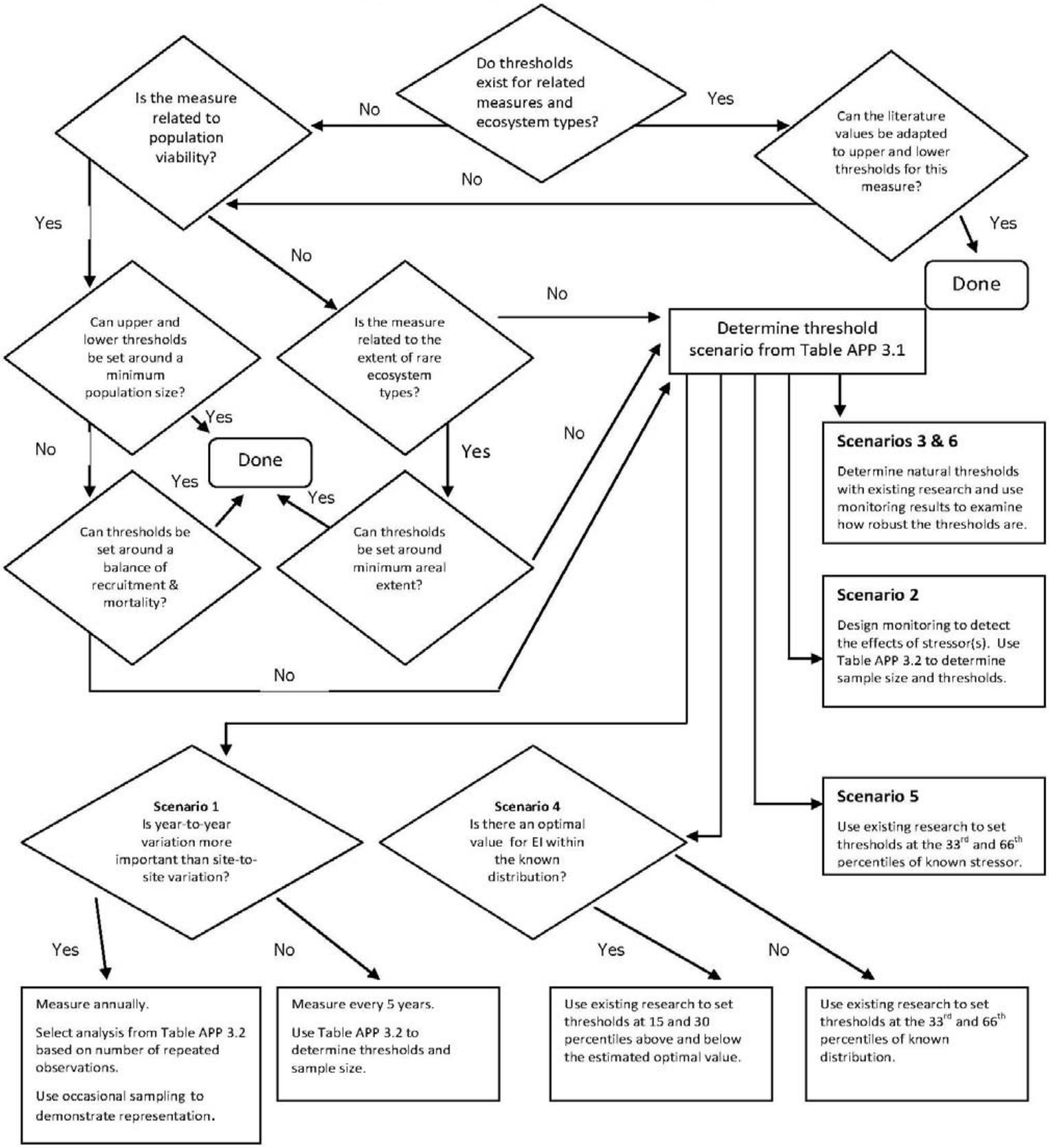
Though each of these threshold approaches produces values with reference to a single EI measure, its biological significance will depend on its contribution to large and irreversible changes in the characteristic aspects of the whole ecosystem. There are some initial approaches for developing whole ecosystem measures (Harte 1979; Brock and Carpenter 2006) that 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 App 4.4 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 APP 4.1 to identify the threshold scenario that will be most informative for you.

Figure APP 4.4: A flow diagram for the process of monitoring threshold selection.



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 APP 4.1 are preferable to those with less specific information on the top and to the left.

Table APP 4.1: Approaches to setting interim thresholds for EI measures.

Relationship with Stressor

	Unknown	Gradual	Stepwise
Distribution Unknown	1. Change Detection a) Comparison with spatial variation b) Comparison with temporal variation - Standard deviation - SE of slope - Statistical Process Control	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
Distribution Known	4. Distribution Segmentation **Selection of thresholds at equal intervals –** with/without optimum 4. Change Detection (temporal) - % of distribution - ARIMA models	5. Distribution Segmentation with Stressor Selection of thresholds at equal intervals along stress gradient – linear/non-linear	6. Distribution Segmentation with Natural Thresholds Identification of stress values with largest impact on the measure at approx. equal intervals

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 the slope of the relationship 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"?

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.

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.

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 APP 4.2). This guidance, based in part on rules of thumb from Cohen (1977), allows you to choose a defensible design whose rigour 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.

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 of the variability of the measure.

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 APP 4.2). 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.

Table APP 4.2: Default thresholds and sample sizes for selected analyses. Both confidence and power are assumed to be 80%.

Scenario	Analysis	Effect Size Upper Threshold	Effect Size Lower Threshold	Type of replication	Minimum number of replicates
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

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.

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 a park highway 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 APP 4.2). 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 stressor. The approaches from Scenario 1 are also available for setting thresholds.

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 APP 4.2b), 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.

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^{th} and 10^{th} 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.

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.

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.

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.

TECHNICAL APPENDIX 5: Combining EI Measures to make EI Indicator Assessments

Objectives

Various strategies exist for developing EI indicators: from strictly qualitative to quantitative methods. To develop the method presented here, we evaluated a number of different methods (that analysis of alternative methods is not presented here). 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 method used to determine its status. In this regard, the guide presents standardized methodols for the derivation of the status and trends at the EI indicator level.

Assessing Ecological Integrity Status for Indicators

Integrating EI measures into a composite score to assess and report ecosystem status is an increasingly common practice in reporting ecological condition. Indicators calculated this way are useful for managers to convey the overall status and trends around complex issues to policy makers and the public. In this big picture context, composite environmental 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., an interpretation of changes in the measures. Furthermore, a mathematical formulation is explicit and repeatable. This is an important feature, given the inherently long timeframe of park monitoring programs.

You should apply and interpret indicators judiciously and transparently. Table APP 5.1 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 individuals 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 decision makers and the public on park ecological integrity.

The central value of the indicator is that it provides an assessment of changes in park EI that can be conveyed to decision makers and to a wide audience.

Table APP 5.1: Potential benefits and pitfalls of using indicators. Derived from Saisana and Tarantola (2002) and Nardo et al. (2005) with additions.

Potential Benefits	Potential Pitfalls
• Summarizes an array of complex and/or multidimensional measures into a few values. • Easier to determine trends than with multiple measures. • Balances conflicting status and trends among different measures. • Facilitates ranking different indicator ecosystems and measures. • Provides a transparent and repeatable method for synthesis. • Extends the interpretation by authors of multiple measures by providing a quantitative synthesis. • Provides a short summary of measures to fit size limits of reporting formats. • Facilitates communication with the public and promotes accountability.	• Invites simplistic conclusions about the ecosystem indicator. • 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. • Selection of measure weightings could be used to support a pre-determined position on the status of an indicator ecosystem or measure. • Construction methodology may disguise patterns in some constituent measures that lead to difficulties in identifying proper management action. • May lead to inappropriate management actions if the measures that are difficult to measure are ignored.

The methods for integrating measures into an indicator vary from qualitative, to semi-quantitative, to fully quantitative formulations. This guide recommends a standardized method for determining the status and trend for each indicator. Parks should develop indicators and ecosystem assessments using this formulation to ensure consistency of approach across the Agency. In other words, a red signal of impaired ecological integrity for an EI indicator in British Columbia should indicate the same thing as one in Newfoundland or the Arctic.

Parks and field units have a great deal of flexibility in

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

Field Unit Superintendents and their management teams set resource conservation priorities based, in large part, on information 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 a standardized, Agency-wide approach to rolling-up and reporting on a park's ecological condition and the effectiveness of active management activities within that park.

Indicator Status

This section provides a method to integrate the status of individual ecological integrity measures into a comprehensive assessment index for the EI 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 credible statement about an indicator’s ecological integrity. There are various reasons to leave an indicator blank:

- 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.

The Field Unit Superintendent and Resource Conservation Manager, supported by the technical team, will decide if there is enough information to determine the status of their EI indicators. If an EI indicator is missing data for one or two measures, a park may still decide there is sufficient basis to make a credible evaluation. If EI measures are added to an EI indicator over time, care must be taken to evaluate the effect of these measures on the trend of the EI indicator.

The general strategy is to convert EI measures into simple scores based on their status in relation to their thresholds. Scores are then amalgamated into an overall score and colour signal that is more easily communicated than the technical data. To do this, results of different EI measures must be standardized. 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. Parks Canada utilizes a relatively simple, equally weighted formulation as a standard for all parks. Figure APP 5.1 is a flowchart of decisions for assessing an EI indicator.

The procedure:

- Determine whether the suite of ecological integrity measures and their associated data and analysis are sufficient to assess and report the indicator's ecological integrity. If not, the EI indicator receives 'no colour'

- If data are sufficient to evaluate EI, give EI measures a status based on their relationship to their thresholds. EI measures with Good EI (or above the upper threshold) score two, while EI measures in the Fair area score one, and those in the area with Poor EI score zero (see Figure APP 4.2).

- If at least a third of the EI measures score zero, (Poor EI), then classify the EI indicator Poor.

- If less than a third of the measures score zero, then average the scores from each measure and re-scale them from 0 – 100.

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

where N is the number of measures for that EI indicator. EI indicator scores are translated into the colour system for EI (Table APP 4.2). In practice, this is only for distinguishing between EI indicators in Fair or Good condition. All EI indicators scoring 33 or less will have at least one third of their EI measures with Poor EI.

Two aspects of this approach require discussion: equal weighting of EI measures and the use of the 1/3 measures rule. Equal weighting is the most transparent and readily justifiable approach for assessing EI indicators. Without credible evidence of the relative importance of all measures, it would be difficult to maintain a system of weighting that allowed some EI measures to have a greater impact on the EI indicator assessment than others. For this reason, equal weighting is used to ensure an unbiased, if somewhat coarse, summary of the state of the EI indicator. A system-wide unweighted approach also improves assessment and reporting consistency across parks.

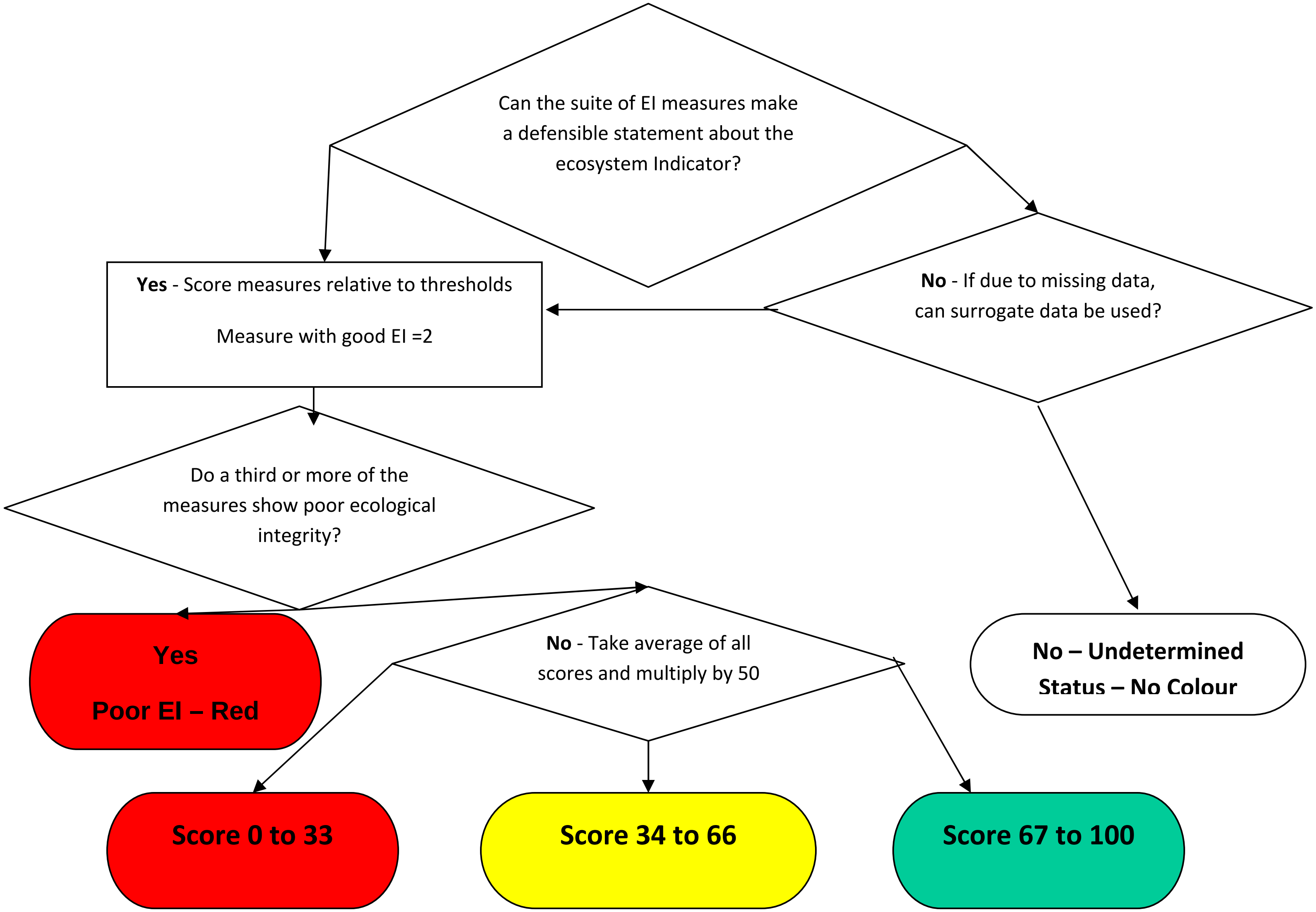


Figure APP 5.1: Flowchart with decision rules for designating the ecological integrity status of the indicator ecosystem

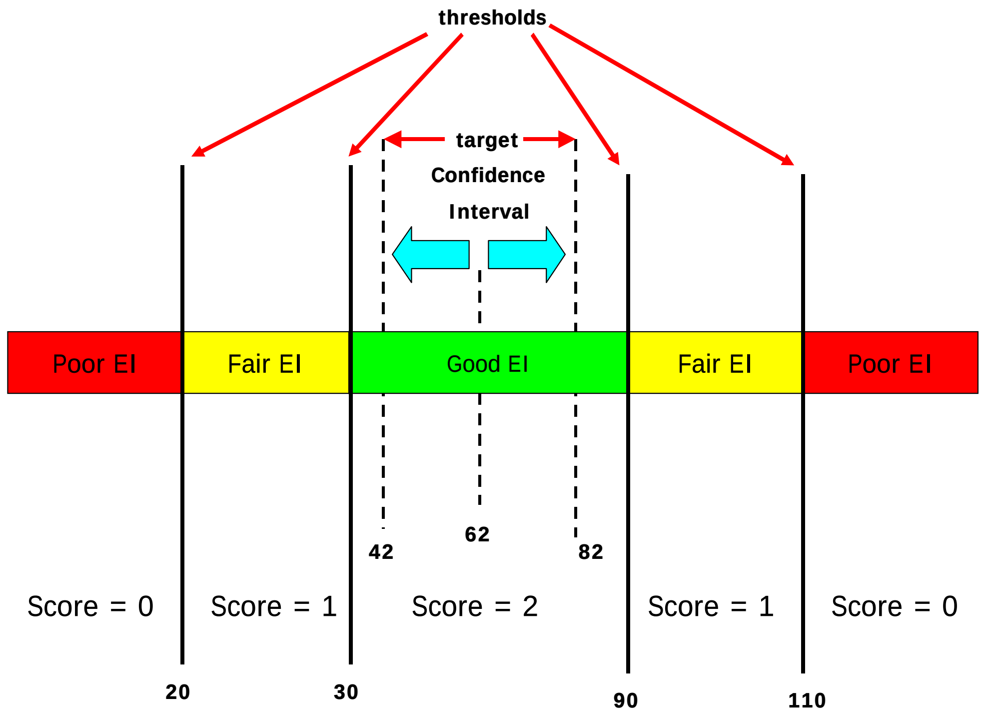


Figure APP 5.2: The relationship between thresholds and scores for ecological integrity measures.

Table APP 5.2: The ranges of indicator scores for each ecological integrity colors.

Scores (Samson[2])	Colour
0 - 33	Red
34 - 66	Yellow
67 - 100	Green

[2] Named after the inventor of the first formulation of the Parks Canada EI scale.

One consequence of equal weighting is that a balance of Good and Poor EI measures receives the same EI indicator score as a set of EI measures in Fair condition. Where a large proportion of EI measures are in Poor condition it should be reported. It does not matter if there is potential for Good EI measures to offset the influence of the Poor EI measures. This approach reflects the precautionary principle. Here, we assess all EI indicators with at least one third of their EI measures in Poor condition as having poor ecological integrity. If these EI measures have, in fact, a greater influence on the ecosystem than the majority of EI measures that are in Fair or Good condition, the net effect on the ecosystem would be a loss of overall EI . This "one third rule" is necessary for signalling potentially serious EI risks until we have a better sense of how EI measures work together in an ecosystem context. In the meantime, it is critical that EI indicators, EI measures and monitoring thresholds be carefully selected and credible, and that all parks are consistent in their assessment approaches.

Another note regarding the 1/3 measures rule is warranted here. As mentioned elsewhere in this document, it is generally recommended that 4-5 measures per indicator provide sufficient confidence regarding the status of that indicator. Field Unit Superintendents who feel their park's circumstances may warrant varying from this direction are reminded to consult with the Director General, National Parks and be aware that as the number of measures is reduced, the level of confidence similarly decreases. In cases where there are three measures or less for an indicator, the result may yield a false "red" when the indicator status is calculated. This occurs because of the 1/3 rule, where a single red measure among three or fewer measures for an indicator will, by definition, result in an overall red rating, regardless of the actual state of things on the ground. This is a necessary risk, ensuring that potential EI threats are fully considered; however, common sense should still prevail. In instances where a low number of measures appears to have resulted in the calculation of a status rating that does not align with the park's on the ground understanding of that indicator, the Field Unit Superintendent should exercise appropriate judgment in assigning a condition rating that better reflects the park's understanding of that indicator. It is important, however, that these circumstances be documented in ICE, to ensure credibility and transparency, and that the rationale for the assessment be substantially documented in ICE.

Trends

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

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

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

- *Points of origin:* EI 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 EI indicator must reflect the relative importance of these measures.

- *Crossing thresholds:* EI measures that cross monitoring thresholds have a significant impact on the reporting of EI. So these trends should be weighted more than others (see Figure APP 5.3). There are six possible transitions between monitoring threshold boundaries and another three where no change occurred (see Table APP 5.3). You will need a scoring system to highlight these transitions.

Table APP 5.3: Categorization of trends based on a change of status of EI indicator.

Indicator Trend	Previous State	Current State
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 EI measures may exhibit trends, the magnitude of change may vary. You should recognize that the ecological significance for some EI 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 EI measures.

- *Differences in sampling intervals and time scales*: EI measures differ in their sampling intervals. This is partly set by the underlying rate of change for each EI measure. Over the reporting cycle of the State of the Park Report, different EI 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 EI measures 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 EI measures:* It is difficult to account for discordance amongst EI measures within an EI indicator. For example, an EI indicator with two EI measures increasing, two measures with no change, and one decreasing, would score as “no change” based on “averaging” of trends. Similarly, an EI indicator with one EI measure increasing, three with no change, and one decreasing would produce the same score. This despite the underlying differences in trends for EI measures.

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

Determining EI Indicator Trend

Figure APP 4.3 outlines the decision rules for determining EI indicator trends. The flowchart’s features include:

- three to five steps for classifying an EI indicator trend;

- a dichotomous key generally requiring yes or no answers;

Decisions involve a hierarchical process reflecting 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. Finally, the decision tree provides a link in the chain of evidence from EI measures to assessment and reporting of an EI indicator trend. The steps:

1. If this is the first State of the Park Report using a quantitative EI indicator, then you generally will not be able to report the trend of your EI indicators. However, you may be able to use archived data to generate retrospective EI indicator scores.

2. If there is a status from the previous EI indicator evaluation, determine whether the current status of the EI indicator has crossed a monitoring threshold. See Table APP 4.3. Above all other criteria, this will establish the trend for the EI indicator.

3. If the status of the EI indicator has not changed, then examine the constituent EI measures. If one third or more of the EI measures are declining then assess the EI indicator trend as Declining. This logic is similar to that for designating Poor ecological integrity status. Since one of Parks Canada's primary goals is maintaining EI, and a park's baseline condition should be at a high level of EI , the scoring system is more sensitive to declines in the EI of EI measures than to No Change or Increasing status.

4. The final level of evaluation is to subtract the number of declining EI measures from the number of increasing EI measures. If this net number of changing EI measures is greater than 2, or less than –2, then the indicator should be accorded a trend reflecting the more abundant group of changing EI measures. Otherwise, record the EI indicator as having No Change.

Table APP 5.4 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 APP 5.3: A decision tree of the steps in determining the trend for an indicator.

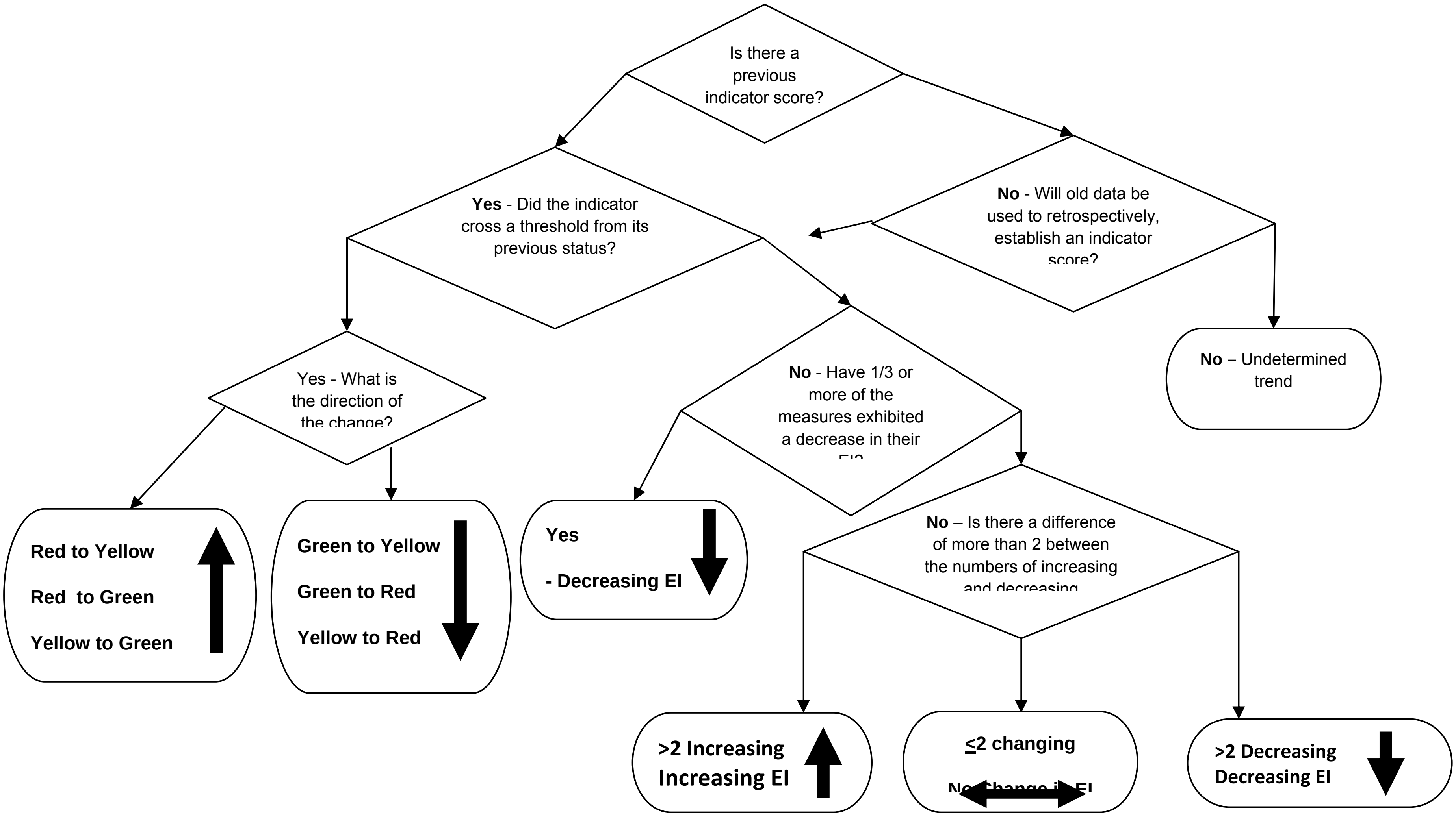


Table APP 5.4: A sample graphic for presenting status and trends on State of the Park Reports after the first or where previous indicator status/scores exist. The data presented are hypothetical. Fill colours represent the status of the indicator. An additional column on trend follows the status column. 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	↑	5	4	1	0
Non-forested	Good	↑	5	4	2	1
Lakes/Wetlands*	Fair	↓	2	4	1	0
Rivers/Streams	Fair	↔	2	5	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.**

Determining Trend for an EI Measure

Methods for evaluating a trend for an EI measure depend on their individual characteristics. For EI measures based on change detection (Scenarios 1 & 4 in Appendix 3) the EI measure is the trend. Determining trend for these EI measures is equivalent to examining the acceleration of change. You can use the same statistical techniques applied 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 that is the difference between Poor and Good EI for that EI measure (see Figure APP 3.1).

Critical Range = Upper threshold-Lower threshold

A value of 1/3 of the critical range is recommended as the criterion for change in an EI measure (see Table APP 4.5). This value provides adequate resolution to warn of impending change in a measure's status.

Table APP 5.5: 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.

EI Measure Trend	**Criteria**
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

TECHNICAL APPENDIX 6: Study Design and Power Analysis

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.

Rationale for a good design selection

The choice of a study design is determined by the question your monitoring project needs to answer to effectively support management decisions. 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. Similarly, answers to questions that do not support management decisions are of little value.

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.

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.

What makes a good design?

A good design produces data that are free of biases. In other words, the study design accurately estimates the variable of interest (e.g., population abundance, average decomposition rate, average clam density per quadrat). To mitigate against 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 variable of interest in an unbiased manner. 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 you may only have sufficient resources to sample within 1 km of access roads. Hence, you will choose a design that gives an unbiased 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 bias in phrasing the monitoring question or control for it when making statistical inferences. The study design only seeks to avoid biases in the context of the restrictions set by the monitoring question.

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 <u>may</u> 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, which will be determined by need and by available resources.

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, and 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.

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 can be 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 over the long term. A few common logistical issues:

- In many parks, access costs prohibit sampling in 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 in your park, your monitoring program will miss your information needs 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.

Autocorrelation

A common assumption of statistical analyses is that sample units are independent. What this means is that variability related to our sampling protocol or, more commonly, variability related to underlying ecological factors (geology, climate) is assumed to be independent from one site to the next. This is 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. You can also use statistical means of testing to see whether you have an autocorrelation problem, and also to control for it (e.g., bootstrapping) but you need very large sample sizes.

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.

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). Several factors influence statistical power:

- effect size: the magnitude of change you are trying to detect (it is easier to detect large changes than small changes),
- variability of the data (noisier data lead to low power),
- abundance: difficult to detect changes in rare species,
- confidence: the more willing you are to accept false alarms, the less likely you will miss a real change,

- time horizon: 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 (e.g., reporting every 5 versus every 10 years)),
- the choice of statistical test to detect trends, and
- sample size (Figure 9.1): the more data you have, the higher the power.

Choosing appropriate power & confidence levels

The user determines the confidence level (you choose it). Power is a function of the elements listed above, 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 studies, where the consequences of missing an important change are graver than the consequences of detecting a false change. Hence, we aim to have 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 case, we want 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.

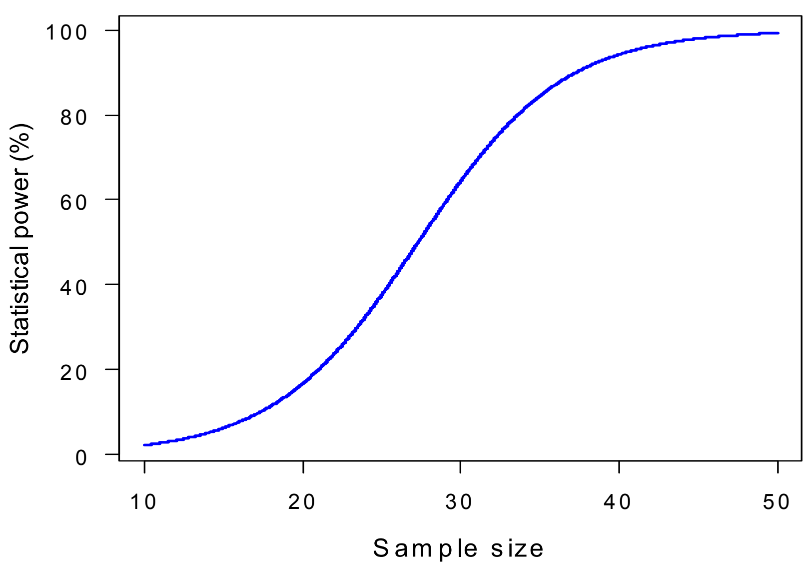


Figure APP 6.1. Example of a power curve. Note that the increase in power with sample size is not linear (all other factors held constant). In this example, taking more than 40 samples yields little gain in power

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.

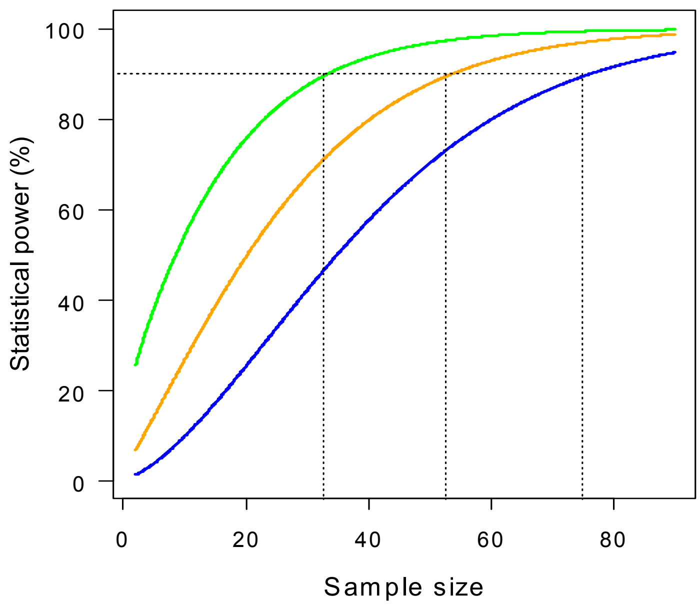


Figure APP 6.2. Example of how changes in desired confidence affect power and required sample sizes. Three curves are shown corresponding to different levels of confidence (blue = 99%, orange = 95%, green = 80%). For each curve, the sample size corresponding to 90% power is indicated by dotted lines.

Tools for power analysis

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

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:

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

TECHNICAL APPENDIX 7: Data Analysis

Importance of good analysis

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

How to interpret change

The values of your 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 effect of the change on the underlying ecological system. Considering what constitutes an ecologically significant change in a measure is an important step in study design (See Appendix 6).

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 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, the management relevance will reflect ecological relevance.

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 Technical Appendix 6 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 deviate from historical data, as recent data may be swamped by historical data (Figure APP 7.1).

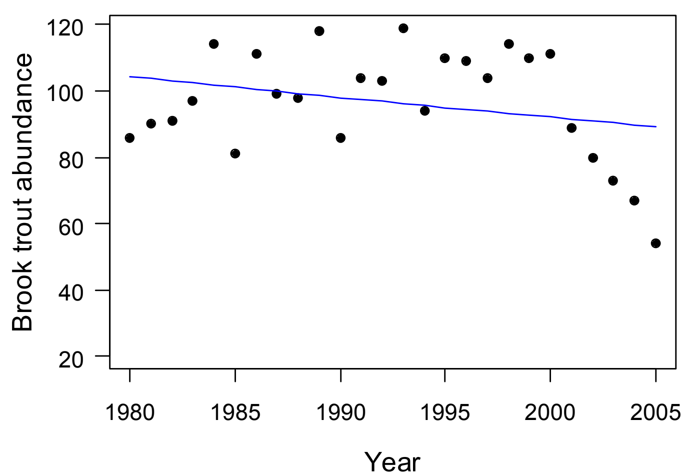


Figure APP 7.1. An example of a trend analysis where data in recent years do not fit the long term pattern.

You can also determine the status of your measure 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 be more useful to use the estimated value from your trend analysis for the most recent year data were collected.

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.

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.

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.

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. Pseudorepl‌ciation 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 patterns 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 x 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 –Technical Appendix 6 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.

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://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

TECHNICAL APPENDIX 8: Information Management for EI Monitoring

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:

- 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.

- 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.

- 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 can 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).

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, and PCA has adopted the Treasury Board data management policy for IM approach and record keeping (http://www.tbs-sct.gc.ca/pol/doc-eng.aspx?section=text&id=12742)

- 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:
  - Information Management, Technology, and Services (http://intranet/content/Imit-Giti/index_e.asp)
  - Research, Collection and Monitoring and Species at Risk in Heritage Areas (http://intranet/content/eco-re/index_e.asp)
  - Information Centre on Ecosystems (ICE): http://intranet/content/eco-re/GI-ecol-IM-eng/monitoring-suivi.asp
- Parks Canada EI Monitoring, Species at Risk, and Research and Collection Permitting Data Management Plans: . http://intranet/content/eco-re/orig/Ecosystem_Science_and_Research_Data_Management_Plan_E.pdf

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 will contain these elements:

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

Park EI Monitoring Plan

Every park will have an EI Monitoring Plan. This plan describes a park's conceptual ecosystem model(s), bioregional indicators, monitoring measures, protocols, and sampling designs.   This monitoring plan will be entered into ICE in the appropriate location and updated as necessary.

Monitoring Project Descriptors

Each project in your EI monitoring program will 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 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/GI-ecol-IM-eng/monitoring-suivi.asp.

- Park Name
- Monitoring Measure Name
- Indicator(s) that measure supports
- Lead Agency
- Project Leader
- Measure Rationale
- Objective
- Scope of sampling (single location to global network)
- Dataset – data file name
- Year of data
- Data access and constraints
- Funding and Person Time
- Park Management Plan reference
- Staff
- Contacts
- Comments
- Category (Ecological, Cultural, Visitor Experience, Public Understanding, etc.)
- Type (Condition Monitoring, Management Effectiveness Monitoring, Research, etc.)
- Framework (Biodiversity, Process, Stressor)
- Description
- Active or Non-Active
- Updated (when and by who)
- Thresholds

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 the following:

- 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:

- *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 Ecologist 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 often learn about monitoring protocols and sampling techniques but not about how to use a database. Some degree of IM training is recommended for monitoring staff.

- *Information Quality Review:* Park monitoring 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.

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).

In general, these functions follow a consistent approach:

- All data records follow the Parks Canada Agency Core metadata standard.
- For data files (versus non-data files like written reports), a Structured Data Profile will apply with selected elements from the FGDC standard.
- 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.
- 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 includePCA 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).

This metadata information should also be entered into ICE to support the measure information and any datasets available.

In-Park File Management Systems

There are no national EI monitoring guidelines for in-park file management. However, it is suggested that 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.

Bioregional Archival of Park Monitoring Plans, Data and Metadata

Annual updating of monitoring data should be a formal part of each national park's IM strategy. Parks should update monitoring plans, protocols, data and metadata by the end of each fiscal year. This serves several purposes:

- It provides redundant, off-site archives of information for security.
- It facilitates responses 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.

Parks Canada's National Information Centre for Ecosystems and Biotics

The Information Centre for Ecosystems and Biotics are centralized tools to help parks record and manage EI monitoring and species at risk related information. ICE is a web-based IM tool managed through the National Parks Directorate. 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.

You can find further information on ICE and a link to the systems at http://intranet/content/eco-re/GI-ecol-IM-eng/monitoring-suivi.asp

Biotics is IM software –developed by NatureServe (International NGO) and adopted by Parks Canada. Parks Canada has had a partnership with NatureServe for many years which supports the sharing of species information, standards and methods. Biotics contains a suite of tools (Biotics Tracker, Biotics Web Explorer, and Kestrel) 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, Species at Risk, and Research and Collection Permitting Data Management Plans* (2006) and the Ecological Integrity Information Management intranet site at http://intranet/content/eco-re/GI-ecol-IM-eng/IE_GI_IM_EI.asp.

ICE and Biotics are mandatory elements of each park's IM strategy for EI monitoring and staff are required to make sure that information in these national systems are up-to-date. This will provide Agency-wide standards, helping us better manage our EI data and share information (internally and externally).

TECHNICAL APPENDIX 9: Protocol Standard

The Need for a Protocol Standard

Park EI condition monitoring activities are intended to be in place indefinitely, so you can expect that park employees who conduct the related activities 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 in ICE and updated as required in the monitoring protocols developed for the program.

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

To ensure consistency among national parks, a protocol standard is used to outline the 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 below.

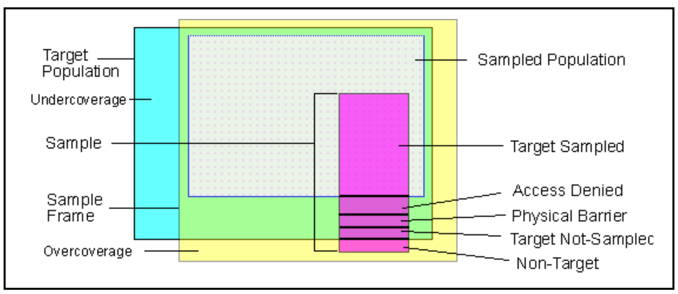
Background and Objectives

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).

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.



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.

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.

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 Memoranda of Understanding that either govern or limit the monitoring identified in the protocol.

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.

Additional Reference Material

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

TECHNICAL APPENDIX 10: Effectiveness Monitoring

What is Effectiveness Monitoring?

Effectiveness monitoring (EM) 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 kind of monitoring relates directly to the park management plan, because the goals and objectives for the proposed management activities are often described there. EM is thus an accountability process for reporting results of management actions or ongoing park management policies and operations, in the context of ecological integrity objectives and project outcomes.

Most EM will be relatively short term (5-15 years) to show the direct consequences of our management actions in the context of park EI. EM is not directly equated with short term monitoring, however. In some cases EM may be long term in relation to ongoing park management policies. These two kinds of EM are distinguished below.

Effectiveness Monitoring in National Parks

Park management activities, and EM, 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

- **operations 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.

Effectiveness monitoring is that component of these management projects and ongoing policies and operations that assesses the effects of management activities in the context of park ecological integrity.

Effectiveness Monitoring and Environmental Assessments

Management projects that trigger environmental assessments (EAs) under the Canadian Environmental Assessment Act (CEAA) are a special subcategory of active management projects that may require EM. The *Parks Canada Guide to Compliance with the Canadian Environmental Assessment Act* (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 EM, the difference is not significant, because the EM 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 effects 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 infrastructure such as buildings or roads are being decommissioned.

Monitoring Active Management Projects

The scientific approach is appropriate to EM, because this type of monitoring aims to determine effects of management on EI status and trend. 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 used for condition monitoring described in Technical Appendix 6 apply equally well to EM projects, e.g., principles of study design, power and significance, and developing clear monitoring questions.

Table APP 10.1 is an outline for a typical EM project where active management is planned. The planned EM 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 impact of the management action 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 as projects are initiated. Bioregional monitoring ecologists are trained to assist parks staff with the design and analysis of EM projects. The EM report should end with a discussion of results in terms of expected targets and conclusions about the project's success.

Table APP 10.1: Content of a typical EM 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
    d. Data management and metadata
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

General Effectiveness Monitoring Models

Figures APP 10-1 and APP 10-2 present generalized monitoring models for the two kinds of management activities described above. The models can guide park EM through a schematic representing the structured thinking for the two management types. You can visualize most EM programs using these models.

Monitoring Active Management Projects

The general model for monitoring active management projects (Figure APP 10-1) compares trends of EI measures for treated sites with untreated sites, for sites above and below a management action on a stream, or with pre-treatment levels of the same measures on the treated site. 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 APP 10-2):

- 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.

- 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 APP 10-2 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.

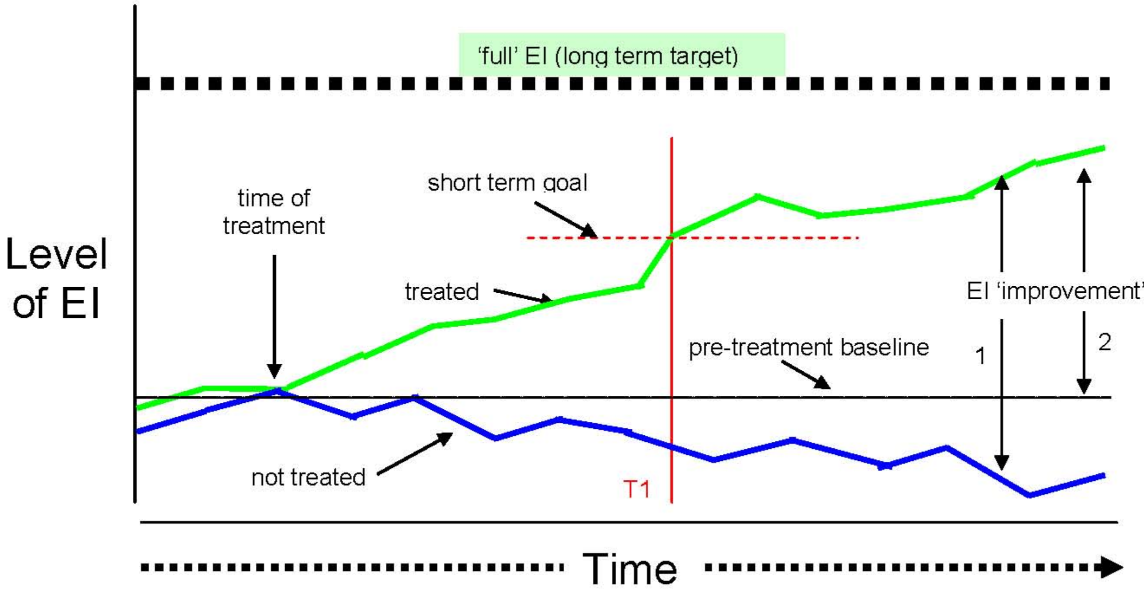


Figure APP 10-1: General model for management effectiveness monitoring of active management projects.

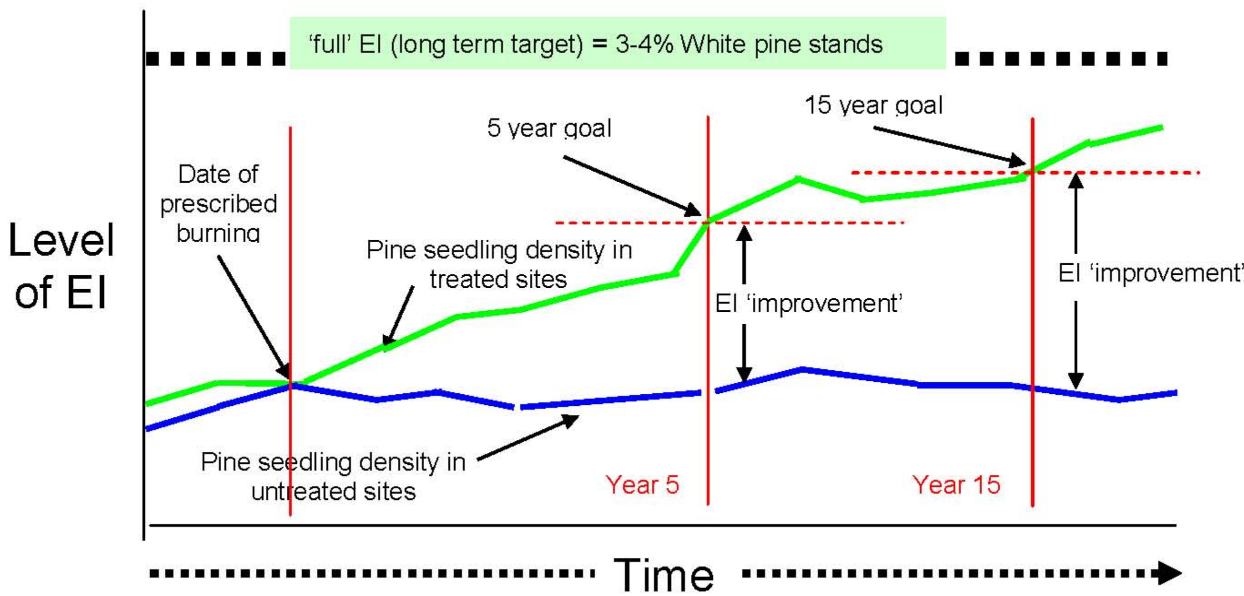


Figure APP 10-2: General model for effectiveness monitoring of active management projects using the prescribed burning in La Mauricie National park as an example.

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 APP 10-1 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 APP 10-1 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.

Examples of Monitoring Active Management Projects

<u>Example 1: La Mauricie National Park (LMNP): Increasing the White Pine Component in Park Forests</u>

1. Identifying the management issue, and establishing desired condition

The Park Management Plan (PMP) 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 at La Mauricie 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 EM 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 Quennevile (1998) determined that pure white pine stands should cover at least 3-4% of LMNP 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 management action’s general, long term 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 an experiment to detect the expected changes

The design for the management action was to select a number of suitable sites, burn a random selection of some of them, leave others untreated, and compare white pine regeneration between the two sets of sites. In Figure APP 10-2 we show the model from Figure APP 10-1 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).

Monitoring as part of operational management

The general model for monitoring ongoing park policies and operations (Figure APP 10-3) shows the trend line for a monitoring measure relevant to a particular ongoing management activity or policy. For example the trend line may measure:

- fish population abundance from lakes or streams where recreational fishing is permitted,
- numbers of grizzly bear encounters 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.

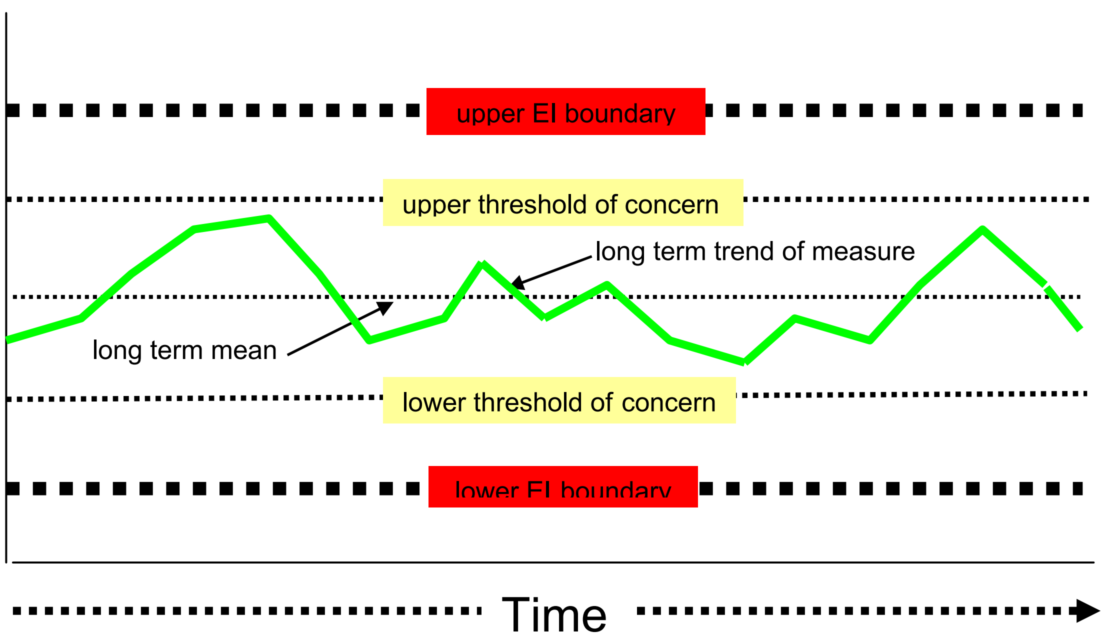


Figure APP 10-3: General model for management effectiveness monitoring of ongoing park management or operations.

The role of EM 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 APP 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. 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 bear encounters you could analyse visitor use 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 excedence of the Canadian drinking water standard, local coli form 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 (hyper-abundant 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.

Other Parks Canada EM Projects

Table APP 10-2 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)

Interactions between Management Effectiveness Monitoring and EI Condition Monitoring

EI condition monitoring and effectiveness monitoring 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 shorter in time than EI condition monitoring. Typically, EM projects focus on the areas where management actions apply, while EI condition monitoring covers broad areas of the 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 EM question about effects of management actions. Effectiveness monitoring projects use more focussed experimental designs addressing specific questions for specific management actions, and often include treatments and controls. This is often 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 hyper-abundant 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 EM 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 EM and EI condition monitoring is in providing long-range EI targets from EI condition data for EM 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 EM mature in your park.

Finally, the project components this guide describes for EI condition monitoring generally apply to EM 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 EM projects the monitoring question will be specific to the needs of the project being monitored.

Table APP 10-2: PCA 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)[1]	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.	• 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 • install gates to permit people to cross and use corridor • install counters on trails to assess human use of corridors • re-locate winter skiing and hayrides away from corridor	• relative abundance of elk, deer, and wolves from winter track transects • wolf movement paths from snow back-tracking • snow depth • human use counters	1. Establish levels of the measures before treatment 2. Compare corridor use measures after fence construction with pre-construction use 3. account for covariates such as snow depth and human use
Stream restoration[2] (Pacific Rim NP)	Historical legacy of logging has left important salmon–bearing streams full of decaying logs and disconnected through poor culvert maintenance. This 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 and fish.	• remove logs and debris to restore flows; • improve culverts to re-establish connectivity • add gravels as required	• water quality • water temperature • benthic invertebrates • salmon smolts • adult salmon returns	1. Establish levels of the measures before treatment 2. Compare measures at treated sites with similar untreated sites 3. Compare measures at all sites with similar pristine old forest sites to establish long range targets

Table APP 10-2 (cont.): PCA 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 [3] (Kejimkujik 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.	• Three old logging dams were removed in 2004 and 2005	• Fish species abundance in fish traps • pH, conductivity, O_2, and turbidity	1. Streams were sampled for fish while dams were in place in 2000 2. water quality was tested in 2003 before dam removal 3. fish abundance and diversity and water quality were sampled following dam removal
Ski Hill Management [4] (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	• electric fence constructed • alterations to human use patterns • control of human noise • strict adherence to NPA garbage regulations • education of lodge staff • staff education of park visitors	• tracking bears in area to determine spatial and temporal use patterns; assess 'bear jams' • birth and death data of local grizzly bears • measure levels, type, and timing of visitor use • compliance monitoring of garbage regulations • visitor surveys to assess awareness of bear issues	1. all measures were assessed at the onset of the management changes 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

[1] 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/

[2] 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)

[3] Dick, J.A., and M. Trudel. 2006. Survey of fish species following removal of old logging dams in Cobrielle Brook, Kejimkujik National Park and National Historic Site. Internal Report, Kejimkujik National Park and National Historic Site. 13 pp.

[4] 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.

TECHNICAL APPENDIX 11: SOPR Information to be recorded in ICE

The scientific rationale used to analyze monitoring results and develop assessments must be documented in ICE for use in a variety of corporate requirements, including the streamlining of SOPR and SOPHA reporting processes. This requirement replaces previous direction concerning the production of a stand-alone Technical Compendium document, which is no longer required.

These data and analyses will be recorded in ICE in a manner that makes them available to various functions for a variety of other uses, such as the production of individual fact sheets, to support corporate reporting requirements or to respond to public or audit/evaluation inquiries. This information represents a key corporate memory legacy of resource conservation activities, and field unit leadership is required to maintain the integrity of the data. Effective and timely documentation in ICE will better ensure the maintenance and utility of the data over the long term, and that it will be more readily accessible to park ecologists, managers, and other Parks Canada staff.

The information that will be documented in ICE will include a series of Technical Summary Reports, one for each EI measure. These reports include mainly the monitoring question, the metric, and a clear presentation of the most important analyses, so that the approach can be understood by others and can be evaluated and/or replicated in the future. If a formal or interim protocol is available for the EI measure, then much of the contextual information will not need to be repeated in the summary report. Information such as the rationale for selecting the EI measure, its role in measuring EI , and the rationale for monitoring thresholds will be in the protocol. A list of required information is summarized in Table APP 12.1 below. As a rule of thumb, information that remains static through time should be in the protocol. Information that will change with each SOPR should be included in the scientific rationale. So that the information can be more easily accessed, some authors may choose to include one or two summary sentences from the protocol such as context, methods, determination of thresholds and recommendations pertinent to management or status assessments.

Once protocols have been finalized and methods and rationale expressed in the first SOPR, it is expected that summary reports will evolve into shorter documents and take less time to produce.

Table APP 10.1: Information required for Technical Summary Reports. An annotated template is also provided for guidance.

1. Indicator, measure, status and trend
2. Monitoring question(s)
3. Specific metric used for each measure, e.g. mean species richness of EPT taxa from all benthic invertebrate sampling sites
4. Thresholds (see Appendix 3)
    a. rationale for selecting biologically-based or legislated threshold levels, e.g., literature source, historical variability, biological model, stress gradient, or legal target such as a required coliform level or water quality index standard
    b. rationale for interim thresholds related to assessing change over time, e.g., 2 SDs
5. Data used for each measure (how many years, which sites – refer to protocol)

6. Assumptions that influenced the analysis
7. Status assessment
    a. Method of assessment (e.g. mean of last year's data, output of the trend model, 5 year average, etc.)
    b. How uncertainty in status estimates are handled
    c. Results of analyses of any sub-measure information (e.g. parameters from the Water Quality Index) that provide context for the measure results
    d. How sub-measures contributed to a single measure assessment
8. Trend assessment:
    a. Statistical model including assumptions about the error distribution
    b. The number of years of used to generate a trend and the rationale for this choice
    c. Test statistic and p-value (where appropriate)
9. Data Quality (e.g. results of a power analysis, reliability of information)
10. State of measure development (e.g. level of completion of protocol and database)
11. Discussion of results of status and trend
12. Recommendations for management and monitoring program development
13. Authors, Partners and Reviewers
14. References
15. Tables, Figures and Photos (if desired)

The following information should be included in the protocol for the measure. If a protocol has yet to be developed, then this information should be documented in the Technical Summary Report.

- Measure context/rationale
- Overview of study design – spatial area of inference, replication, site selection
- Recommendations to improve measure quality through data collection methods
- Record of changes made to the protocol

Recommended Template for the SOPR Information to be Recorded in ICE

Name of the measure	Condition and trends (Symbol and arrow)

1. Context

Explain why this measure is an important component of the monitoring program, including specific EI issue (ex: deer overbrowsing) and reference to the monitoring framework (biodiversity, process and function, and stressor). Support the major statements with references to the literature. Refer to tables or figures as need be.

2. Metric(s) & Thresholds

State the specific metric(s) used for this measure and briefly define the thresholds for the metric(s) with reference to the protocol if available. Otherwise, state the threshold values, the rationale for selecting biologically-based or legislated threshold levels, gradient, or legal target, the rationale for interim thresholds related to assessing change over time (e.g. 2 SDs) (include references to support statements). Explain how they were developed (e.g. from literature or from site-specific data), and why this development approach was taken (see Appendix 4 for details). Refer to tables or figures as need be.

3. Monitoring Question(s)

State the question(s) asked to understand status and trend of measure. Include threshold values and the time period when trend was monitored. Here are examples of the structure of an appropriate monitoring question:

a) "Did the abundance of loons average >27 territorial couples, and produce an average of >0.5 chicks/couple/year, during the last 5 years?"
b) "Did the surface area of eelgrass beds decrease by >33% since 1992?"
c) "Did the dominance of key tree species decrease by >10% during the last 10 years?"

4. Methods

For the details of the methodology, refer to the protocol if it is available. Otherwise, provide a brief overview of the study design and a short summary of data used for the measure (e.g. how many years and which sites with reference to the protocol if available). Briefly explain the statistical approach used to determine whether or not the metric(s) were significantly different from the threshold. Briefly explain the statistical model used to determine trend (include implied assumptions about the error distribution). In a paragraph, explain how power was analyzed. Remind that for the need of the monitoring program, the level of confidence used to determine statistical significance and the required level of statistical power are 80% (see Appendix 6). Finally, explain how sub-assessments are combined into a single measure assessment if this is the case. Refer to tables or figures as need be.

5. Status and Trends Assessments

State the status rating and trends, or, explain why status and trends were not assessed. Refer to tables or figures as need be.

6. Data Quality: Qualitative assessment symbol (see below)

Confidence in the status and trend reported for a measure is influenced by data quality. The statistical power, study design and consistency in data collection mainly determine data quality (see Appendix 6). Adding the number of “true” statements from the list below can be used to assess data quality:

Criteria	**Evaluation statement**
Statistical power	The power to detect the desired effect size is ≥80%.
Study design	The statistical population is representative of the desired biological population.
	The sampling temporal frequency provides a representative portrait of the expected range of variability.
	The sampling approach is based on a random design.
Data Collection	The data was collected using the same method each time (the protocol did not change)
	Variability in the data was not affected by differences in observers’ ability.

The number of true statements is afterward used to assign a qualitative assessment, as in the following table:

Number of true statements	**Qualitative assessment**
6	**Good**
3-5	**Fair**
1-2	**Poor**

In a table, list the criteria and whether each evaluation statements was true or false.

7. State of development of the monitoring measure: Score/10 (see below)

Use the following criteria to assess the development of the monitoring measure:

Criteria	Evaluation statement	Score
1. EI Thresholds	Thresholds are well established, based on scientific literature and historical data	2.5
	Thresholds are preliminary and will be supported by a future literature review and/or an analysis of available historical data	1.5
	Thresholds are preliminary and based on a statistical approach (ex : ± 1 STD), and the appropriate range of variability will be determined by accumulating data during the next years .	1.0
	No threshold has been identified yet.	0
2. Power analysis	A complete analysis has been performed	2.5
	A preliminary analysis has been performed, but requires more data to be completed.	1.5
	No analysis has been performed yet, but preliminary data are available.	1.0
	No data are available to perform an analysis	0
3. Protocol	A detailed and complete protocol has been archived in the ICE system	2.5
	A protocol is available but require some editions to be complete	1.5
	Work instructions or a draft protocol is available but have not been reviewed	1.0
	No document describing the methodology is available yet	0
4. Database	Database, including metadata, are complete, have been controlled, and archived in the ICE system	2.5
	Database are completed but uncontrolled, and/or metadata are incomplete	1.5
	Database are incomplete	1.0
	No data has been filed yet	0

In a table, present the criteria, the evaluation statement and the related assessment score on a /2.5 scale. If required, the evaluation statement could be adapted to the context of a specific measure.

8. Discussion

Explain why the condition and trend are rated as they are. When the condition of the measure has been assessed as “Fair” or “Poor”, discuss the implications for park management. Refer to the literature to support statements.

9. Recommendations

If required, present recommendations on what can be done to improve data quality in the future (e.g., suggest changes to methods or ways to improve power of statistical analysis), and what should be the next priority to complete the development of the monitoring measure. Recommend future directions for park management when the condition of the measure was assessed as “Fair” or “Poor” (e.g., forestall the next survey to confirm the observed trend, or elaborate a recovery plan in collaboration with stakeholders). If none of these situations applies, simply recommend the continuation of monitoring as planned.

10. Acknowledgements

List the individuals and organizations involved with this work. Include data collectors, data analysts, reviewers and authors. If applicable, explain the individual contributions of co-authors.

11. References

Citations of all documents referred to in the text.