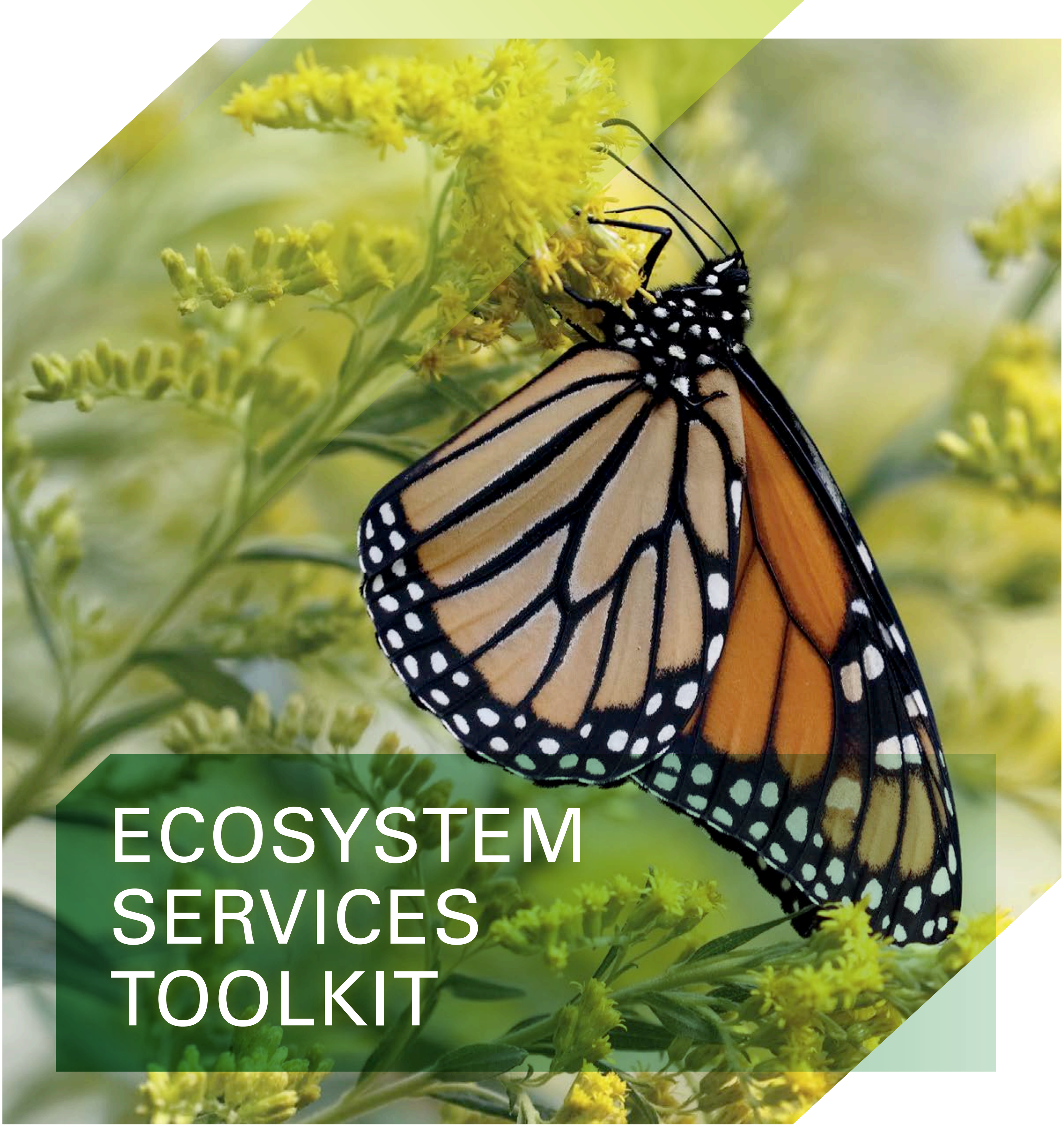

ECOSYSTEM SERVICES TOOLKIT

Completing and Using Ecosystem Service Assessment for Decision-Making: An Interdisciplinary Toolkit for Managers and Analysts

Value of Nature to Canadians Study Taskforce
Federal, Provincial, and Territorial Governments of Canada

Completing and Using

Ecosystem Service Assessment for Decision-Making:

An Interdisciplinary Toolkit for Managers and Analysts

Lead Authors: Susan M. Preston and Ciara Raudsepp-Hearne
On behalf of the Value of Nature to Canadians Study Taskforce
Federal, Provincial, and Territorial Governments of Canada

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Lead authors: Susan M. Preston, Ph.D., and Ciara Raudsepp-Hearne, Ph.D.

About the *Value of Nature to Canadians Study*

The *Value of Nature to Canadians Study* (VNCS) is a modular initiative launched in 2009 under the auspices of the Canadian Councils of Resources Ministers, and is directed by the Federal-Provincial-Territorial (FPT) Assistant Deputy Ministers' (ADM) Conservation, Wildlife and Biodiversity Steering Group, and the Interdepartmental ADM Federal Biodiversity Committee. Work is completed cooperatively through a national taskforce with representatives from six federal departments and agencies, and all 13 provinces and territories.

This initiative responds to the need for updated analysis on the importance of nature to Canadians in support of policy and decision-making, in recognition of national goals endorsed by Ministers in the *Canadian Biodiversity Strategy* (1995). An in-depth needs assessment and gap analysis completed in 2009–2010 found that (1) at a national scale there was extensive but uneven data on nature-based recreation, and even less on conservation activities; (2) there was very limited data on Canadians' awareness and views of biodiversity, ecosystem services (ES), and species at risk; and (3) there were limited resources for collecting, integrating, and using diverse values data. The VNCS consists of multiple interrelated works, which together have the objective of identifying the social, economic, and ecological significance of nature to Canadians in urban, rural, and wilderness environments. Central to the workplan is developing a national approach to ES assessment and a practical guide for completing and using ES assessment. This Toolkit fills that portion of the mandate. Additional products completed for, or in association with, the VNCS are:

- *How Canadians Value Nature: A Strategic and Conceptual Review of Literature and Research (2009)*
- *Nature Matters! Contest* for youth engagement during the 2010 International Year for Biodiversity, and associated content analysis of submissions
- Methodological exploration in the *Value of Ecosystem Services to the Natural Resources Sectors (2010) and in Carbon Sequestration Protocol for Tall-grass Prairie (2011)*
- A case study on the social and economic values of the marine ecosystem in Mount Waddington, British Columbia (*2011*)
- The *2012 Canadian Nature Survey*, on awareness, participation, and expenditures in nature activities *(2014)*
- The "Nearby Nature" module in Statistics Canada's biennial *Households and the Environment Survey (2011)*

About the Toolkit's Lead Authors

Dr. Susan Preston is responsible for the design of the FPT *Value of Nature to Canadians Study*, and for leading its implementation. An interdisciplinary scholar of environment and culture, her research and publications focus on environmental values in both Indigenous and non-Native Canadian communities, from socio-cultural and policy perspectives. Susan joined Environment Canada's Biodiversity Convention Office (now Biodiversity Policy) in 2008, and continues to serve as a Senior Analyst in ecosystems and biodiversity. Among other things, she provides policy advice on ES and nature values for the Government of Canada, and participates in the Core Group of Experts on Values for the *United Nations' Intergovernmental Science Policy Platform on Biodiversity and Ecosystem Services* (IPBES). She is a co-author of the IPBES guide to diverse conceptualizations of values and valuation.

Dr. Ciara Raudsepp-Hearne is a researcher and consultant based at the Quebec Centre for Biodiversity Science at McGill University in Montreal. Her research centres on ES theory and implementation, as well as on sustainability, resilience, and future thinking. Ciara has recently collaborated with the United Nations Convention on Biological Diversity, FutureEarth, the Program on Ecosystem Change and Society, the Stockholm Resilience Center, and the Sustainable Canada Dialogue. Ciara served as the coordinator of the Subglobal Assessment Working Group of the Millennium Ecosystem Assessment and has co-authored several follow-up methodology documents for decision-makers, including a World Resources Institute handbook on ES for the public sector, and a United Nations Environment Programme textbook for ES assessment. Ciara has worked directly with governments at different scales that are trying to operationalize ES concepts within policies and programs.

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EXECUTIVE SUMMARY

Introduction

Ecosystem services (ES), sometimes referred to as "nature's benefits," draw attention to the ways that people depend on a healthy environment.[1] ES support life (e.g., by providing air, water, food, raw materials, medicines), security (e.g., by mitigating extreme weather events, spread of vector-borne diseases), and quality of life (e.g., by supporting mental and physical health, cultural identity, recreation), among many other things. Regardless of what they are called, nature's benefits are the basis of human lives and economies. Humans are instrumental in most ES to varying degrees through environmental management and modification. Biodiversity—the variability of life among and within species and ecosystems—is an essential component in ES. Biodiversity underpins ecosystem resilience, integrity, and functioning.[2]

Human activity, however, has caused major declines in biodiversity worldwide and significant degradation of ecosystems.[3] In 2010, the United Nations (UN) *Convention on Biological Diversity's* (CBD) *Global Biodiversity Outlook-3* (GBO-3) report found that all major pressures on biodiversity were increasing and that "some ecosystems were being pushed towards critical thresholds or tipping points."[4] These losses severely compromise the ability of ecosystems to produce ES, with measurable costs to public health, security, and well-being. The UN *Millennium Ecosystem Assessment* (MA) assessed the condition and trends of ecosystems and ES, and how they benefit human well-being. Among the MA's main findings is that "*over the past 50 years, humans have changed ecosystems more rapidly and extensively than in any comparable period of time in human history, largely to meet rapidly growing demands for food, fresh water, timber, fiber, and fuel. This has resulted in a substantial and largely irreversible loss in the diversity of life on Earth.*"[5]

The Need for Ecosystem Service Assessment

Increasing human populations and increasing urbanization are intensifying demands on ecosystems, placing ES at greater risk. Due to the complex and interrelated nature of ES, a more comprehensive approach is needed to address situations where decisions involving or impinging on ecosystems would leave human well-being diminished through ES loss. "Ecosystem service assessment" is an approach that has been developed to meet this need, and governments around the world are increasingly considering ES assessment and its associated analyses to inform their policies, decisions, and management practices. ES assessment requires consideration of ecosystem functions, how those functions generate the services to produce benefits, and how those benefits are distributed to society. It is therefore a broadly interdisciplinary, technical activity, requiring an interdisciplinary expert team to complete. This approach identifies the consequences of environmental change and how environmental management decisions can enhance, diminish or maintain the flow of ES benefits. The intent of ES assessment is to provide comprehensive information regarding the costs and benefits to assist in environmental management decisions.

Example: An agricultural community has signalled their worry about decreasing fruit crops and suspects that declining pollination rates are the cause. An ES assessment might focus on improving ecological knowledge about how pollinator species are faring, and look at associated ES such as crop production, habitat, natural erosion control, and ecotourism at the same time. These additional ES are linked to pollination via ecological and economic pathways, and have been identified as socially and economically valuable to local populations. As part of the assessment, there may be a need to assess the economic value of pollination in this area to justify specific management interventions.

1 See *Tools – Tab 9: Glossary* for definitions of key terms that appear in this Toolkit, such as benefits, values, and ES.

2 See *Issue 6* in *Tools – Tab 2: Cross-cutting Issues and Key Considerations* for role of biodiversity in ES.

3 The UN *Millennium Ecosystem Assessment* (MA) found that 60 percent of the ES they assessed on a global scale (15 out of 24) were degraded or being used unsustainably.

4 UN *Convention on Biological Diversity* (CBD) 2010. GBO-4 reported in 2014 that while there has been some improvement, current trends indicate that these pressures will continue until at least 2020, see CBD 2014.

5 MA 2005.

Policy Relevance of ES Assessment

ES assessment can support and inform analyses and decisions related to many issues. Guidance is provided (in *Chapter 3*) for using ES assessment for the following five broad groups of policy issues:

- **Area-based planning.** Featured examples are regional strategic environmental assessment and land-use/spatial planning.
- **Regulatory decision analysis.** Featured examples are environmental (impact) assessment, strategic environmental assessment, and regulatory and policy development.
- **Environmental damages assessment.** Featured example is environmental damages assessment.
- **Environmental management.** Featured examples are establishing and managing protected areas, managing species and ecosystems, and managing invasive alien species.
- **Conservation instruments.** Featured examples are conservation incentive programs and conservation offsets.

For any particular policy issue that is being addressed, it is important to identify the relevance of ES, as well as the entry points in the policy process for considering ES and what some of those considerations might include.

ES Assessment Is a Technical, Interdisciplinary Activity

ES assessment provides a practical set of procedures for understanding what might be gained or lost from a given management choice and the human dimensions of such effects. It can help managers to better comprehend and address potential issues and reduce conflict. Briefly, ES assessment involves:

- identifying high-priority ES;
- assessing their environmental, socio-cultural, and economic dynamics and their significance; and
- identifying the consequences of change on these ES.

ES assessment typically requires biophysical measures and descriptions of the ecosystems and the dynamics involved in the production of ES. It also requires description of ES benefits to people and the dynamics of how benefits are distributed among different groups of people. People are often not aware of some benefits that they rely on from ecosystems. ES assessment clarifies these benefits as well as benefits that people commonly know of. ES assessment may include identifying the significance of ES benefits to people through valuation. Valuation can be particularly useful when decisions involve trade-offs, when decision-makers need to justify costs associated with the management of ES or when there is a need to inform diverse stakeholders of the broad value, or importance, of ES. Integrated analysis of the various relevant ecological, socio-cultural, and economic factors can be completed using a decision-support approach (such as cost-benefit analysis, multi-criteria analysis or structured decision-making) that can identify trade-offs and implications of different environmental management and development options.

The primary objective of ES assessment is to support evidence-based decision-making to improve human well-being and ensure environmental sustainability. Because ES are the basis for most of the relationships between ecosystems and human well-being, ES assessment necessarily considers *both* ecosystem dynamics and human dependence on those dynamics. Therefore, **ES assessments do not replace other ecosystem-focused analyses**, but can be used in conjunction with them.

A Conceptual and Analytical Framework for ES Assessment

The conceptual and analytical framework used by this Toolkit for conducting ES assessment is shown in *Figure i*. By illustrating how ecosystem components are connected, this framework helps with understanding how a proposed activity or decision might impact the supply of ES. The depiction of multiple disciplines and kinds of knowledge that are needed to understand ES dynamics is a feature of this framework. It shows how most ES assessments will need biophysical, socio-cultural, and economic information. In addition to the processes of ES production and benefit distribution, the framework recognizes the role of management and governance in affecting these processes, as well as the broader social and natural drivers of change—both direct and indirect—that influence how ES are produced and managed.

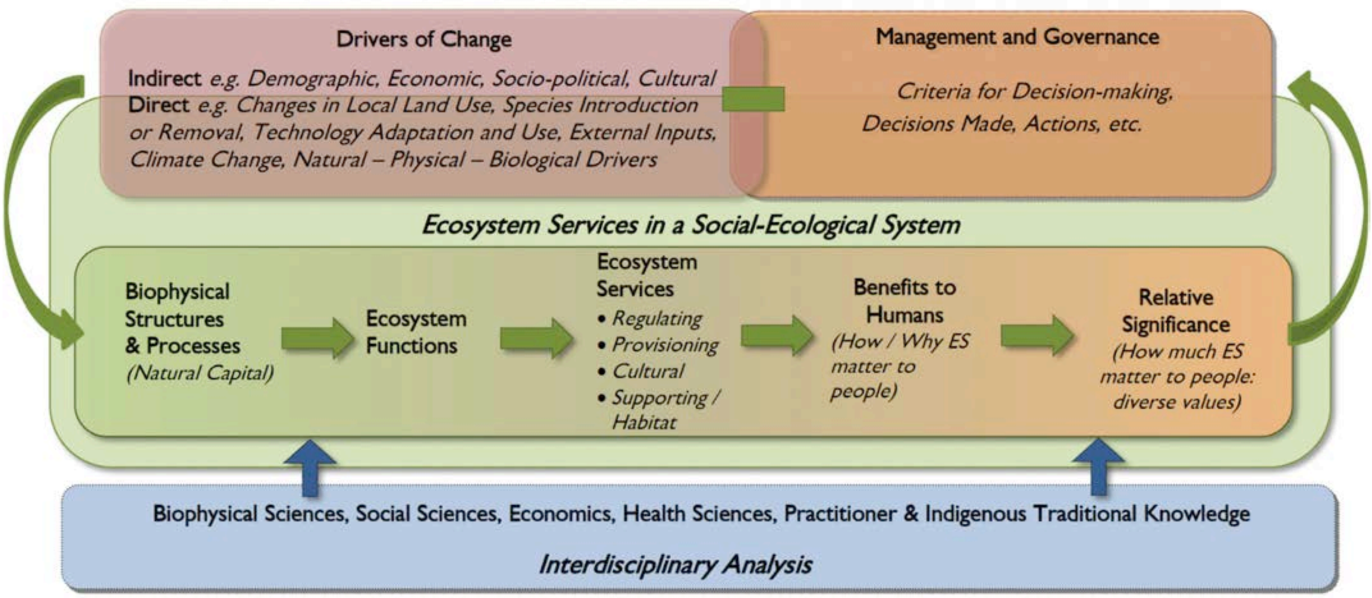


Figure i. *Conceptual and analytical framework for this Toolkit. (Adapted from Haines-Young et al. 2006)*

A Six-Step Assessment

This Toolkit provides step-by-step guidance to complete a robust, comprehensive ES assessment. This includes guidance about the information, analysis, and process that can be helpful. The effort required to complete a thorough ES assessment depends on the complexity of the questions and the types of information and analysis needed to support the decision. The following six steps can be completed to different degrees depending on what is required to address the specific issue for which an assessment is being undertaken. For example, a small team can attempt to work through the steps quickly to decide which steps will be needed to answer their questions, and where more resources should be directed.

Table i is a quick reference guide to the six-step process for completing an ES assessment detailed in *Chapter 2*. Although steps are defined sequentially for ease of communication, in practice the process is both iterative and progressive.

Table i. *Quick reference guide to ES assessment in six steps.*

Six Steps in ES Assessment: Quick Reference Guide
Step 1. Defining the issue and context • Setting up a lead team • Defining the issue(s) that are driving the assessment • Reviewing key terms and considerations
Step 2. Identifying priority ES and beneficiaries for assessment • Identifying priority ES and beneficiaries
Step 3. Identifying what needs to be evaluated to answer assessment questions • Organizing assessment team and process: – Identifying resource requirements: time, expertise, and funding – Establishing advisory, technical, and review groups – Developing an administrative plan – Reviewing the *ES Priority Screening Tool* with assembled team • Identifying what will be evaluated to answer assessment questions: – Describing the priority ES within their social and ecological contexts – Tracking how system components relate to each other – Developing a technical assessment plan
Step 4. Going into detail: Identifying and using indicators, data sources, and analysis methods • Identifying which indicators are most relevant for assessing each ES • Identifying and gathering existing data sources or developing new data • Selecting and using analysis methods and tools to answer the assessment questions • Choosing analysis approach
Step 5. Synthesizing results to answer assessment questions • Integrating and synthesizing results
Step 6. Communicating assessment outcomes • Understanding what results mean and do not mean • Communicating results to different audiences • Distilling complex, integrated results into key messages

Step 1 is the most critical step in an ES assessment: the clear definition of the issue and identification of the questions for which answers are needed. In some cases, the issue may already be well understood but, especially with complex issues, there is often considerable work required to develop a detailed understanding of the issue and the various ecological, economic, and socio-cultural factors that are relevant. The second most valuable activity is completion of the *ES Priority Screening Tool*. It is used to identify whether or not an ES assessment is warranted for a particular case. In all ES assessments, it is used to logically determine which ES may be at risk in a particular case and the key considerations, including how people are likely to be affected. Working through the *ES Priority Screening Tool* provides an analytically sound justification for the decision of which ES should be the focus of an assessment. The information gathered to complete the tool's worksheets is the foundation for the remainder of the assessment.

Due to the interdisciplinary nature of an ES assessment, multiple analysis methods and tools will be needed. It is very important to select and use analytical methods and tools that are appropriate for answering the assessment questions. The five most common broad types of analyses used in ES assessment focus on:

- the *extent, condition, and trends* in ES (this may include how the extent, quality, and connectivity of landscape components relate to the provision of ES; "trends" means how ES are changing);
- the socio-cultural and economic *values* of ES benefits (valuation);
- the *interactions* among multiple ES, including trade-offs, synergies, and bundling;
- the *relationships* among ES, drivers of change, and the provision of ES benefits (this may include the distribution of and access to benefits); and
- alternative *future scenarios* of ES and human well-being resulting from possible management interventions.

An ES assessment can include one or any combination of these analysis types.

The conclusions generated through the analyses can be applied to answer the assessment questions and support the decision for which the assessment was completed.

It is essential to understand what the results mean; however, it is equally important to understand what the results do not mean. The scope, orientation, meaning, and relevance of results will all be influenced by the choices that were made in designing and implementing the assessment. Deciding on the key messages of an assessment is one of the most important steps of the communication process.

It is not likely to be feasible to complete a comprehensive assessment for every decision. However, ES analyses and considerations can still inform different decisions through a strategic approach. The scope of the assessment may include anything from a short literature review to an in-depth collection and analysis of data, depending on the importance and complexity of the issue and the availability of resources to complete it. A more thorough ES assessment is likely to be very useful and appropriate for issues that are large and complex and pose significant threats to the environment. Such a fully developed assessment will provide results that can inform many decisions about the issue. In the case of issues that are smaller and less complex and pose lower risk to the environment, it is realistic to complete more modest analyses while still using the analytically robust steps and tools in this Toolkit in a strategic way. Even for a relatively simple "desk-based" analysis, considering the ecological, socio-cultural, and economic aspects of the issue in an integrated way is helpful to identify the critical considerations, and to choose actions that can result in more positive outcomes.

This Toolkit Is a Comprehensive "How-to" Guide and Resource

This Toolkit offers a practical, step-by-step guide and numerous resources for further understanding and direction. The Toolkit approach is fully interdisciplinary. It is meant to assist in addressing the need to build capacity to use ES assessment and to help reflect ES considerations in environmental management and decision-making. Roles for different kinds of knowledge are interwoven throughout this Toolkit. This is because ES are a result of the interactions between ecosystems and human societies. ES assessment and many of its component analyses will, therefore, be accomplished through interdisciplinary collaboration among biophysical scientists, social scientists, and economists in every step.

Toolkit users are strongly encouraged to scan through this whole document prior to beginning an assessment to orient themselves on what is involved and what tools are available, and to understand when and how their own areas of expertise can contribute to the work of an assessment.

The Toolkit approach can be adapted as needed to each context. Because each ecosystem is unique, an assessment is typically context-specific. In some cases, decision-makers may want to know whether a set of ES is being managed sustainably or if any ES are close to collapse. In other cases, they may want to know which ES are important to local populations, in what ways they are important, and their relative significance, for example, in order to develop a regional plan.

This Toolkit contains key tools and resources for planning and undertaking an ES assessment and the analyses that contribute to such an assessment (see the *What's Inside This Toolkit* graphic below):

- ***Chapter 1*** sets the foundations. It illustrates the utility of ES assessment for a wide range of policy-related activities, with four examples ranging from flood control to freshwater provision. Important from the outset is familiarity with the types of ES, and the conceptual and analytical framework used to assess them in this Toolkit. The chapter closes with advice on how to determine whether or not an ES assessment is advisable or warranted for a given situation.
- ***Chapter 2*** explains how to complete ES assessments for a range of needs. The chapter explains the six steps of ES assessment, from clearly identifying the reasons and context for the work to communicating the final results. Links to key tools and resources in the *Tool Tabs* are integrated to help complete each step. Suggestions for strategic use of the steps are offered for when time and resources are unavailable for a comprehensive assessment, but some degree of ES analysis is still desired.
- ***Chapter 3*** offers advice on how to address ES considerations in a variety of different policy contexts such as spatial planning, environmental assessment, and wildlife management, among others. For each context, the chapter advises on the relevance of ES, entry points for incorporating ES analysis or considerations in typical processes, additional considerations, and sources. Canadian examples are featured for most of the contexts.
- **Ten "*Tool Tabs*"** provide tools and resources for completing an ES assessment, including:
  - – practical descriptions with examples for each of 28 types of ES;
  - – concise advice about seven cross-cutting issues in ES assessment;
  - – considerations for ES assessment involving Indigenous communities in Canada;
  - – nine practical worksheets to complete an ES assessment;
  - – explanations of 11 indicator categories, and an extensive table of indicators for each type of ES;
  - – clear advice about both economic and socio-cultural approaches to valuation;
  - – a compendium of factsheets about more than 40 data sources, analysis methods, and tools for ES assessment;
  - – answers to the 45 Frequently Asked Questions (FAQs) posed in the Toolkit chapters;
  - – a glossary of definitions for more than 70 key terms; and
  - – a reference list of more than 110 Canadian ES-related analyses.
- ***Footnotes*** are used throughout the document to clarify and substantiate content, direct users to important resources elsewhere in the Toolkit, and contribute to the resource value of the Toolkit.
- ***A complete bibliographic list*** of sources cited is provided at the end of the Toolkit.

Genesis of This Toolkit

For more than twenty years, Canada's federal, provincial, and territorial governments have worked collaboratively to support the sustainable use and conservation of biological diversity, further to Canada's national commitments under the UN CBD. They developed and implemented the *Canadian Biodiversity Strategy, Biodiversity Outcomes Framework,* and *2020 Biodiversity Goals and Targets for Canada.*[6]

Under the guidance of a national committee of assistant deputy ministers (ADMs), governments undertake practical initiatives that help to strengthen capacity for informed decision-making about biodiversity in Canada. One such initiative is the *Value of Nature to Canadians Study* (VNCS), mandated to develop information on the ecological, socio-cultural, and economic significance of nature in Canada, to Canadians. A national taskforce with one representative from each province, territory, and federal department with an environment-related mandate has worked together since 2009 to deliver useful products. Most recently, they published the results of the *2012 Canadian Nature Survey.*[7]

[6] Federal-Provincial-Territorial Governments of Canada 2014a; 1995; 2005. See www.biodivcanada.ca.
[7] Federal-Provincial-Territorial Governments of Canada 2014b.

A major aspect of the VNCS has been to advance the ability to work with the concept of ES for decision support. Canada's governments at all levels have an interest in how ES assessment can help them with a wide range of decisions at different scales. The national ADM Conservation, Wildlife, and Biodiversity Steering Group, and the ADM Federal Biodiversity Committee recognized the need for clear, practical guidance that would help their staff and consultants complete ES assessments. The ADMs sought an approach that fully integrates biophysical sciences, social sciences, and economics for reliable results, so they requested this Toolkit as part of the VNCS program of work. The VNCS Taskforce was, therefore, to address the following four issues through this Toolkit:

- how to determine if an ES assessment is right for the situation;
- how to complete a robust, interdisciplinary ES assessment incorporating biophysical, social, and economic sciences;
- how to know what assessment results mean, and what they do not mean; and
- how to use ES assessment in a variety of policy and decision contexts.

This Toolkit was developed collaboratively with federal, provincial, and territorial government staff and non-government expert reviewers and contributors from academia and the private sector. It is informed by a synthesis of ES assessments and related peer-reviewed research carried out around the world for more than 15 years. The work was led by the VNCS Secretariat in Environment and Climate Change Canada.

Who Is This Toolkit for?

The primary audience for this Toolkit is analysts and managers working for governments and their agencies in Canada at the federal, provincial, territorial, regional, watershed or municipal scale. The Toolkit can be used to complete ES assessments or component analyses in-house, if suitable expertise is available, or to instruct consultants who have suitable expertise on what procedures to follow when contracting the work on government's behalf. As a technical guide, this Toolkit provides specific how-to advice for work to be completed by people with very different areas of expertise who come to the field of ES from different perspectives.

The Toolkit is especially relevant to professionals in the areas of environment and natural resources management. Its relevance also extends beyond these areas because the concept and measurement of ES help to integrate consideration of "the environment" in decisions that are not typically considered "environmental." For example, it could also be useful to analysts and experts in health policy or transportation policy. Users of the Toolkit are encouraged to correspond with the lead authors to provide feedback on their experience.

What's Inside This Toolkit

CHAPTER 1
Foundations

CHAPTER 2
Completing an Ecosystem Service Assessment

CHAPTER 3
Addressing Ecosystem Services in Different Policy and Decision Contexts

TOOLS

- **Tab 1:** ES Descriptions
- **Tab 2:** Cross-cutting Issues & Key Considerations
- **Tab 3:** ES Assessment Involving Indigenous Communities
- **Tab 4:** Worksheets for Completing ES Assessment
- **Tab 5:** Indicators of Natural Capital, ES & Benefits from ES
- **Tab 6:** Values & Valuation: Economic & Socio-cultural
- **Tab 7:** Compendium of Data Sources, Analysis Methods & Tools
- **Tab 8:** Answers to Frequently Asked Questions (FAQs)
- **Tab 9:** Glossary
- **Tab 10:** Canadian ES Reference List

Other features

Tip boxes, examples, step overviews, progress tracker, internal and external links, footnotes and complete list of sources cited

Ecosystem Service Assessment in Six Steps:

1. Defining the issue and context
2. Identifying priority ES and beneficiaries for assessment
3. Identifying what needs to be evaluated to answer assessment questions
4. Identifying and using indicators, data sources, and analysis methods
5. Synthesizing results to answer assessment questions
6. Communicating assessment outcomes

Nine Practical Worksheets:

1. Define the issue and context
2. ES Priority Screening Tool
3. Summarize Screening/ Confirm Priority ES
4. Characterize the Priority ES
5. ES Cascade Tool
6. Develop Detailed ES Assessment Plan
7. Select Relevant Indicators to Assess ES
8. Determine Approach to Analysis Methods & Tools
9. Synthesize Analysis Results

CHAPTER 1 – FOUNDATIONS

In This Chapter:

- **The value of ecosystem service assessment**
- **Types of ecosystem services**
- **Conceptual and analytical framework**
- **Determining if an ecosystem service assessment is right for the situation**

1.1 The Value of Ecosystem Service Assessment for Resource Management, Policy, and Decision-Making

Governments have many intractable and complex environmental management issues to address which involve trying to achieve various ecological, social, and economic objectives. Ecosystem service (ES) assessment can be a valuable tool to analyze socio-cultural, economic, and environmental implications and trade-offs, and to inform decision-making. It is relevant in any context where human activity may affect ecosystems, and where human well-being may be affected by environmental change. Consideration of ES is being integrated into government programs and policies in Canada because governments see the value of trying to support a sustainable economy and improve the quality of life for all Canadians.

ES assessment can support and inform analyses and decisions linked to:

- regulatory processes such as environmental assessment;
- wildlife management and habitat stewardship;
- land use and infrastructure planning at municipal, watershed, regional, and provincial scales;
- establishing protected areas, undertaking ecosystem restoration and rehabilitation, and other conservation initiatives to maintain or improve ecological integrity;
- damage assessment, risk assessment, cumulative effects management, and hazard mitigation;
- design of incentive measures to support conservation and sustainable use of ecosystems;
- economic development;
- resource allocation, use, and management;
- reporting and monitoring;
- natural capital accounting and national ecosystem accounts;
- public health and well-being;
- full-cost accounting;
- raising awareness of the importance of healthy ecosystems to human well-being; and more.[8]

What Are Ecosystem Services?

Ecosystem services (ES) are the result of environmental processes, sometimes with human interventions. ES provide benefits that humans depend on to support life (e.g., because ecosystems produce air, water, and food) security (e.g., by mitigating extreme weather events), and well-being (e.g., by supporting mental and physical health, cultural identity, spirituality, recreation). For analysis purposes, four commonly used categories of ES are:

- Provisioning ES – result in material goods
- Regulating ES – support habitable conditions
- Cultural ES – contribute to non-material benefits
- Supporting/habitat ES – underpin the other three categories

Each category includes several types of ES (see *Table 1.1*). In reality, different ES are often interconnected and co-produce bundles of benefits to human well-being.

An ES assessment is a technical, interdisciplinary analysis of the ES produced and/or received within a defined study area, and how they may be affected by change. Normally based on existing data and analysis, it involves:

- biophysical measures and description of ecosystems and dynamics involved in the production of ES that they provide; and
- description/measures of how humans benefit and dynamics of how benefits are distributed, and may include:
  - identifying the significance of ES benefits through socio-cultural and economic valuation; and
  - using a decision-support tool/method to integrate and analyze results, implications, and trade-offs.

[8] For details on many of these applications, see *Chapter 3*.

Considering ES can help identify how and where nature's benefits are produced and accrue to human communities. ES assessment can be used to identify (1) how an ecosystem produces services that people benefit from and depend on; (2) the extent of those benefits; (3) how much the ES and benefits matter to people; (4) how changes in the environment influence the ability of ecosystems to produce those "services"; and can be used to (5) inform planning to ensure that ES flows are sustainable. ES assessment can help to reveal differing views within society prior to implementing decisions. Such understanding provides more complete information to assess choices, improving the likelihood of increasing benefits for society, the economy, and the environment. It can also introduce effectiveness and efficiencies in program design and implementation.[9]

Considering ES can help manage risk and avoid unexpected, unintended, detrimental or costly outcomes from decisions. Decisions about development, resource use, and conservation can have both expected and unexpected outcomes. Unexpected outcomes often result from changes to the affected ecosystem and its ability to function in ways that produce benefits that people (and other species) depend on. This may be a result of cumulative effects of change. Impacts can be non-linear and severe when system stability thresholds are breached, resulting in sudden and potentially large-scale shifts such as collapse of fisheries.[10] ES assessment offers the potential to show the overlapping and interconnected processes within and between ecosystems and how changes to one process can affect others, and trace that change to how people are affected. This supports the ability to anticipate and avoid detrimental changes that might not otherwise have obvious connections to human well-being. Understanding how ecosystem processes are affected by specific human activity throughout a region can result in options that may pre-empt many negative and costly outcomes. This can save millions of dollars—even billions of dollars—in engineering infrastructure and property damages.[11]

Considering ES can help efficiency, provide new opportunities, and minimize negative impacts. The World Resources Institute (WRI) reported on the benefits of ES to corporations and other businesses as well as to communities.[12] By identifying and incorporating these values into development planning or daily operations, projects can be designed or implemented to maintain existing ES benefits and minimize negative and costly impacts on business, society, and the environment. As business increasingly adopts ES assessment in its reporting beyond corporate social responsibility (e.g., in environmental impact statements during environmental assessment), governments need to be prepared to understand and evaluate this documentation. In the short term, this can include immediate benefits to quality of life and property values, with long-term benefits such as social license to operate and sustainable availability of natural resources, among others.

> ***TIP:*** **This Toolkit uses the term "ecosystem services" consistent with the CBD and major international initiatives (rather than "ecological goods and services" or "EG&S"). Ecosystem "goods" are the "provisioning" category of ES. See *Tools – Tab 1* for a listing of ES with descriptions.**

Four examples of how considering ES in decisions has led to positive outcomes, or could have led to positive outcomes if it had been a factor in decision-making, are provided over the next three pages. The examples also show how managers are increasingly looking for tools and strategies to build ES analyses into planning and decision-making.

[9] Bright et al. 2003. See also *Figure 1.2. Analytical and Conceptual Framework for ES Assessment*, below, which shows this sequence of relationships.

[10] See *Tools – Tab 2: Cross-cutting Issues and Key Considerations* for explanations of cross-cutting issues, including thresholds, and see *Tools – Tab 9: Glossary* for a full glossary.

[11] For current examples of green infrastructure projects based on ES, see US Army Corps of Engineers projects at http://www.nad.usace.army.mil/CompStudy.

[12] Landsberg et al. 2013 and 2014. See also *Chapter 3* in this Toolkit for advice on including ES in environmental assessment.

EXAMPLE:
Pollination of Food (and Other) Crops

In this example, the human dependence on food crops and other plants that require diverse animal species for the "pollination-regulating ES"[13] is illustrated in economic terms. Encouraging the adoption of agricultural practices that support pollinator health can help ensure the continued availability of food and other plant-based materials that rely on pollinators.

Although difficult to estimate conclusively, the United Nations (UN) Food and Agriculture Organization (FAO) cited the global value of pollination *only* for food crops as €(2009)153 billion (C$(2009)243 billion).[14] This does not account for pollination of non-food-bearing trees and other plants that are important to other economic sectors. Nor does it account for the role of pollinators in biodiversity and ecosystem functions, including the persistence of natural vegetation. And it does not account for the other ES provided by pollinator species (e.g., insect control). Pollination by honey bees alone is valued at well over C$2 billion per year in Canada,[15] and more than US$15 billion per year in the United States (US). The annual value of pollination by all pollinators combined in the US is estimated at more than US$24 billion.[16] The continued decline of pollinators will have direct costs for the agricultural, food, cosmetic, pharmaceutical, and other sectors that rely on pollinated plants for production, with a wider range of impacts on society, for example, in terms of human health.

Pollination is considered a "keystone" ES that is in decline. As a result of this status, it is the subject of a global ES assessment by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), and is the focus of a UN FAO initiative. In a review of expert literature, the FAO reported in 2013 that "[E]ighty-six percent of all flowering plant species require an animal pollinator to reproduce (Ollerton, Winfree and Tarrant, 2011). About one-third of food production depends on animal pollinators, and 75 percent of all fruits and vegetables increase production when visited by animals (Klein et al., 2007)."[17]

EXAMPLE:
Louisiana Coastal Master Plan

The example of Hurricane Katrina illustrates both the catastrophic costs of not maintaining the natural erosion control and water-flow regulation ES, and the benefit of using ES modelling in developing new regional land-use plans.

Hurricane Katrina resulted in the loss of 1,833 human lives and US$125–148 billion in total costs and damages.[18] Much of this damage could have been prevented if coastal marshes and the natural buffering they provide against storm surge had not been eliminated by human activity over the past century. After the storm, state planners were tasked to prepare a new Coastal Zone Master Plan and, in so doing, they developed predictive models for ES, vegetation, hydrology, and other aspects of the biophysical environment. The models were "used to predict how well Louisiana's future coast will provide habitat for commercially and recreationally important coastal species and habitats for other key species."[19] The approach sought to predict how restoration and risk-reduction projects would support the overall objectives of the Coastal Zone Master Plan objectives. These objectives include support for flood protection, natural processes, coastal habitats, cultural heritage, and a working coast. Their approach did not include economic or socio-cultural *valuation*, but focused on objective measures of how the ecosystems, society, and economic activity were affected.

13 See *Table 1.1, List of Ecosystem Services,* later in *Chapter 1*, and *Ecosystem Service Descriptions* in *Tools – Tab 1: Ecosystem Service Descriptions* for explanation of ES types.
14 FAO 2014, citing Gallai et al. 2009. Gallai's figure of €153 billion converts to C$243 billion in 2009, which converts to C$263 billion in 2014 (using Bank of Canada calculators http://www.bankofcanada.ca/rates/exchange/ and http://www.bankofcanada.ca/rates/related/inflation-calculator/).
15 AAFC 2014a.
16 The White House 2014.
17 FAO 2014: 4. "Animals" in this quote refers to many types of insects, birds, bats, and other mammals.
18 The US National Oceanic and Atmospheric Administration (NOAA) reported that between 1980 and 2013 the US experienced 151 weather or climate disasters where individually "damages/costs reached or exceeded $1 billion (including CPI adjustment to 2013). The total cost of these 151 events exceeds $1 trillion." http://www.ncdc.noaa.gov/billions/
19 State of Louisiana, 2012. The approach includes linked models that predict change in the conditions of the Louisiana coastal system under a future without additional restoration and risk reduction projects, and the conditions which would result from project implementation. The model output was used as input for a planning tool that sorted and viewed model results and compared projects to each other, and sorted projects based on costs, funding constraints, and stakeholder preferences.

Separate analysis published shortly after the hurricane estimated that Louisiana's coastal wetlands provide US$(2004)940 per hectare annually in storm and flood regulation ES, and a further US$11,760 per hectare per year in additional ES.[20] Restoration of these wetlands and the levees in New Orleans carries an estimated cost of about US$25 billion, and the authors note that "restoring the 4,800 km^2 (480,000 ha) of wetlands lost prior to Katrina would thus restore an estimated $6 billion per year in lost ES, or $200 billion in present value (at a three-percent discount rate)."[21]

EXAMPLE:
Alberta Wetland Rapid Evaluation Tool

The example of Alberta's ABWRET tool illustrates the increasing shift by jurisdictions to incorporate ecosystem functions—in this case, from wetlands—into land-use planning, which may then be used to examine potential impacts to the provision of ES.

Applications and approvals for land-use or land-cover change affecting wetlands in Alberta, as in many other jurisdictions, have been assessed on a "per area" basis. There was a recognized need to look beyond the immediate area as the assessment criteria for compensation and mitigation and to adopt a "function" approach, resulting in development of the Alberta Wetland Rapid Evaluation Tool (ABWRET).[22] ABWRET provides rapid, standardized assessment of wetland ecosystem functions and provides a score for a wetland based on those functions. The 2013 release of the *Alberta Wetland Policy* confirmed that Alberta was moving to a function approach for understanding and managing wetlands. ABWRET is being used to support that policy. The Alberta government requires anyone who is obligated to obtain a Water Act approval to work in, or disturb, a wetland to use ABWRET.

Organizations have expressed interest in using the ABWRET approach to support initiatives related to other types of landscape management, including riparian management. ABWRET will contribute to cataloguing and managing for the multiple ecosystem functions of wetlands. This tool enables decision-makers to examine the ES associated with wetlands to be considered in future decision-making.

EXAMPLE:
New York City Water Supply

This final example illustrates how recognizing the natural regulating ES of water purification was the basis for major cost savings in engineered infrastructure, with biodiversity and human co-benefits.

New York City provides a well-known example of how a decision was made to protect ES on a large scale to provide fresh water, and thus avoid infrastructure costs that would have been needed to achieve the same outcomes. The City saved US$(1997)6–8 billion by avoiding the construction of a new water filtration facility and US$(1997)200–300 million per year by avoiding related maintenance costs. In contrast, as of November 2013, the entire program investment, including future commitments, was US$1.5 billion.

This was achieved by implementing a comprehensive environmental management program in the Catskills Watershed that included, among other components, conservation easements with a "payments for ecosystem services" (PES) incentive program to upstream landowners to secure water quality from pollution.[23] The system provides almost 40 percent of the City's water supply. Additional funding has been secured to continue the conservation elements of the program, including actions to support natural flood regulation. In 2014, the City affirmed its "continued commitment to long-term watershed protection" through an updated

[20] Costanza et al. 2006.
[21] Costanza et al. 2006. See section *6.2-6* on Discounting in *Tools – Tab 6: Values and Valuation: Economic and Socio-cultural*, below.
[22] Adamus 2013.
[23] For more information about PES, see *Chapter 3*.

plan, acknowledging that it had become recognized internationally as a model for using an ES conservation approach to meet infrastructure needs.[24]

FAQ 1: What is the Canadian context for an ES approach?

FAQ 2: What is the international context for an ES approach?

FAQ 3: What are the types of "value" that people attribute to nature that have been identified by researchers?

TIP: **Frequently Asked Questions (FAQs) are answered in *Tools – Tab 8.* Click on a question to jump to its answer. At the end of the answer, click to jump back to the question.**

1.2 Types of Ecosystem Services

As indicated in *Table 1.1*, ES are experienced by humans either *directly* (e.g., provisioning, cultural, some regulating ES) or *indirectly* (e.g., supporting, some regulating ES). See *Tools – Tab 1: Ecosystem Service Descriptions* for descriptions and examples of each ES. Key distinctions between the four main categories of ES are:

- most *provisioning* ES generate a *tangible thing* (e.g., food, medicine) and in many societies these things become viewed as products that can be processed, traded and, in some cases, bought and sold;
- most *regulating* ES generate a *process* that influences the environment in ways that are beneficial to humans (e.g., air purification, pollination);
- most *cultural* ES generate *experiences* that people feel internally—emotionally or intellectually—that are both individual and shared, and that support core human needs for connection and growth;[25] and
- most *supporting and habitat* ES underpin the *capacity* in ecosystems for the other categories of ES to be generated.

[24] Information Center for the Environment, University of California (Davis) n.d.; New York City Department of Environmental Protection 2011; and Catskill Center 2013, which notes shortcomings and opportunities to enhance the program.
[25] These needs are well established in science; for brief explanation of their link to ES see Summers et al. 2012.

Table 1.1. *Classification of ES adopted for this Toolkit.*[26]

Ecosystem Service (ES)
Provisioning services – *the result of ecosystem processes and functions that provide goods or products that humans obtain and rely upon; often with some human inputs of labour, financial, and social capital*
Food (e.g., crops, livestock, capture fisheries, aquaculture, wild foods)
Timber and other wood products / fibres, resins, animal skins, and ornamental resources
Biomass fuel
Fresh water
Genetic material
Biochemical and medicinal resources
Regulating services – *the result of ecosystem processes and functions that regulate all aspects of the environment, providing security and habitable conditions that humans rely upon*
Air-quality regulation
Climate regulation and carbon sequestration (e.g., global climate regulation, regional and local climate regulation)
Water-flow regulation
Erosion regulation
Water purification and waste treatment
Disease regulation
Pest regulation
Pollination
Natural hazard mitigation
Cultural services – *the result of ecosystem processes and functions that inform human physiological, psychological and spiritual well-being, knowledge and creativity*
Cultural identity and heritage
Spirituality and religion
Knowledge systems and education
Cognitive development, psychological and physical health, and well-being
Aesthetic experience
Inspiration for human creative thought and work
Recreation, ecotourism
Sense of place
Supporting or habitat services – *the underlying ecosystem processes and functions that are necessary for the production of all other ES, creating the biological environment*
Soil formation
Primary production
Nutrient cycling
Water cycling
Habitat

[26] The typology used here is based on a combination of those used in the *Millennium Ecosystem Assessment* (MA) http://www.millenniumassessment.org and *The Economics of Ecosystems and Biodiversity* (TEEB) www.teebweb.org.

FAQ 4: Why did the authors choose this ES typology? What about other ES typologies or classification systems?

Key Message:
Many of the terms used in this Toolkit have different meanings for practitioners within the different disciplines that participate in ES assessment (e.g., values). It is very important for all members of an assessment team to come to a common agreement on understanding of the definitions for **core terms** before they proceed with the other assessment activities. These terms, all defined in *Tools – Tab 9: Glossary*, are *biodiversity, ecosystems, ecosystem services, natural capital, critical natural capital, [ES] benefits, beneficiaries, value, values, valuation, interdisciplinary*, and *ecosystem service assessment.*

1.3 Conceptual and Analytical Framework for ES Assessment

The conceptual and analytical framework adopted for this Toolkit is shown in *Figure 1.1*.[27] This framework helps to explore how a particular decision might impact the short- and long-term supply of ES by providing guidance on how different system components are connected and can be understood. The depiction of multiple disciplines and kinds of knowledge that are needed to understand ES dynamics[28] is a feature of this framework. In addition to the processes of ES production and benefit distribution, the framework recognizes the role of management and governance in affecting these processes, as well as the broader social and natural drivers of change—both direct and indirect—that influence how ES are produced and managed.

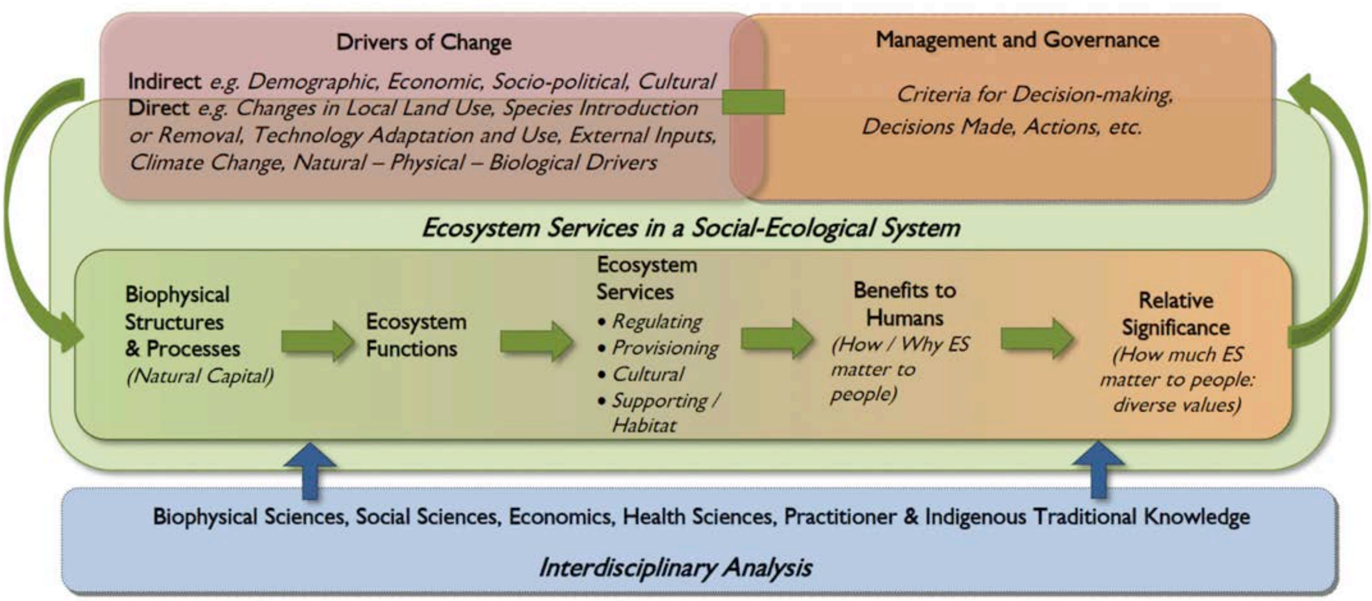


Figure 1.1. *Conceptual and analytical framework for this Toolkit. (Adapted from Haines-Young et al. 2006)*

[27] This framework is modified from the well-known and widely adapted diagram by Haines-Young and Potschin produced for the UN MA, and since used as the basis for most ES conceptual frameworks.

[28] Social sciences and environmental studies span many disciplines and specializations within disciplines. There are ways other than "ecosystem services" to consider human-nature relationships. The United Nations Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) framework recognizes a diversity of worldviews and knowledge systems that often overlap across cultures in how human-nature relationships are represented. It characterizes these relationships in three broad groupings. Each group includes multiple worldviews: 1. Nature / biodiversity and ecosystems / Mother Earth / Systems of Life; 2. Nature's benefits to people / ecosystem goods and services / Nature's gifts; and 3. Good quality of life / human wellbeing / living in harmony with nature / living well in balance and harmony with Mother Earth. See Díaz et al. 2015 for details.

The framework diagram above shows how:

- *(in the centre bar)* ES arise within a "social-ecological system" as **biophysical structures and processes** of ecosystems (also known as natural capital[29]). These structures and processes give rise to **ecosystem functions**. Ecosystem processes and functions are often mediated by human interventions that can contribute to the production or reduction of **ES**. The ES provide **benefits to humans**, and these services and benefits have **significance** to human well-being.[30]
- *(in the top bar)* **Management and Governance** and **Drivers of Change** influence the ability of ecosystems to generate ES. Understanding the ES process described in the previous bullet can influence the actions of management and governance, and can serve as drivers of change, for example, through cultural practices or changes in land use.
- *(in the lower bar)* An interdisciplinary assessment of ES is likely to take into account aspects of all five elements in the ES production cycle (*centre bar*). It will recognize the **need for expertise from biophysical sciences, social sciences, economics, health sciences, and practitioner and Indigenous traditional knowledge.**[31]

The advantages of a framework that combines qualitative and quantitative analyses include:

- more accurate capture of the relationships between drivers of change and the production / flow of ES and their benefits to people;
- improved identification of key relationships among multiple ES; and
- greater flexibility to incorporate participatory components in the assessment.[32]

As with any research, assessment results will vary significantly depending on the methods that are used. Results can be biased or limited if analysis focuses on only one of the ecological, economic or socio-cultural "value domains." Recent research shows that addressing each of the three domains helps to obtain a more robust and reliable set of results.[33] Different methodological approaches enable measurement of different concepts of value,[34] and an integrative decision-support framework helps keep diverse types of results manageable.[35]

Economic, socio-cultural, and ecological aspects of an ES assessment are addressed and reported in different ways. Each has its own theories and methods for identifying and measuring values. They will result in numeric measures and description of ecosystem characteristics; numeric measures and description associated with human health; numeric measures, monetary measures, and description of economic considerations and economic values; and numeric measures (including ordinal ranking) and description of socio-cultural values.[36] Because biophysical (ecological), socio-cultural, and economic values are often not mutually exclusive, an interdisciplinary—rather than simply multidisciplinary—approach that also draws on traditional and practitioner knowledge is recommended. Canadian experiences in ES assessment have shown that an interdisciplinary team should work collaboratively rather than having the different disciplines work independently of each other.[37]

29 See *Tools – Tab 9: Glossary* for definition and illustration of natural capital.
30 Haines-Young and Potschin 2009: 56 advise that "It is essential to distinguish benefits and values clearly, because different groups may hold different values or perspectives on benefits. While the capacity of ecosystems to deliver benefits to people may be constant the values we attach to them may also change over time." See also Müller and Burkhard 2012, Fig. 1.
31 The diversity of values for each ES within a population of beneficiaries is referred to as "value pluralism" and is increasingly recognized in models and frameworks for ES assessment, such as for OpenNESS—see Gómez-Baggethun et al. 2014.
32 Lopes and Videira 2013; Muller and Burkard 2012; Bennett et al. 2009.
33 Martín-López et al. 2014.
34 Allen et al. 2009: 16-17.
35 See *Step 1b* and *Step 5* in *Chapter 2,* and related factsheets in *Tools – Tab 7: Compendium of Data Sources, Analysis Methods, and Tools* for more on decision-support frameworks and tools.
36 See *Tools – Tab 6: Values and Valuation: Economic and Socio-cultural* for details on economic and socio-cultural values and valuation approaches.
37 Raudsepp-Hearne and Kerr 2011 (*Lessons Learned*); and as noted, for example, by Abson et al. 2014; Chan, Satterfield, and Goldstein 2012; Liu, Costanza, Farber and Troy 2010; and Cowling et. al. 2008, among others.

Table 1.2 illustrates the practical links between the conceptual and analytical framework shown in *Figure 1.1*, the potential scope of an ES assessment, and the actual steps in an assessment as laid out in *Chapter 2*. In practice, the steps are typically overlapping and iterative, requiring the assessment team to revisit some steps as they develop more information. Reminders of the need to revisit earlier steps are signalled in this Toolkit by a small graphic illustrating the iterative approach, as seen on the right edge of this paragraph.

Table 1.2. *Links between the conceptual and analytical framework and the ES assessment.*

Section in framework	Biophysical structures and processes, and ecosystem functions	Ecosystem services and benefits to humans	Relative significance	Management and governance
Aspect of analysis	*Conditions* of the biophysical environment	*Ways* that ecosystem processes and functions are benefiting people	*Significance* of these ES benefits to people	*Implications of change* to these ecosystems and delivery of ES benefits
Examples of analysis activity	• Measure/map extent & condition of "natural capital" • Measure/map processes & functions • Identify/measure drivers of change	• Identify ES on site • Identify physical benefits (e.g., health) • Identify economic benefits (e.g., productivity) • Identify experiential benefits • Examine distributional factors (i.e., aspects of access)	• Ecological assessment (ES integrity; resilience) • Socio-cultural valuation (qualitative; quantitative: non-monetary) • Economic valuation (qualitative, quantitative, monetary, non-monetary)	Complete decision-support analysis (e.g., multi-criteria analysis; structured decision-making; cost-benefit analysis; or other approach) and prepare to communicate results
Assessment Steps *(Chapter 2)*	3, 4	2, 3, 4	2, 3, 4	1, 5, 6

An ES assessment can range from a purely qualitative description of all relevant aspects of the case, to a highly technical analysis combining quantitative and qualitative analysis with mapping, valuation, and more. The degree of detail achieved in each assessment will depend on the resources available and the types of questions that are driving the need for an assessment.

In ES assessments, each discipline[38] adds to knowledge from different perspectives:

- **A *biophysical* perspective provides** an understanding of the measures of the biophysical structures, processes, and functions (natural capital) in ecosystems that produce ES. Such information is key to managing for sustainable use and conservation of biodiversity. It is also important to inform decisions that will affect—and that will be affected by—ecosystem resilience, cumulative effects, and thresholds or tipping points.[39] By considering these issues, the relationships between ecosystems and the drivers of change that determine their viability can be much better understood. This consideration can support much more strategic decision-making to moderate drivers of change and avoid approaching thresholds and tipping points.
- **A *socio-cultural* perspective provides** an understanding of the human role in ES production, use, and depletion through their actions and values, and is essential to informing environmental management and related decisions along with the biophysical and economic perspectives . Some of the key variables to assess from a socio-cultural perspective include (1) individual and group *access* to ES; (2) how people *interact* with the environment, including choices that both introduce and mitigate change in ecosystems through informal, formal, and institutional behaviour; and (3) the *significance* of different ES to different people (non-monetary values).[40] A socio-cultural perspective applies to *all* types of ecosystem services, not just the Cultural Ecosystem Services.

[38] For an illustration of the different kinds of expertise that could be involved, see Cowling et al. 2008.
[39] See explanations of these factors in *Tools – Tab 2: Cross-cutting Issues and Key Considerations*.
[40] See explanation of socio-cultural values in *Tools – Tab 6: Values and Valuation: Economic and Socio-cultural*. See also Chan, Guerry, et al. 2012; and Chan, Satterfield and Goldstein 2012.

- **An *economic* perspective provides** an understanding of the measurable economic implications when ecosystems are affected and when human well-being is changed as a result of diminished or increased access to the benefits produced by ecosystems is often an essential part of decision-making. Assessing the full range of costs that society must pay for lost or degraded ES in terms of compensation, mitigation, remediation or replacement is a key component of assessment. It is also important to identify positive economic implications and provide an indication of the importance that society gives to ES in monetary terms when relevant.[41]

Each step in *Chapter 2* will benefit from—or indeed, will require—expert knowledge and skills from each of the perspectives just described, as well as from stakeholders and holders of Indigenous traditional knowledge.[42]

The roles for different kinds of knowledge and different disciplines are found throughout this Toolkit. At each of the steps in *Chapter 2*, Toolkit users need to consider when and how their own areas of expertise can contribute to answering the questions that are used to build the assessment and produce results. It is important to be sure that individuals with the range of relevant expertise are engaged to answer the questions and address data needs.

Key Message:

Identification of values—in economic and/or socio-cultural terms—can be an important product from ES assessment (for considerations informing valuation approaches, see *Tools – Tab 6: Values and Valuation: Economic and Socio-cultural*; for factsheets about different kinds of valuation methods, see *Tools – Tab 7: Compendium of Data Sources, Analysis Methods, and Tools*).

Economic analysis and socio-cultural analysis both also have key roles to play in other aspects of ES assessment from beginning to end. They do this by providing evidence about human activity as it affects ecosystems, and about how people are using and benefiting from ecosystems and ES. These analyses are central to completion of worksheets (in *Tools – Tab 4: Worksheets for Completing ES Assessment*) that support each assessment step in *Chapter 2*.

TIP: **This Toolkit adopts the broad definitions for each of the terms "value," "values," and "valuation," referring to different ways of assessing importance using measures of extent and condition, descriptions of significance, priority ranking, and monetary units, as appropriate. For details, see *Tools – Tab 6, Tools – Tab 7,* answers to *FAQs 3* and *4* in *Tools – Tab 8*, and *Chapter 2* (especially *Step 4*).**

FAQ 5: Why should we assess multiple ES together?

FAQ 6: How can integrating the ecological, socio-cultural, and economic value domains affect analysis of trade-offs?

FAQ 7: What are some of the key principles of ES assessment?

FAQ 8: Does ES assessment replace other approaches for assessing environmental conditions?

FAQ 9: How might different groups view ES assessment and the use of an ES approach?

FAQ 10: What are the main challenges to an ES approach?

41 See explanation of economic values in *Tools – Tab 6: Values and Valuation: Economic and Socio-cultural*.
42 For advice on ES assessment involving Indigenous communities, see *Tools – Tab 3: ES Assessment Involving Indigenous Communities*.

1.4 How to Determine If ES Assessment Is Right for the Situation

A decision of whether to undertake an ES assessment can be made by following a series of logical steps that provide an informed view of the situation. To determine whether an ES assessment would be warranted, complete *Steps 1b, 1c,* and *2* in *Chapter 2*, and complete *Worksheets 1, 2* and *3* (worksheets are located in *Tools – Tab 4: Worksheets for Completing ES Assessment*). The *ES Priority Screening Tool* (*Worksheet 2*) is used to identify the most important ES for a case, the way that people are benefiting from those ES, whether they are substitutable, and how a proposed or anticipated action is likely to impact ES. *Worksheet 3* helps to distill this information. This should result in a good understanding of the site-specific issues and the risk associated with the proposed decision or action. If the risk appears to be high, an ES assessment may be warranted and could help reduce impacts and improve opportunities for positive outcomes.

For decisions that may affect Indigenous peoples, it is important to first consult with their community leaders to find out whether an ES assessment is perceived as beneficial for the task. Most of the steps in *Chapter 2* can be relevant in the context of Indigenous communities. See *Tools – Tab 3: ES Assessment Involving Indigenous Communities* for more specific advice.

There are many different situations for which an ES assessment can be a very helpful part of decision support. There are also situations for which an ES assessment may not be needed and some other form of evaluation may be more relevant. Although ES assessment can be a rich source of analysis about ecosystem health, ES assessment is, by definition, oriented to the dependence of human well-being on healthy ecosystems. ES should not be the basis of analysis if it obscures the importance of biodiversity and other variables that are important for the long-term sustainability and resilience of ecosystems, or if it impedes public understanding of these things.

Key Message: A Note on Data Availability

All ES assessments and their component analyses depend on accessing and interpreting data. Ideally, the assessment team will be able to access *existing* data that describe the biophysical, socio-cultural, and economic conditions and values that are needed for the case. The *kinds* of data and the *sources* of data will be different for each of these aspects of analysis.

It is very likely that at least some of the data will not be readily available and a decision will have to be made as to *whether to collect new data* or *identify acceptable proxy data*. Collecting new data can introduce costs in terms of time and money. In many cases, it will be worth the investment if the team is able to do so.

This Toolkit provides advice about methods for collecting new data for two reasons:

- to help users be aware of potential influences that different data collection methods have on the ***existing*** data that they find and that they may plan to use—this will help users to know how to interpret and use the data correctly; and
- to help users make informed choices about what methods to use if they decide to collect ***new*** data.

Advice about finding and accessing existing data, proxies, and indicators, and collecting new data is provided in logical sequence through *Chapter 2* and, importantly, in the answers to FAQs that are positioned through the chapter, as well as in several of the *Tool Tabs* that are positioned immediately after *Chapter 3.*

CHAPTER 2 – COMPLETING AN ECOSYSTEM SERVICE ASSESSMENT

In This Chapter:

- **Introduction and quick reference guide, with tips for abbreviated ES assessment for situations with tight resource constraints**
- **Guide to ES assessment in six steps**
- **Links to tools and resources in *Tool Tabs***

2.1 Introduction and Quick Reference Guide

The concept of ecosystem services (ES) was developed to make visible that which is not visible in current systems of decision-making. Because decision-makers are often unaware of the impacts their decisions have on ES, unnecessary impacts to—or loss of—ES that are directly valuable to people can occur. This chapter of the Toolkit takes **a methodical approach to make the biophysical, socio-cultural, and economic values of ES more easily discernable.**

An ES assessment will often involve seeking answers to many questions, such as:

- Which ES are priorities in a given situation?
- What to measure or assess and which analysis tools to use?
- How are various ES produced and how do they interact with each other ecologically?
- How do ES benefit different groups of people (whether they are aware of it or not)?
- What are the values of these ES benefits to those groups of people?
- Are ES benefits increasing or decreasing over time?
- What are the likely effects of a project or policy on ES and associated ES benefits?
- How can specific policy objectives be achieved without undue negative impacts on important ES?

An interdisciplinary approach is necessary to understand how ecological trends intersect with human activity. Experts are encouraged to consider collaboratively what different disciplines can contribute to each assessment activity. While separate disciplinary teams will realistically work on their respective aspects of analysis, ongoing communication and co-ordination among teams enable teams to build knowledge through sharing and thus more effectively arrive at answers to assessment questions. The advice in the Toolkit focuses on the questions that need to be answered and offers tools to help answer them.

This chapter provides step-by-step guidance to completing a robust ES assessment. This includes guidance about the information, analysis, and process that can be helpful for making informed decisions regarding ES. The extent of the work that is required to complete a robust ES assessment depends on the complexity of the questions that need to be answered and the types of information and analysis that are needed to support the decision. The steps can be completed to different degrees depending on what is needed to address the specific issue, for example, by one person sitting at a desk using available information or by a team of experts conducting complex analyses and developing new information. A small team can attempt to work through the steps quickly to decide which steps will be needed to answer their questions, and where more resources should be directed.

Table 2.1 provides a quick reference guide for completing an ES assessment using a six-step process. Steps are defined sequentially for ease of communication. In practice, the process is both iterative and progressive. Suggestions for completing a partial or shorter assessment can be found in *Table 2.2*. The worksheets in *Tools – Tab 4: Worksheets for Completing ES Assessment* contain detailed questions to move users through the steps.

Table 2.1. *Quick reference guide to ES assessment in six steps.*

Six Steps – Quick Reference Guide	TOOLS	Location in Kit
Step 1. Defining the issue and context • Setting up a lead team • Defining the ES issue • Reviewing key terms and considerations	Glossary ES Descriptions Worksheet 1 Cross-cutting Issues	Tab 9, p.238 Tab 1, p.82 Tab 4, p.105 Tab 2 p.87
Step 2. Identifying priority ES and beneficiaries for assessment • Identifying priority ES and beneficiaries	ES Descriptions Worksheet 2 Worksheet 3	Tab 1, p.82 Tab 4, p.108 Tab 4, p.113
Step 3. Identifying what needs to be evaluated to answer assessment questions • Organizing assessment team and process: – Identifying resource requirements: time, expertise, and funding – Establishing advisory, technical, and review groups – Developing an administrative plan – Reviewing the *ES Priority Screening Tool* with assembled team • Identifying what will be evaluated to answer assessment questions: – Describing the priority ES within their social and ecological contexts – Tracking how system components relate to each other – Developing a technical assessment plan	Worksheet 2 Worksheet 3 Worksheet 4 Indicators Worksheet 5 Worksheet 6	Tab 4, p.108 Tab 4, p.113 Tab 4, p.115 Tab 5, p.127 Tab 4, p.117 Tab 4, p.118
Step 4. Identifying and using indicators, data sources, and analysis methods • Identifying which indicators are most relevant for assessing each ES • Identifying and gathering existing data sources or developing new data • Selecting and using analysis methods and tools to answer the assessment questions • Choosing an analysis approach	Cross-cutting Issues Indicators Worksheet 7 Sources-Methods-Tools Values & Valuation Worksheet 8	Tab 2, p.87 Tab 5, p.127 Tab 4, p.120 Tab 7, p.158 Tab 6, p.137 Tab 4, p.123
Step 5. Synthesizing results to answer assessment questions • Integrating and synthesizing results	Worksheet 9	Tab 4, p.125
Step 6. Communicating assessment outcomes • Understanding what results mean and do not mean • Communicating results to different audiences • Distilling complex, integrated results into key messages		

Note: FAQs (*Tools – Tab 8*) and Glossary (*Tools – Tab 9*) are relevant to many steps.

Table 2.2*. Tips for completing shorter or more targeted ES assessments.*

Decision Context	Suggested Assessment Approach
Any decision context	**Complete Step 1:** Define the issue and context. Skip any subsections that do not apply, such as suggestions for organizing an assessment team. Regardless of the planned use for the results, the objective should be as precisely defined as possible. As suggested in this step, the more thoroughly that the team can review ES concepts and come to common understanding of these topics, the more successful the work will be. **Complete Step 2:** Identify priority ES and beneficiaries. This step is almost always useful, as even if the priority ES may seem self-evident, there may be other unacknowledged ES that support a system. Likewise, some important stakeholders may have been overlooked. Skip this step only if the project is already well defined and a specific ES measurement is needed. Even so, it may be useful to complete *Step 2* to identify any issues that may have been overlooked.
Want to understand how ES fit into a specific decision-making context	**Complete Step 2:** This step identifies priority ES within a context as well as how they benefit surrounding populations. It includes completing the first three worksheets in *Tools – Tab 4: Worksheets for Completing ES Assessment*, particularly the *ES Priority Screening Tool*. Any questions that arise from this work could potentially be answered by local experts or a quick literature review.
Want a simple measurement of a specific ES	**Complete Step 4:** This step introduces different analyses and points to resources for completing different types of measurements or assessments. The *Compendium of Data Sources, Analysis Methods, and Tools* (*Tools – Tab 7*) is a key resource that will help to complete the analysis. Skipping previous steps may be possible when simply developing information that will not be used immediately in a decision.
Want to understand how a specific system produces ES and how they benefit people, without any actual measurements	**Complete the *Cascade Tool* in Step 3:** This worksheet will help to identify the natural capital, ecological functions, and built infrastructure that contribute to producing ES, and how these ES benefit different stakeholder groups. The *Cascade Tool (Worksheet 5* in *Tools – Tab 4: Worksheets for Completing ES Assessment)* can be used by itself to work through how the components of a system fit together to provide ES and benefits. Local experts and stakeholders can be brought in to help understand how the system fits together.
Want to build capacity in a department or organization for understanding and managing ES	Read through introductory material and all steps to understand how an assessment might be undertaken, and how ES are understood to be produced from landscapes, natural capital, built infrastructure, and management. Pay particular attention to sections that address the need for an interdisciplinary approach to understanding how ES are produced and how they benefit people. Read *Chapter 3* for more information on how ES information can inform different types of projects, policies, and programs. The *Cascade Tool (Worksheet 5)* is a particularly good and simple tool for building common understanding of how ES are produced, benefit people, and could be managed.
Want to complete a *full* assessment, but have very little time	Although the steps included in this Toolkit may seem daunting at first, working through the steps once reveals that they are relatively simple and can be completed without too much effort, depending on the desired results. The more detailed the results need to be, the more time-consuming the exercise will be, and the more resources will be needed. If there is a lack of resources or time, the analyses themselves can be chosen to be less complex and require fewer experts. A smaller number of ES could be included in the assessment. Instead of quantitative analyses requiring lots of data, an assessment could include expert opinion on the condition and trends of ES. It is recommended that the assessment team at least read through all the steps carefully. There are many sub-steps that could be omitted, for example, those related to the organization of the assessment team. A review process is always suggested, but could be scaled down. The experience of government teams in Canada that have attempted full assessments has shown that omitting steps related to developing a common understanding of ES concepts is not a good idea, as this is crucial to efficient completion of ES analyses. ***Continued on next page…***

Decision Context	Suggested Assessment Approach
Want to better understand link between biodiversity and ES, or to build ES into existing biodiversity programs and policies	First, read *Issue 6* in *Tools – Tab 2: Cross-cutting Issues and Key Considerations* to learn how biodiversity and ES are linked. Many groups interested in ES assessment may be seeking to link ES and biodiversity programs and policies. There is value in this approach as there are many overlaps between biodiversity conservation and ES management. However, there may also be conflicts between biodiversity and ES goals. The *Cascade Tool (Worksheet 5)* can help define what elements of biodiversity underpin specific ES. Mapping the distribution biodiversity and specific ES can also help determine how ecosystem components overlap (or not) in space (e.g., using GIS or Marxan, see *Tools – Tab 7: Compendium of Data Sources, Analysis Methods, and Tools*). *Chapter 3* provides advice on how ES can be integrated into existing processes for many different policy areas.
Want to add ES considerations to environmental (impact) assessment processes	Many of the steps in this chapter are useful for assessing ES as part of an environmental (impact) assessment (EA). To begin, read *Chapter 1* to be familiar with ES concepts, and study the *Cascade Tool* (*Worksheet 5*) to understand how different components of the ecosystems contribute to ES. Read the section on EA in *Chapter 3* for advice on integrating ES in different phases of the EA process. Consider the guidance provided by World Resources Institute (WRI).[43]
Want to build an ES or natural capital accounting program	One of the current leaders in this area is the UN Statistics Division.[44] Its focus is on accounting for all ES in an ecosystem, that is, their extent, condition, and values. The *Cascade Tool* (*Worksheet 5*) is very useful in this context, supported by completing *Steps 1* through *3* in *Worksheet 2* (the *Screening Tool)* and assessment *Steps 3* through *5*.

2.2 Ecosystem Service Assessment in Six Steps

The remainder of this chapter consists of the practical technical advice for completing an ES assessment in six steps. Each step includes an overview box, a discussion of the work involved in completing the step, links to key tools and resources in the *Tool Tabs*, including worksheets, and FAQs that flesh out how to complete the tasks. There are periodic progress-tracking boxes to help keep users oriented.

Step 1. Defining the Issue and Context

Overview

Set up a small lead team to initiate the assessment process, including:

- **exploring and defining the issue that is driving consideration of whether to complete an ES assessment, and determining parameters of the assessment using *Worksheet 1***
- **reviewing and agreeing on common understanding of core terms, descriptions of ES, and cross-cutting issues**

[43] Landsberg et al. 2013.
[44] UNEP-WCMC 2015.

1a. Setting Up a Lead Team

At the outset of discussions to decide on how to complete an ES assessment, a lead team should be established to complete the initial exploratory work. If an assessment is to be completed, this team will take the first steps in organizing it. The team can be small (e.g., three people), but ideally would include:

- a project manager (initiates, oversees, and authorizes the assessment);
- one or more experts on the human and environmental context and environment-related issues in the subject location (including expertise on ES); and
- one or more experts on the policy or decision that is driving the need for an assessment.

These individuals will be responsible for:

- exploring how an assessment should be undertaken and prioritizing issues (*Worksheets 1* through *3*);
- identifying and assembling the expertise needed to complete the remaining steps;
- overseeing development of an administrative plan for the assessment; and
- overseeing the assessment and reporting of results.

1b. Defining the Issue(s) Using *Worksheet 1*

The most critical step in an ES assessment is the clear definition of the issue and identification of the questions for which answers are needed. In some cases, the issue is already well understood but, especially with complex issues, there is often considerable work required to develop a detailed understanding of the issue and the various ecological, economic, and socio-cultural factors that are relevant. Information needs and objectives for the assessment should be defined in terms that are specific enough to inform the detailed plans for the assessment. This is called a *problem-oriented approach.* It involves identifying precise objectives and then orienting the steps of the assessment towards meeting those objectives. A "problem-oriented" approach simply means that a specific issue is driving the assessment process. Tailoring an assessment process to result in solutions to a specific issue is more important than following a rote set of steps.

At this stage, the lead team can benefit from exploring available decision-support tools or approaches, such as multi-criteria analysis, cost-benefit analysis, structured decision-making or software designed to support specific kinds of decisions. Decision-support tools or approaches are used to:

- support the identification of realistic management choices;
- support the integration of information into a coherent framework for analysis and decision-making, extracting key information that impacts decision-making from more basic information; and
- provide a framework for transparency (i.e., all parameters, assumptions, and data used to reach the final ES assessment result should be clearly documented) and ensure that the assessment process itself is documented.

Decision-support tools or approaches are presented in *Step 5* of this chapter, but it is a good idea to be familiar with them before starting the assessment. If the team knows that a particular approach will be used, the assessment should be tailored so that information is generated in the correct format to fit that approach.

Use *Worksheet 1* (in *Tools – Tab 4: Worksheets for Completing ES Assessment*) to define the issue and policy context for the ES assessment. This includes defining the main questions related to ES, and the geographic, ecological, social, economic, and decision-making contexts. If there are questions that cannot be answered, consider seeking input from local or regional experts or stakeholders.

Click on the link below to access the worksheet:

[*Worksheet 1:* Define the Issue and Context for the Assessment]

1c. Reviewing Key Terms and Cross-cutting Issues

The next activity is to ensure that all team members have a common understanding of the core definitions and related cross-cutting issues that may play a role in their assessment. It is a common experience to find that different people have very different ideas of what ES, values, and valuation are, and how they fit into environmental, social, economic, and policy contexts. Spending some time on this early in the assessment can actually save time in the long run, because ongoing disagreements or miscommunications about core definitions and concepts can impede the assessment progress. Note especially the "core" definitions indicated by red text in the glossary: *biodiversity, ecosystems, natural capital, critical natural capital, ecosystems, ecosystem services, benefits, beneficiaries, value, values, valuation, interdisciplinary,* and *ecosystem service assessment*. To review these items, click the following links:

- Glossary (in *Tools – Tab 9*)
- Descriptions of ES (in *Tools – Tab 1*)

At this early stage, it will also be valuable to review the concise explanations provided for seven cross-cutting issues that are very likely to arise in ES work. To review these items, click the following links:

- Cross-cutting issues related to ES assessment (listed below and explained in *Tools – Tab 2*)
  1. Assessment Scale
  2. Flows of ES Across Time and Space
  3. Resilience and Social-Ecological Systems
  4. Cumulative Effects of Change and Thresholds of Ecological Resilience
  5. Drivers of Change
  6. Biodiversity and ES: Compatibilities and Trade-offs
  7. Uncertainty and Data Gaps

The Alberta Pilot Assessment of Wetland Ecosystem Services found that completing the *Cascade Tool* (*Worksheet 5*) was a highly useful exercise in getting everyone on the same page regarding how ES relate to natural capital and ecological functions, how the benefits are distributed to different stakeholders, and what indicators might be used to measure any or all of these things.

Step 2. Identifying Priority ES and Beneficiaries for Assessment

Overview

- **Complete the *ES Priority Screening Tool* (*Worksheet 2*) to confirm whether an assessment is warranted, at what scale, and how it should be focused. This includes a preliminary scan of the case to identify high-priority ES and the risks and opportunities for ES presented by proposed projects, policies or decisions**
- **Complete *Worksheet 3* to synthesize the results from *Worksheet 2***

Identifying Priority ES and Beneficiaries Using *Worksheets 2* and *3*

While the high-priority ES may *seem* apparent in relation to the decision or problem to be solved, the likelihood is that other ES may also be important to different stakeholders. It is also rarely the case that all relevant ES can be assessed due to resources that may be required (e.g., time, expertise, funding). Selection of which ES to assess should not be arbitrary, as that would create a potentially significant risk of overlooking critical ES and the ecosystem processes involved. The *Screening Tool* (*Worksheet 2* in *Tools – Tab 4: Worksheets for Completing ES Assessment*) and its companion *Worksheet 3* provide a logically defensible, robust way of identifying all relevant ES and prioritizing ES to assess. Priority is based on the extent of ES importance to beneficiaries *and* on the risk of significantly impacting the ES and beneficiaries.

The *Screening Tool* is meant to be used iteratively. Initially, members of the lead team will complete the tool based on their knowledge of the area and its residents, and referencing existing sources in published and reliable grey literature about the assessment site/region. It is a desk-based process. This will provide a sense of the situation sufficient to identify what expertise will be needed to complete the assessment. If there are areas of the *Screening Tool* that the lead team cannot answer, they are encouraged to seek input from knowledgeable sources to address those gaps. Completing *Worksheets 2* and *3* for the *first time* should provide good indications of:

- the ES likely to be affected by the project or decision, who will be affected, in what ways and to what extent, whether there are acceptable substitutions in each case, and whether the project or decision is likely to jeopardize the ability of the ecosystem to function viably to produce ES;
- whether an ES assessment should be undertaken and, if so, to what level of detail;
- which ES should be the primary focus of an assessment, including identifying "bundles" of ES that appear to be functionally interdependent (when one is affected, the others will be as well);
- what issues may be of high importance to consider during the assessment, and may be most likely to require mitigation measures or development of alternative options for the decision or policy;
- what areas of specific expertise will be required to complete the assessment; and
- when stakeholder [45] and beneficiary engagement will be especially important.

The *Screening Tool* includes the tasks of identifying what ES are in the study area, who is benefiting from (or depending on) them and, in descriptive terms, how important each ES is to each beneficiary group.

The team responsible for completing the *first pass* through the *Screening Tool* may find that the exercise yields unexpected results or questions. They may need to seek input from other individuals who are knowledgeable about the local community or communities and their connections to the environment.[46] These individuals could be asked to review the results of the first pass through the *Screening Tool* and participate in a second pass through the tool. This second iteration can be used to focus more deeply on challenges, issues, and dynamics between different ES. It may also reveal factors overlooked in the first pass.

When soliciting information from stakeholders and local knowledge-holders, it is important to follow established procedures for the ethical engagement of people in research.[47]

Moreover, there are unique practices that apply to engaging Indigenous communities, which are explained in *Tools – Tab 3: ES Assessment Involving Indigenous Communities*.

Access *Worksheets 2* and *3* by clicking these links:

Worksheet 2: ES Priority Screening Tool

Worksheet 3: Summarize Screening Results and Confirm Priority ES

TIP: **There may be a perceived trade-off between efficiency in progress and time spent consulting with stakeholders. However, in addition to supporting the legitimacy of an assessment, stakeholders can help identify potential conflicts and compliance issues as well as provide important social, economic, and ecological knowledge. Time spent validating information with stakeholders can mean time saved by not having to resolve problematic results that can be derived from poorly informed analysis.**

[45] Klain et al. 2014 demonstrate how stakeholders are key sources for identifying priority ES and their benefits. Guides to help with stakeholder analysis (identifying stakeholders and their issues) include Bright et al. 2003 and http://www.aboutvalues.net/data/method_navigator/values_method_profile_identification_of_stakeholders.pdf.

[46] EPA 2002 is a practical community-based guide in this regard.

[47] TCPS – Government of Canada 2010.

TIP: **All the "right" answers and complete evidence to back them up are not needed before starting to fill out the worksheets in this Toolkit. Get started immediately and flag any questions that cannot yet be answered. Find help to fill in any gaps. Once identified, uncertainties about how the system functions can become a focus of the assessment.**

FAQ 11: Why should we complete a priority screening to identify the ES to be assessed, rather than just focusing on the ones we think we are interested in?

FAQ 12: Do cultural ecosystem services apply to all people, or only to Indigenous people and communities with distinctive ethnic or cultural identities?

FAQ 13: How are "cultural ecosystem services" different from "cultural values"? What steps can we take to include them in assessment?

FAQ 14: How do we know whether specific ES are actually benefiting different groups of people?

FAQ 15: Why is stakeholder involvement useful and important in ES assessment?

PROGRESS TRACKER

After completing *Worksheets 1, 2,* and *3,* the lead team will have completed a scoping of the ES issues and their significance to beneficiaries in the potentially affected area. They will have a preliminary identification of ES at risk of significant impact from a decision or action, whether these ES are substitutable, and if there are realistic options for avoiding negative impacts. If this scoping reveals that there are important ES that are likely to be negatively affected as a result of the decision or project, or that there is potential for enhancing ES and associated benefits to people through better management of ES, completing an ES assessment is warranted. The scope and complexity of the assessment may include anything from a short literature review to an in-depth collection and analysis of data, depending on the importance of the issue and availability of resources to complete it.

Step 3. Identifying What Needs to Be Evaluated to Answer Assessment Questions

Overview

- **Organize assessment team and resources, and develop administrative plan**
- **Review *Screening Tool* results with the assembled team and finalize**
- **Describe the ES being assessed to identify what will be measured or evaluated and at what scale using *Worksheet 4* and *5***
- **Develop a detailed technical assessment plan using *Worksheet 6***

3a. Organizing Assessment Team and Process

Identifying Resource Requirements: Time, Expertise, and Funding

Now that the lead team has identified the issues and scope for the assessment, it is time to determine what resources will be needed, including time, expertise, and funding, obtain the needed resources, and develop an administrative plan for managing the process to its completion. ES assessment can include anything from a literature review to original field research and participatory approaches. Depending on the approach taken, it can require little to large amounts of funding and time. This activity is interlinked with the other two activities in *Step 3a*, and best completed simultaneously.

Establishing Advisory, Technical, and Review Groups

The following suggestions for establishing different types of groups to lead or advise assessment work may only be appropriate for larger assessment exercises. A transparent process is important to ensure legitimacy.

***TIP:* Answering specific questions about ES often requires a high level of specific expertise. Each broad area of technical expertise such as physical science or social science has many disciplines, and each discipline has sub-disciplines. Choosing the right experts means focusing on the specific sub-disciplines relevant to the situation.**

Advisory group. The involvement of relevant decision-makers, Indigenous community representatives, stakeholders, and experts in an assessment can be a critical factor in ensuring (1) a clear focus for the work; (2) continued stakeholder engagement; (3) raising funds, if necessary; and (4) overseeing progress in implementation of the assessment. The lead team may be sufficient for a small-scale assessment, but it may be desirable to engage a larger group of stakeholders and expert advisors to advise on larger-scale or more complex assessments. Advisory group members may also provide feedback and reviews to the technical team.

Technical or expert group. An ES assessment is conducted by an interdisciplinary technical team with expertise in the relevant subjects. For example, if the project is considering alternative approaches to managing a forest and the resulting impacts on ES benefits, the expert team may include a forest ecologist, an ecological economist, a hydrological modeller, a GIS expert, an environmental anthropologist, and a geographer. A community or stakeholder group could also be established to provide information held by recognized knowledgeable local individuals, Indigenous traditional knowledge holders and/or Indigenous community representatives,[48] and local academic, business or consulting experts. Members of this group can work with the technical team to refine the assessment questions using the information from *Worksheet 1* and the *ES Screening Tool* (*Worksheets 2* and *3*). In many cases, expertise may need to be added as assessment questions are refined and needs are clearer.

Review group. External experts in the subject matter of the assessment, which may include stakeholders, can provide feedback on assessment progress, methods, and results. The peer-review process helps to validate the work, supporting its credibility and relevance. This increases the likelihood that the results will be used.

[48] See *Tools – Tab 3: ES Assessment Involving Indigenous Communities* for essential advice to be reviewed prior to establishing the assessment team or scoping the assessment.

TIP: **Expert opinion can be an important source of information in all stages of an ES assessment, from the initial scoping and screening to core data gathering and analysis. The reality is that experts do not always agree on all issues for different practical reasons (e.g., different theories they apply, different evidence they know, different analysis methods they use).**

When expert sources disagree with each other, the generally accepted practice is to acknowledge that there are dissenting views, what those views are, how they are substantiated (by evidence and reasoning), explain how they could be expected to influence results of analysis, and state what the implications of that influence could be. This reinforces the importance of recording the process, metadata, degree of uncertainty, reasons for uncertainty (see *Issue 7* in *Tools – Tab 2*), and assumptions used in completing the assessment. *Steps 5* and *6* below explain how this information is used to support results.

Developing an Administrative Plan

The next task is to develop an administrative plan for the ES assessment. This entails mapping out the administrative tasks, budget, scheduling and milestones, reviews and approvals, and who will be responsible for leading different parts of the substantive assessment work. These will be specific to the organization's operations and needs.

Remember that the approaches and steps included in this Toolkit can accommodate anything from a relatively rapid and resource-light approach to a lengthy and resource-intensive assessment. Both need the same thorough planning and should follow most of the steps and worksheets in this Toolkit (see *Table 2.2* for tips on scaling down an assessment). Additional technical experts, decision-makers, and stakeholders may be added at any point when a need is identified. Worksheets may be worked through several times to develop an appropriate, cost-efficient assessment plan.

Reviewing ES Screening Tool with Assembled Team

Once these organizational aspects are settled, the expert team will review the completed *Screening Tool* (*Worksheets 2* and *3*) to flesh out, revise or confirm the prioritization of ES for assessment. The expert team may need to refer to additional existing documents and consult local or professional experts to fill information gaps, but screening information should be approaching completion by this point. If needed, the administrative plan may also be adjusted. An adaptive, iterative approach will be more efficient in the long run.

FAQ 16: What do we need to consider when identifying resource requirements?

FAQ 17: What exactly does an advisory group do? Is it the same as a steering committee?

FAQ 18: What are key considerations for establishing a technical expert team?

FAQ 19: What types of expertise should we be aware of and consider seeking to complete an ES assessment?

PROGRESS TRACKER

By this point, the assessment team and advisors have been identified and have documented:

- **a well-characterized problem or decision that may affect ES in a specified context;**
- **a short list of precise questions that need to be answered to support decision-making;**
- **a broad characterization of the environmental and human context potentially affected by the decision;**
- **a confirmed list of high-priority ES that could be (significantly) affected by a decision or action;**
- **a broad understanding of who the main ES beneficiaries and other stakeholders are;**
- **a broad understanding of how beneficiaries depend on ES from the study area;**
- **a broad understanding of how the priority ES may interact with the problem/decision; and**
- **an administrative plan for project-managing the assessment.**

3b. Identifying What Will Be Evaluated to Answer Assessment Questions

The next three worksheets are designed to help assessment teams understand their priority ES in the context of the systems in which they are produced and used, and to get immediately into the details of what needs to be evaluated or measured. Completing these worksheets will help move the assessment forward rapidly by prompting teams to write down what is known and track down what is unknown.

Describing the Priority ES Within Their Social, Economic, and Ecological Contexts Using Worksheet 4

Worksheet 4 is a set of questions used to characterize prioritized ES so that the dynamics of their production and benefits will be better understood. An important part of this task is determining the scale at which the priority ES are produced and used. *Worksheet 4* prompts a consideration of the scale of these processes (for more on scale considerations, see *Issue 1* in *Tools – Tab 2: Cross-cutting Issues and Key Considerations*). When using ES assessment to inform decisions, it is often necessary to understand the difference between the current situation and the situation after the decision or action is taken. This comparison requires information on current conditions as well as information on how conditions are changing or projected to change in the future. *Worksheet 4* starts to build the "current conditions" layer of information.

Access *Worksheet 4* by clicking this link:

Worksheet 4: Characterize the Priority ES

Tracking How System Components Relate to Each Other Using Worksheet 5 (Cascade Tool)

The *ES Cascade Tool* (*Worksheet 5*) is particularly useful for developing shared understanding of how an ES is produced, used, and valued. The *ES Cascade Tool* supports the team's understanding of the relationships between natural capital (the ecosystem), how key ES are produced (i.e., what parts of the landscape contribute to their production), how the ES benefit specific stakeholders, and which drivers of change may be impacting the situation. The tool allows everyone to place their interpretations of what ES are into a common framework. Understanding the relationships between these system elements facilitates the choice of indicators, and the substitution of indicators when data are unavailable to assess some of the system components. For example, if data are not available to measure how ES are changing in a region, data may be available to at least measure the underlying natural capital. *Figure 2.1* is an example of a completed *Cascade Tool* from a wetland ES assessment carried out by the Government of Alberta (who used the *Cascade Tool* to study other ES as well). The content in the right column ("units") shows a selection of indicators that were used. (See *Tools – Tab 5: Indicators of Natural Capital, Ecosystem Services, and Benefits from Ecosystem Services* for a table of commonly used indicators for the biophysical and social aspects of each type of ES.)

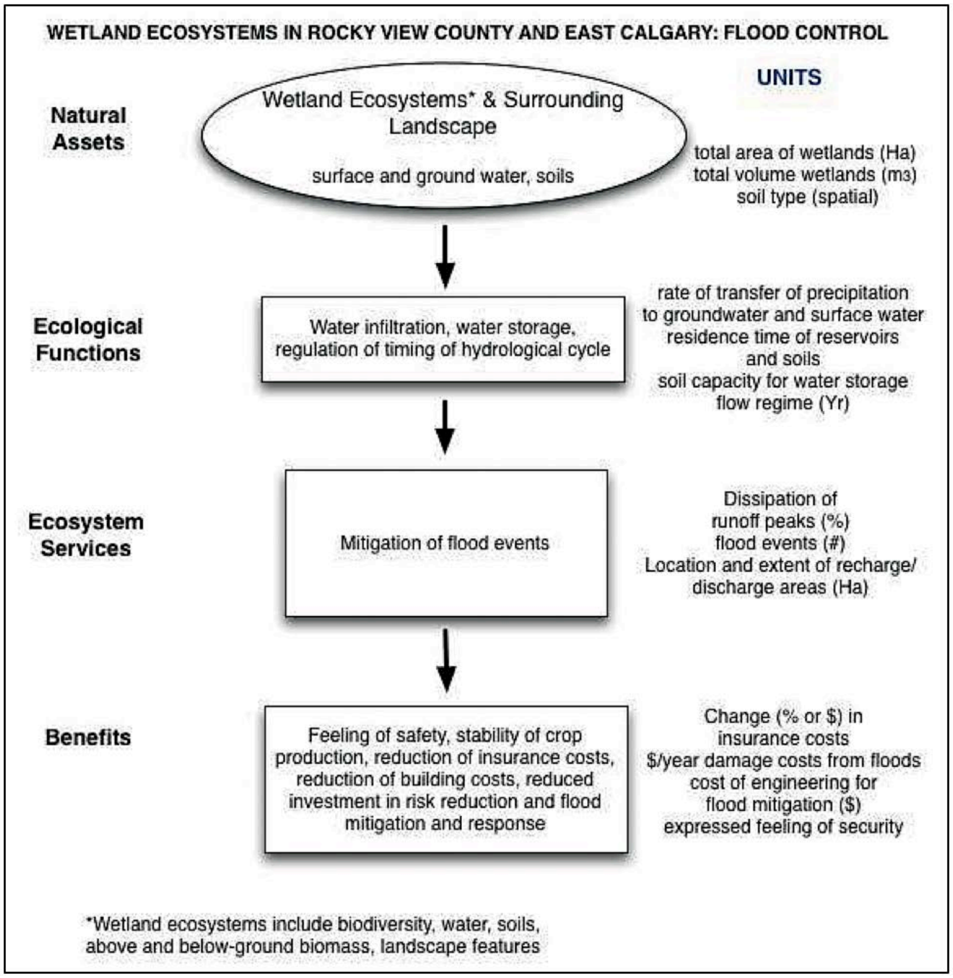


Figure 2.1. *Example of completed Cascade Tool, from the Alberta Wetlands Ecosystem Services Assessment Pilot Project.*

TIP: **The *Cascade Tool* builds understanding of what ES are and how they can be measured, because it displays natural assets (or capital), ecological functions, ES, and benefits together on the same graphic page, and relates these system components to each other. An example of how this tool helped clear up a misunderstanding in a Canadian project is when an assessment team assumed that cultural ES had to be assessed by social scientists, using only cultural values. When the team placed the cultural ES of interest into the *Cascade Tool*, they realized that cultural ES are still produced by ecosystems and have underlying ecological functions and natural capital that need to be assessed by biophysical scientists to understand how to manage them in a way that is both sustainable and consistent with the cultural values assessed by the social scientists.**

The assessment team should fill in the sections of the *Cascade Tool* to summarize the most relevant aspects of the ES that will be assessed. Complete this process for each prioritized ES on a separate copy of the *Cascade Tool*. Compare the information in each cascade for similarities in how the different ES are produced and benefit people.

Access *Worksheet 5* by clicking this link:

***Worksheet 5:* Ecosystem Service Cascade Tool**

Developing a Technical Assessment Plan Using Worksheet 6

The accumulated information from *Worksheets 1* through *5* positions the assessment team to develop a first draft of a technical assessment plan. This is different from the administrative plan in that it does not include a time schedule, budget, meetings, and so on. In *Worksheet 6*, the assessment team will start to develop an approach to answer each of the assessment questions. The approach will include (1) a choice of relevant indicators; (2) a search for data to match these indicators; and (3) methods of analysis to make sense of the data in relation to the assessment questions. *Worksheet 6* may be refined as data, tools, and approaches are investigated in greater detail in subsequent steps. In practice, ***a complete, operational assessment plan requires simultaneous exploration of indicators, data, and analysis approaches, as these all need to align***. *Worksheet 6* is an introduction to what will be needed to complete a technical assessment plan. To finalize the assessment plan (and therefore *Worksheet 6*), the team will need to explore all of the elements presented in the following sections and to develop iteratively the plan.

The five most common types of analyses used in ES assessment are introduced here. An assessment can include one or any combination of these types. Each type is associated with different kinds of data and different approaches to using data (i.e., different analysis methods and tools). Descriptions of each of these analysis types are provided in *Step 4* below, along with examples of data sources, analysis methods, and tools. All of this will support preparation of the detailed (technical) assessment plan using *Worksheet 6*. Becoming familiar with them now will help in the first pass through the worksheet. Remember that the assessment question(s) formulated in *Step 1* should be the basis for determining the overall approach. The broad types of analyses explore:

- the *extent, condition, and trends* in ES (this may include how the extent, quality, and connectivity of landscape components relate to the provision of ES; "trends" means how ES are changing);
- the socio-cultural and economic *values* of ES benefits (valuation);
- the *interactions* among multiple ES, including trade-offs, synergies, and bundling;
- the *relationships* between ES, drivers of change, and the provision of benefits (this may include the distribution of and access to benefits); and
- alternative *future scenarios* of ES and human well-being, taking into account the presence or absence of possible management interventions.

Access *Worksheet 6* by clicking this link:

***Worksheet 6:* Develop Detailed ES Assessment Plan**

FAQ 20: When do we assign assessment tasks to the various experts on the assessment team?

FAQ 21: We've heard about the importance of maintaining relevance, credibility, and legitimacy in carrying out an ES assessment. How do we achieve these objectives? Is there a checklist of best practices?

FAQ 22: Why should we be trying to understand multiple ES and how different ES interact with each other?

FAQ 23: How does the Cascade Tool (Worksheet 5) build common understanding of what needs to be measured or evaluated?

FAQ 24: How does biodiversity fit into Worksheets 4 and 5 (and more generally into ES assessment)?

FAQ 25: We are having a hard time identifying how each ES is produced and what contributes to its production. Are there resources available to help us answer all the questions in the worksheets?

FAQ 26: How can we take into account in our assessment the cumulative effects of multiple drivers of change acting in combination on ecosystems and ES?

FAQ 27: How do we plan an assessment in a system that is constantly changing?

FAQ 28: How can we determine the scale at which different processes are occurring?

PROGRESS TRACKER

By completing *Steps 1, 2,* and *3* in the assessment, the team has developed a *methodical evaluation of the issues and priorities* of the assessment context from an ES perspective. The team has prepared an administrative plan to project-manage the work, and identified team members. The *logical scope for an ES assessment* has also been identified to support the needs of the decision-making context. With this information, the team has begun to develop a first draft of a *technical plan* to answer the assessment questions using data, knowledge, and appropriate analyses.

Consult with senior managers. This is a key time to engage with senior managers or the oversight committee to brief them on the detailed assessment plan and seek agreement to proceed to next steps.

Step 4. Going into Detail: Identifying and Using Indicators, Data Sources, and Analysis Methods

Overview

- Identify indicators to use as the focus for evaluating and describing the status, trends, dynamics or benefits of the ES that are being assessed using *Worksheet 7*, supported by the table of *Commonly Used ES Indicators* in *Tools – Tab 5*
- Review common types of ES analyses, and review and select data sources and the methods and tools for gathering and analyzing data using *Tools – Tabs 3, 6* and *7*
- Refine the technical assessment plan iteratively as all these pieces fall into place
- Complete the analyses using *Worksheet 8*

Identifying Which Indicators Are Most Relevant for Assessing Each ES Using Worksheet 7

Indicators are metrics based on measured data that convey information to assessment users about a particular attribute of a system. For example, while it is difficult to measure exactly how much forests contribute to flood regulation in a study area, measurements of the amount of aboveground runoff in similar forested areas versus deforested areas can provide an indicator for the ES. Determining what is measurable is a first step towards developing a detailed technical assessment plan. Identifying the most relevant indicators or proxies comes next.[49]

TIP: **Useful indicators…**

- **are relevant to a problem or decision-making context;**
- **match with existing data for the area; and**
- **match with available tools and expertise for analysis.**

[49] For explanation of how "attributes" can be defined (natural, constructed, and proxy), see factsheet on *Constructed Scales* in *Tools – Tab 7: Compendium of Data Sources, Analysis Methods, and Tools*. See also *Tools – Tab 9: Glossary*.

Information availability is improving for direct measures of individual ecosystem processes, functions, services, and benefits to people. However, in many cases, an assessment team will need to rely on closely related measures that act as proxies for the direct measures. In either situation, the team needs to identify first which indicators they will use to estimate the extent and condition of ecosystem components that contribute to ES and the benefits people receive from them. *Tools – Tab 5: Indicators of Natural Capital, Ecosystem Services, and Benefits from Ecosystem Services* provides an extensive list of potential indicators for ecological and social aspects of each ES. While not a complete list, this is a good starting point for choosing appropriate indicators for ES. The example of the completed *Cascade Tool* in *Step 3b* shows how the chosen indicators will relate to the different elements of the ES production and benefit process.

The questions in *Worksheet 7* will help the team to decide on indicators that are relevant to the assessment questions. Use the guidance in *Worksheet 7* to fill in indicators next to system components on the team's completed *Cascade Tool* (*Worksheet 5*). Some of the questions in *Worksheet 7* will address data and analysis approaches, and can be answered after reading the following two sections on these topics. Once a list of indicators that can potentially be used has been prepared, it will be necessary to obtain data to populate the indicators. It will also be necessary to select analysis methods and tools that are coherent with the chosen data and indicators. This is an iterative process, as data availability and expertise will constrain what can be measured. Because data will not always be available that match the chosen indicators, the team may need to substitute other indicators. Use the *Glossary* in *Tools – Tab 9* to check the precise meaning of technical terms.

Access *Worksheet 7* by clicking this link:

***Worksheet 7:* Select Relevant Indicators to Assess ES**

Identifying and Gathering Existing Data Sources or Developing New Data

To assign measures of stocks, flows or benefits to each indicator, the assessment team must obtain data. Existing data sources can include censuses, databases, peer-reviewed publications, non-peer-reviewed but reputable "grey" literature and reports, meeting minutes, websites, maps, and remotely sensed data. The following steps can be taken if data cannot be found for preferred indicator(s):

- Discuss whether available data are good enough for the moment. Can some questions be answered with other data?
- Choose different indicators that still represent the important system components (e.g., the "value" of summer cottages could be represented by their real-estate value, rental value, property-tax values, or subjective value statements in descriptive form, or through "willingness to pay" analysis).
- Choose indicators that represent other system components, possibly less focused on the system components of interest (e.g., instead of assessing the amount of water retained by forests, assess forested land-cover area). Discuss how this may change results.

TIP: **Indicators of different system components differ significantly in what they represent. A *benefit* indicator is substantially different from a *service* indicator. The former incorporates both access and demand, and the latter does not. If substituting an indicator with another that represents a less precise metric for the subject, it is important to note what is being lost and gained through the substitution. There may be an important loss of information or certainty about the condition or trends in the ES or in its associated benefits. When communicating the results of the assessment, it is important to note any relevant information concerning the indicators used, including any concerns about the quality of data, use of proxies, data that represent a snapshot in time, or any other possible limitations that may need to be taken into account. (See *Step 6*, below, for more on this aspect of communicating results.)**

- Find data that are available at a coarser scale if this still allows the assessment questions to be answered (e.g., remotely sensed data are often available, although sometimes do not provide enough detail at local scales).
- Discuss with end-users whether it is still useful to go ahead with use of the second-best data and/or indicators.
- Alter the scope of the assessment to system components for which data on the ES being assessed exist. Discuss how this will change results.
- Gather or assemble new data, which may fill important gaps in the data already available.

Revisit the assessment plan (*Worksheet 6*) to ask whether the chosen indicators and corresponding data will allow the team to adequately answer the assessment questions. See *Tools – Tab 7: Compendium of Data Sources, Analysis Methods, and Tools* for factsheets on many different sources, methods, and tools.

Reliability of data. The reliability of any data source is strongly influenced by the robustness of collection and analysis practices. For all conventional data collection and analysis methods, there are well-established criteria and procedures to ensure reliability is attainable. It is important to evaluate the quality of data before using them.[50]

Selecting and Using Analysis Methods and Tools to Answer Assessment Questions

Once identified and obtained from existing sources or through new research, the data will need to be analyzed to answer the specific assessment questions. *Table 2.3* illustrates a mix of approaches, analyses, and tools needed to answer different kinds of questions about ES.

TIP: **If the team already envisions using models that are designed to assess specific ES (e.g., SWAT for soil erosion) or whole suites of ES (e.g., InVEST), it is important to understand how each ES is estimated within the model, and determine whether the indicators produced by the model are sufficient for answering specific assessment questions. For example, InVEST models biodiversity in a particular way and the information output (i.e., specific indicators) may or may not be relevant within a particular decision-making context.**

[50] See *Tools – Tab 6: Values and Valuation: Economic and Socio-cultural* for more information on reliability relating to different types of data.

Table 2.3. *Examples of ES questions to be addressed and potential analysis tools.*

Example Questions	Potential Types of Analyses and Tools
Are temperate grasslands known to contribute to flood regulation?	• Literature review of grasslands, flood control • Expert consultation with local / regional grassland ecologists, hydrologists
How will housing development in a specific area impact any ES benefits?	• Screening tool to identify relevant ES • Stakeholder consultations to elicit values associated with focal ES • Modelling or scenarios of changes to ES and benefits from alternative housing • Risk analysis • Cost-benefit analysis • Municipal development plans
Where is the optimal location for a new protected area for the greatest benefits for both biodiversity and ES?	• Spatial mapping of multiple ES and biodiversity indicators (participatory and data driven) • Bundle analysis • Interviews, surveys, and/or focus groups with local communities
Can agricultural production in the area of interest remain sustainable in the face of important drivers of change in the region?	• Statistical analysis of trends in drivers of change (e.g., climate change, demographic change, global markets) • Statistical analysis of condition and trends in ES that support and regulate food production (e.g., soil and water ES, pest control) • Modelling of driver impacts on focal ES, food production quantities, input costs, and prices • Scenario exercise • Workshops with local farmers
Should natural or man-made infrastructure be used to increase water quality?	• Determine which indicators of water quality are most relevant to local communities • Modelling analysis of how watershed contributes to water quality • Economic valuation of ES contributing to increased water quality • Cost-benefit analysis of watershed management approach versus built infrastructure

At the end of *Step 3*, the **five most common types of analyses** used in ES assessments were introduced to help inform the drafting of the technical assessment plan. They explore different aspects of ecosystem change, the values that people place on ES, and management impacts. Here they are explained to show how each type leads to different approaches to *specific data analysis* using different methods and tools. This can help to identify the suite of data analysis methods and tools to use.[51] Read these sections before completing *Worksheet 8*.

The five most common types of analyses used in ES assessments include those that explore:

1. <u>The extent, condition, and trends in ES</u>

The state of ES is a snapshot of their "condition" or state in a given area and at a given time, usually the present or recent past. Condition can be measured in many ways, for example, the yield or quantity of a service, the quality of the ES, the stock of natural capital that permits the yield, and various comparisons of indicators of stocks and flows. "Trend" is an analysis of the change in condition over time and requires data from more than one point in time.

Understanding how ES are produced is an important part of understanding their condition, as the condition of the service is only as good as the condition of the underlying ecosystem elements that contribute to the production. The *Cascade Tool* (*Worksheet 5*) provides an opportunity for developing understanding of what components of natural capital and which ecological functions contribute to ES production. Some analysis and investigation may be required to further develop knowledge about the specifics of these relationships (if this is part of the goal of the assessment). While it may not always be necessary to understand how ES are produced, this type of information can feed into models or scenarios and will permit a more dynamic assessment of the system. Examples include assessing landscape fragmentation, the extent of certain land covers or the

[51] The choice of data analysis methods and tools will also be influenced by the scope of the assessment, available resources and expertise, and most importantly, the specific assessment questions.

reliability or magnitude of particular ecological functions. Any of these may be needed to answer questions about the sustainability of certain ES. Extent, condition, and trends analyses provide essential baseline information for many policy-related activities, for example, environmental damages assessment due to pollution events (see *Chapter 3* for more on this example).

Analyses to determine condition and trends in ES may involve very few calculations, as data may directly indicate the condition of the service (e.g., data on water quality). In other cases, determining the condition of an ES may require multiple analyses. Examples include comparison of recent data with data representing baseline conditions, an analysis of how the extent of a particular land cover relates to the production of ES, and modelling regulating ES to determine whether the current level of the ES is sufficient to achieve a desired result.

Examples of analytical methods and tools that are useful for completing a condition and trend analysis can be found in *Tools – Tab 7: Compendium of Data Sources, Analysis Methods, and Tools*, and include (among others):

- expert opinion
- group assessment
- literature review
- mapping
- modelling
- rapid assessment techniques
- statistical analysis (e.g., mean, variability, average versus marginal values)
- web-based tools and ES models

2. The socio-cultural and economic values of ES benefits (valuation)

"Valuation" here refers to both economic and socio-cultural approaches to identifying and analyzing the significance of ES. The subject is introduced here briefly. *Tools – Tab 6: Values and Valuation: Economic and Socio-cultural* provides much more detail and clarifies the potential and considerations for using both approaches in ES assessment. These are important elements to include in ES assessments if decision-makers are to be well informed about the full range of implications in the policy development process for environmental management issues. It is increasingly recognized that environmental issues can have significant implications for socio-cultural and economic values and policy objectives, and hence decision-makers are very interested in these components of ES assessment. Best practices for including these types of valuation in ES assessment are still developing and there are lively debates about valuing nature in the expert literature. Valuation approaches should be chosen based on their suitability for answering specific assessment questions, that is, approaches should be compatible with the types of ES and the ways that they matter to people.[52]

There are many approaches to economic valuation and socio-cultural valuation. The methods and assumptions for economic and socio-cultural valuation analyses are different, but both can provide important knowledge about how people benefit from ES. In most cases, economic and socio-cultural approaches require biophysical measures of the ES. For example, to quantify monetary values associated with an ES, the subject of valuation must first be described in terms of its quantity and quality. Although socio-cultural values can be recorded directly from interviews with beneficiaries, management decisions about these services still require biophysical assessment information about their condition and trends.

While values in an ES framework are usually considered to be the outputs of benefits valuation, in many cases stakeholders may have strong values that pertain not (only) to the benefits of ES but to relationships with nature (or with people in nature). These 'relational values' can have important implications for ES decision-making.[53] Some values and benefits can be ranked and analyzed quantitatively in terms of their importance or use, and value can be described qualitatively, an approach that can capture and communicate complex sets of values within and across populations. Money is the most commonly used metric in economic analysis.

The type of valuation analysis should be guided by central questions of the assessment. Given the linkages between the economic and socio-cultural components of an integrated assessment, **an interdisciplinary discussion on benefits can improve the overall usefulness and quality of work**. In many situations, the ability to analyze and understand the significance of ES to people will benefit from both a socio-cultural *and* an economic lens.[54] Decision-makers are often interested in understanding the full implications of their actions in monetary and other economic terms, biophysical measures and considerations, and socio-cultural impacts and values. This was shown by the team of scholar-practitioners responsible for developing the InVEST (Integrated Valuation of Environmental Services and

52 An interdisciplinary, international expert panel has also developed a detailed guide to values and valuation for ES assessment for the IPBES—see IPBES 2015. See also Chan, Satterfield, and Goldstein 2012 on relevance of different approaches depending on the type of ES being assessed.
53 Chan, Balvanera, and Benessaiah et al. 2016.
54 For example, Kettunen and ten Brink 2013 discuss this in the context of protected areas.

Trade-offs) tool for ES assessment. Based on their experience in several countries, the InVEST team advises that, in communicating to decision-makers, the link should be clearly made between changes in ecosystems and changes in multiple human well-being metrics, including income, health, and access to culturally important places and benefits.[55] Examples of analytical methods and tools that are useful for completing valuation analyses can be found in *Tools – Tab 7: Compendium of Data Sources, Analysis Methods, and Tools*, and include (among others):

- multiple approaches to economic and socio-cultural valuation
- multiple deliberative and participatory approaches to economic and socio-cultural valuation
- rapid assessment and mapping approaches

3. Interactions among multiple ES, including trade-offs, synergies and bundling

It is comparatively straightforward to plan and execute an assessment of a single ES, including its drivers of change and associated benefits to human well-being. It becomes more complex to take into consideration multiple ES and multiple beneficiary groups. Interactions among ES include trade-offs, synergies, and bundling behaviour. All of these may be important to identify in order to manage landscapes and resources effectively and sustainably. When one ES is impacted by a management decision, often this decision impacts other ES as well, in positive or negative ways. This can occur directly through the actual management actions or indirectly when changes in one ES cause changes to another service. For example, a decision to increase the amount of fertilizer per hectare on a farm is likely to increase crop yields, but is also likely to decrease water quality nearby. Showing preference for some ES in management decisions often leads to trade-offs with other ES. Developing understanding of how ES interrelate, or bundle together, can make those relationships more transparent and minimize overall losses. ES bundles are sets of ES that change together across space or time.

ES trade-off analysis can be applied to many different situations, including the measurement of trade-offs between two or more ES, decreases in ES due to changes in management approaches or land use, and trade-offs of benefits between groups of people. One goal of assessing trade-offs is that, once identified, trade-offs can often be minimized without reducing any of the ES that are desirable or valuable. The result is increased net benefits from multiple ES. For example, if a reduction in water quality is identified as a trade-off to improving crop production through fertilizer application, a policy may be developed to increase riparian buffer zones to reduce that trade-off without excessive costs to food producers. Such a policy could simultaneously conserve other ES, such as landscape beauty and animal habitat. ES trade-off analysis can help identify regulatory bottlenecks to efficiency, illustrate how ES outcomes can be improved, and reduce stakeholder conflict by making at least one user group better off and no group worse off.[56]

Examining interactions among multiple ES may be important for achieving the following policy/project objectives (among others):

- understanding and minimizing trade-offs among ES and benefits that could occur under a proposed policy or project, including reducing associated long-term economic and environmental costs;
- understanding the full range of ES that are provided in an area to allow people to discuss their short- and long-term priorities for managing the landscape;
- optimizing ES provision by revealing the best options for management, conservation or restoration, and balancing that with other societal goals;
- managing cumulative effects from multiple drivers of change on multiple ES;[57]
- managing economically important resources (e.g., crops, timber) in a sustainable manner to enhance long-term benefits for people; and
- developing conservation incentive programs that bundle together multiple ES.[58]

Methods for trade-off analysis have been developed specifically for ES assessment.[59] Trade-offs can be measured directly using correlation analysis, if data are available, or stakeholder consultation. Trade-off dynamics can be modelled to understand what the relationships between interests are and how conditions might change under different scenarios. A connectivity diagram that relates important ES in one area to each other is a simple way to explore interactions among ES and can be developed through discussion with experts.[60] Another approach is to compare completed *Cascade Tools* for each ES and see whether there are commonalities in their production, benefit distribution or associated drivers of change. Mapping out these interactions or connections among ES is valuable in

[55] Ruckelshaus et al. 2015: 18.
[56] For a comparison of three approaches to ES trade-off analysis—map comparison, scenario analysis, and trade-off analysis—see Lautenbach et al. 2010. For review of quantitative approaches for ES trade-off analysis, see Mouchet et al. 2014. Naidoo and Ricketts 2006, Chan et al. 2006, and Nelson et al. 2009 are foundational publications for advice on ES trade-off analysis.
[57] See *Issues 4* and *5* in *Tools – Tab 2: Cross-cutting Issues and Key Considerations* for advice about cumulative effects and drivers of change.
[58] See section *3.6* in *Chapter 3* for advice about conservation instruments.
[59] See Lester et al. 2013, Raudsepp-Hearne et al. 2010a, and Briner et al. 2013 for methods and examples
[60] One illustrated example of a connectivity diagram can be seen in *FAQ 23* in *Tools – Tab 8: Answers to FAQs (Frequently Asked Questions)*

the planning stages of the assessment, and can be analyzed further using statistical or modelling approaches. More complex analyses of ES interactions, such as cluster analysis and principal components analysis,[61] can be used to identify and explore ES bundles. Examples of data sources and analytical methods and tools that are useful for analyzing interactions among ES can be found in *Tools – Tab 7: Compendium of Data Sources, Analysis Methods, and Tools*, and include:

- mapping
- literature review
- statistical analyses that identify synergies and trade-offs between pairs of ES or relationships among ES bundles (e.g., correlation analysis, cluster analysis)
- modelling
- expert opinion, as well as other participatory approaches

4. The relationship between ES, drivers of change, and the provision of benefits

Causal pathways between natural capital, ecological functions, ES, benefits of ES, and drivers of change can be thought of as a hypothesis, linking the ES in question to the benefits it is thought to provide, or to the drivers that are potentially responsible for changes in that ES. The pathways may have several steps, for example, if the ES is a supporting or regulating type of ES. To establish a significant correlation between elements in a system, analysis is required to determine the statistical relationships among the different elements. It is important to think about how impacts are distributed across time (not just in the present) and across space, affecting different stakeholder groups. For example, there may be people who benefit and people who lose out in the immediate wake of a proposed project or policy, but the benefits and losses may change over time or across space. An analysis of the impacts over time can be conducted qualitatively or quantitatively using scenarios, models or statistical analysis. Spatial analysis requires spatial datasets.

Analyzing causality is challenging but it is key to answering many policy-relevant questions, such as what the impact of any new policy, project or plan will be on ES and the people that rely on them.[62] Levels of uncertainty associated with results are important, as causality is generally difficult to establish.[63] Modelling changes is ideal to understand and explore potential impacts of alternative policy or management options, but if this is not feasible, it is important to at least discuss the probable causal pathways and how they can be managed. Examples of data sources and analytical methods and tools that are useful for analyzing causality between drivers of change and ES/benefits can be found in *Tools – Tab 7: Compendium of Data Sources, Analysis Methods, and Tools*, and include:

- expert opinion
- literature review
- group assessment
- statistical analysis (e.g., correlation, regression)
- mapping and overlaying
- modelling
- impact statements
- narratives
- scenarios

5. Alternative future scenarios of ES and human well-being

Scenario-building is one of the methods for assessing the connections among drivers of change, ecosystems, and society. It also warrants some further discussion, because scenarios can be particularly useful for exploring uncertainty in systems. There is often a lot of uncertainty involved in ES assessments, because ES often change slowly across time. They are also subject to feedback from other ES, drivers, and management approaches, and may be lost suddenly if certain

TIP: **Almost any assessment of ES would benefit from understanding how ES might change under different management alternatives or drivers of change, as opposed to simply representing how ES are currently found on the landscape. Although dynamic representations of ES are more challenging and generally require modelling expertise and more time to complete, understanding ES in a dynamic way permits a better exploration of management alternatives and their consequences. For information on how to understand the dynamics of ES, see Luck et al. 2012b and Chan, Guerry et al. 2012.**

[61] On cluster analysis, see *Tools – Tab 7: Compendium of Data Sources, Analysis Methods, and Tools*, particularly *Statistical Analysis*.
[62] This is relevant, for example, for considering ES in strategic environmental assessment, see section *3.3-2 in Chapter 3*
[63] For advice on understanding and communicating uncertainty, see *Issue 7 in Tools – Tab 2: Cross-cutting Issues and Key Considerations*.

thresholds are crossed. For example, the build-up of phosphorus in soils often goes unnoticed over decades until soils are saturated, leading to sudden run-off episodes, algal blooms, and dead zones in nearby waterways, which can, in turn, destroy important fisheries or recreation areas. Scenarios are often included in ES assessments to explore possible future outcomes and promote robust management practices that will lead to long-term sustainability and resilience of ES production. Scenarios can also be useful to test what the long-term impacts of policies are, for example, by running "business as usual" scenarios and comparing them to scenarios with specific policies built in. Understanding how the system will change in the absence of a decision or management response can be a useful test of what level of response is needed. More information on scenario approaches can be found in *Tools – Tab 7: Compendium of Data Sources, Analysis Methods, and Tools*.

TIP: **These three considerations should be prioritized to support the relevance, legitimacy, and credibility of the results:**

1. **Do the methods and tools chosen obtain the information that is needed with sufficient accuracy?**
2. **Do the methods and tools chosen provide information in a format that can be used in decision-support?**
3. **Are the methods and tools chosen administratively pragmatic (i.e., available time, money, and expertise)?**

Choosing Analysis Approach Using Worksheet 8

Worksheet 8 guides the team through assembling the analysis approach that it will take. This will involve (1) identifying *what existing data sources* the team will use; (2) identifying *what new data* the team needs to develop and the *methods* used to develop them; and (3) determining *what set of analysis methods or tools* will be applied to the data to answer the specific assessment question(s). Remember that the indicators that will be relevant to answering assessment questions need to match with both data availability and methods of analysis, and therefore some back and forth will be necessary before the team can complete relevant analyses. Determining which methods or combinations of methods to use should be a transparent process that includes clearly stating the assumptions and addressing the requirements for relevance and integrity of the analysis.[64]

Revisit the assessment questions regularly as the analysis is completed to make sure that the assessment is on track to answer them.

Revisit the *Cascade Tool* to track how well the data collected in this step report against the elements of the system the team wants to measure. When the indicators are populated with specific measures or descriptive content, the team will be ready to synthesize the results for use in decision-support tools or frameworks.

Access *Worksheet 8* by clicking this link:

Worksheet 8: Determine Approach to Analysis Methods and Tools

FAQ 29: Should we develop a list of indicators first, or start by investigating what tools, approaches, and data are available?

FAQ 30: What if decision-makers are interested in types of indicators that cannot be developed or seem to be less relevant?

FAQ 31: Do we need to measure ecological functions to understand ES?

FAQ 32: What are the different kinds of indicators available for assessing benefits from ES?

FAQ 33: Do we need to use economic values as well as socio-cultural values to understand the benefits from ES or do they provide overlapping information?

FAQ 34: What are some different kinds of driver indicators and how are they incorporated into an ES assessment?

FAQ 35: Where can we find some additional information about ES indicators, their purpose, and suitability?

FAQ 36: We cannot find data about ES benefits, what should we do?

FAQ 37: When collecting new data from experts or stakeholders, how can we know if the data are credible and representative?

[64] For example, criteria for selecting methods are provided in SAB/EPA 2009, in particular, see pages 41–43.

FAQ 38: We only have access to remotely sensed data. Can we trust this source to deliver credible results in our assessment even though we cannot validate the findings separately?

FAQ 39: The questions we are asking are complex and require a lot of data to match our multiple indicators. Some of the data exist and some do not, what should we do?

FAQ 40: Is it realistic to expect to be able to collect new data?

FAQ 41: What time frame should we include in the assessment?

FAQ 42: Do we need to determine a baseline for ES condition?

PROGRESS TRACKER

By now the assessment team has put together a detailed technical plan to answer the assessment questions and is completing all the necessary analyses. Tools and resources to help complete the analyses are provided in all of the *Tool Tabs*.

Step 5: Synthesizing Results to Answer Assessment Questions

Overview

- **Gather results of all data-gathering and analysis activities**
- **Begin synthesis by organizing the results of analysis using *Worksheet 9***
- **Select and use a decision-support tool that accommodates different kinds of metrics and modes of evidence to weigh alternative policy or management options in terms of impacts on multiple ES and the well-being of different populations**

Integrating and Synthesizing Results

To answer simple questions about ES, the information conveying the condition or trends of the services, or their importance, may be sufficient. However, more complicated questions, such as the impact of particular projects or policies on human well-being, will often require more complex analyses that compare different sets of data (e.g., multi-criteria analysis or cost-benefit analysis). Comparing alternative project plans or policies often requires trade-off analyses to see who wins or loses when different options are projected or to compare costs and benefits across different options. These types of trade-off analyses analyze the repercussions to different stakeholders of ecosystem change. Policy-related processes should consider the link between changes in ecosystems and changes in multiple human well-being metrics.

Because the data that have been obtained for the assessment represent different subjects and measures (e.g., stocks, flows, condition, dynamics, dependencies, significance), the pool of evidence is a mixture of different formats. Synthesizing *comparable* units of measure for further analysis can be very helpful but, in some cases, it can lead to analytic errors. It can also require making assumptions to develop comparable units. Experts caution that aggregating common units that were derived by using different methods may not be "scientifically justified" and that the units should be reported separately.[65] Another approach is to measure each element in its "natural units" (i.e., monetary units for things that are actually in dollar terms; other quantitative measures as appropriate; or qualitative measures). The decision-makers can see the trade-offs when different, but natural, units are used.[66] Tracking metadata can help an assessment team to manage different types of information and stay clear about how the information can be used. Recording metadata also supports transparency and accountability.

[65] SAB/EPA 2009: 23.
[66] On metrics including natural units see Satterfield et al. 2013.

Worksheet 9 helps the assessment team to organize the information produced through the assessment so that it can be used to answer the focal questions. This may involve additional synthesizing analyses, which are presented below.

Access *Worksheet 9* by clicking this link:

[***Worksheet 9:* Synthesize Analysis Results**]

Decision-support frameworks to weight alternative outcomes. Once analysis results are organized and integrated in a chart, the outcomes can be evaluated. Typically, this involves use of an established decision-support framework or approach. These frameworks are simply tools to support the processing of the results of the analysis, and range from simple to complex. Many decision-support tools and methods are available and relevant for use in ES decision-support analysis. Although each framework is different, they all typically involve identifying an issue or problem within a particular context, exploring what is known about the problem qualitatively—and also quantitatively, to the extent feasible—and then weighting alternative solutions.

Consideration of trade-offs among potentially competing interests or benefits is often a key part of such frameworks and approaches.[67] Trade-offs may occur between different ES, between well-being outcomes of different groups that rely on the services, and/or between ES and other activities that would alter (or potentially eliminate) ES. In general, the focus in ES assessment is on marginal change, although it is possible that a complete loss of one or more ES could result from a management or policy decision. Trade-off analysis can be used to optimize decision outcomes that have minimal losses across the board and can also be used to seek synergies or win-win scenarios, as described in the section on "Interactions among multiple ES including trade-offs, synergies, and bundling" in *Step 4*.

Individual jurisdictions may be required to use specific decision-support approaches in specific contexts and they may have guidelines for how each tool is to be applied. Toolkit users are advised to verify any requirements in their jurisdiction, and clarify how an approved approach can accommodate ES assessment. Some jurisdictions may not have fixed requirements for considering ES information, and there may be some flexibility in selecting an approach that offers a good fit. *Table 2.4* provides an introductory comparison of three common decision-support frameworks. Each of these frameworks is applied by following a set of steps and can be tailored to different situations. The steps include the use of a range of analytical procedures and, in some cases, several tools.

SDM is an integrative, interdisciplinary framework developed for environmental decision-making. MCA is an umbrella category encompassing many distinct self-contained approaches (most of which are software-based) and is used in many disciplines. SDM and some types of MCA accommodate diverse types of quantitative and qualitative information and can be well suited to integrating different types of information in ES assessment. CBA is the dominant economic framework used in trade-off analysis, and is not specific to environmental decisions. CBA does not preclude a comprehensive analysis of ES. It requires identification of all impacts, and then quantification and monetization of those impacts amenable to that. A CBA framework advocates for a description of all impacts, even those that cannot, or should not, be monetized.

In addition to these decision-support frameworks, there are many new software-based analysis and decision-support tools that have been developed specifically for ES, some of which can be found in *Tools – Tab 7, Compendium of Data Sources, Analysis Methods, and Tools*. It is beyond the scope of this Toolkit to compare and contrast the diversity of decision-support frameworks that exist, especially as their value will be context- and question-dependent.

Table 2.4. *Comparison of common decision-support approaches.*

Approach	Selected Features Relative to ES Assessment
Structured decision-making (SDM)[68]	• Accommodates monetized, numeric, and descriptive data • Integrates technical- and values-based information, with practical tools • Primarily expert activity but incorporates stakeholder engagement • Compares multiple criteria and shows trade-offs between options
Multi-criteria analysis (MCA)	• Prioritizes monetized and numeric data, but can incorporate descriptive data • Compares multiple criteria and objectives to rank options • Several different approaches, including computer-program-based • Can be expert- or stakeholder-based/participatory
Cost-benefit analysis (CBA)[69]	• Primarily oriented to monetized data[70] • Sums costs and benefits to determine net gain or loss from social perspective • Expert activity with possible input from stakeholders

[67] See Ash et al. 2010, CBD 2007; Maness 2007; and TEEB 2013 for additional advice on trade-off analysis and other aspects of decision-support analyses.
[68] See http://www.structureddecisionmaking.org/ for details. A practical guide book is Gregory et al. 2012.
[69] One approach to CBA is explained in TEEB 2010 (for local and regional policy makers). Another approach to CBA (specific to regulatory proposals) is available from the Treasury Board Secretariat of Canada at: http://www.tbs-sct.gc.ca/rtrap-parfa/analys/analystb-eng.asp.
[70] Canada's federal guidelines on CBA prioritize monetary units but accept quantitative and qualitative data when monetary units are not available (s.4.2.3).

FAQ 43: How can we use information gathered during the assessment to understand potential future impacts or trends?

FAQ 44: How does the concept of resilience relate to ES? How can it be assessed?

FAQ 45: How can the results of an ES assessment be interpreted in a credible and transparent way?

Step 6. Communicating Assessment Outcomes

Overview

- **Translate results into answers to the assessment questions using clear and precise language**
- **Understand and communicate what the results mean *and* what they do not mean**
- **Both the communication approach and the results can be tested using a review process involving experts and stakeholders**
- **Communications products are tailored for specific audiences and purposes**

The conclusions generated through the analyses can now be applied to answer the assessment questions using simple and precise language. The effective communication and dissemination of assessment results need to be guided by clear communication goals that support the purpose of the whole assessment. At the broadest level, the primary goal will be to communicate information to support the decision for which the assessment was undertaken. A secondary goal will likely be to share the results more broadly to build the knowledge base on ES and support future decision-making. The first and most important step is to ensure that the assessment and lead teams (if they are not the same individuals) understand what the results mean, and what they do *not* mean.

Understanding What Results Mean and Do Not Mean

It is essential that the assessment team understands what the results they have generated mean and, equally important, that they understand what the results do not mean. These distinctions should be clearly communicated.

The scope, orientation, meaning, and relevance of results will all be influenced by the choices made in designing and implementing the assessment. The results should be understood to reflect:

- the specific questions that were used to design the assessment. If the assessment is carried out following a process that logically has the ability to answer the questions that were defined in *Worksheet 1*, the results should be presented as answering that question or set of questions, but not necessarily other questions that did not inform the collection and analysis of data;
- only what was possible with available resources (e.g., time, effort, expertise, funding), within the capabilities of the tools, methods, and activities that were adopted, the scope of the raw data used, and the thoroughness of the analysis—being clear about the scope of the work should prevent the absence of certain findings from being misconstrued; and
- only what was actually measured in terms of what each chosen indicator represents, what the data sets measured, and what the collection and analysis methods determined. Proxies should be clearly presented, with all data limitations and assumptions explained. For example, the cost of a lost ES may be assessed in terms of the expenditures for physical infrastructure, security, and health care that might have been supported by the original ES. However, this is not likely to encompass all of the ES benefits that are affected and is generally considered to be a "minimum value." It will rarely be possible to state with full knowledge the condition of an entire ecosystem or the supply of an ES, or the comprehensive value of an ecosystem to society due to the many components, services, and benefits that ecosystems produce. Presenting the data clearly can make a significant difference in how the results can be interpreted and used in support of decisions.

TIP: **For all results, be prepared to report on the level of reliability by asking and answering these questions:**

- **How credible are the data that were used?**
- **What are the temporal or spatial limitations of the approach?**
- **What important factors were the team unable to capture?**
- **What are the limitations of the tools/analyses used?**
- **How representative of the whole system are the results?**
- **Can uncertainty/probablility levels be applied to the results?**
- **Are conclusions sensitive to the uncertainty in the results?**
- **How can the team communicate results in the strongest manner, while being transparent about their limitations?**

It is worth the effort to be specific in documenting how the results were obtained, both in the primary report and in any appendices or metadata. The information that an assessment team compiles by completing *Worksheets 1* through *9* in this Toolkit can be used to develop a concise summary of key factors that establishes the scope for what the results can be understood to mean. In all cases, the information is most useful to decision-makers if it states briefly and explicitly what was included and what was excluded from the assessment (and why). This summary could include:

- geographic and social (including cultural and economic) scope of the assessment;
- the specific questions that were asked and answered by the assessment;
- which specific components of the ES system were assessed: ecosystem structure and processes (e.g., wetlands and hydrology), ecosystem functions (e.g., groundwater recharge), ES (e.g., water purification), ES benefits (e.g., physical health), and/or relative significance (e.g., avoided costs for health care and infrastructure, stated preference estimates to secure the benefits, and/or stated priority ranking or descriptive accounts of importance), because each of these represent something different;
- what indicators and/or data were used to answer the questions and why;
- what specific methods and/or tools were used to gather and/or analyze the data;
- which cross-cutting issues were considered and which issues were not considered or factored in to the resulting conclusions;
- any known limitations to data, knowledge or procedures that might have influenced the results (such as what indicators and/or data *could* have been used but were not and why); and
- any other factors the team identifies as relevant to the interpretation of results.

In the process of developing this summary, the assessment team itself is likely to gain greater clarity about what the results can be understood to mean, and what they do not mean. Providing this clarity in a way that decision-makers can quickly and easily grasp will increase the likelihood that the information will be used and, importantly, that it will be used correctly.

Communicating Results to Different Audiences

For government-based ES assessments, the audience is most often senior managers and elected representatives. Communication with Indigenous communities, the general public, and different stakeholder groups may also be needed. For these audiences, communications should use plain language rather than technical language. It is also important to communicate effectively results to other technical experts and analysts using relevant technical language. Each case calls for a relevant format and the identification of relevant and understandable information.

Transparency about procedures, including estimates of certainty and any limitations that could affect the results, is important for maintaining the credibility and legitimacy of the assessment.[71] Full transparency in how information provided by, or about, Indigenous communities is used is a high priority in presenting assessment processes and outcomes to those communities.

[71] On how to communicate estimates of certainty, see *Issue 7* in *Tools – Tab 2: Cross-cutting Issues and Key Considerations*. For advice about credibility and legitimacy, see answers to *FAQs 21 and 22* in *Tools – Tab 8: Answers to FAQs (Frequently Asked Questions)*. Additional advice on communicating results of ES assessment includes SAB/EPA 2009; Kettunen and ten Brink 2013; TEEB 2013; and Ash et al. 2010 Chapter 2.

There are two main types of communication for results of an ES assessment. The first type is to support the decision for which the assessment was completed. If decision-makers have been involved in the assessment all along, the appropriate language and level of information that need to be communicated will already be known to some degree. It is always a good idea to test the final reports with decision-makers and get feedback from them to ensure the relevance and credibility of the products.

The second type of communication for results of an ES assessment is to build the knowledge base, enhance awareness of ES, and support future decision-making. This involves sharing results widely with:

- other ES practitioners
- environment and natural resources managers and decision-makers
- Indigenous governments, communities and organizations
- the public
- relevant industry sectors, non-governmental organizations and stakeholders

Distilling Complex, Integrated Results into Key Messages

Deciding on the key messages of an assessment is one of the most important steps of the communication process. Full assessment reports are useful reference documents and will contain all the information produced during the assessment, but these documents are of great interest to other analysts and will rarely be used by senior managers and decision-makers or by the public generally. For these audiences, the content and conclusion must be synthesized into short, specific messages that will resonate. Most importantly, the indicators that are most relevant to decision-makers (often related to the benefits associated with ES) need to be highlighted in simple ways. Any connections between proposed actions, drivers of change, and ES or benefits valued highly by people need to be emphasized.

Key information for decision-makers:

- Key results relevant to the decision(s) at hand
- Level of reliability of the results
- Relationship between the results and other information sources relevant to the decision, e.g., how the results correspond (agree or disagree) to other information sources, and how the results should be understood relative to other information (what they *mean* relative to the substantive meaning of other information)
- Timeline and cost of the assessment, and how it was funded (any partners and their contributions)
- Overview of stakeholders and others engaged in the assessment and to what extent
- Views expressed by stakeholders and Indigenous peoples about the assessment and their potential response to its use in decision-making

Note: Good record-keeping throughout the assessment is essential in assuring the ability to communicate all of the points above.

Formats to present results include:

- **Technical reports** provide detailed information about the assessment, including descriptions of the methodology, analysis, and presentation of all of the results of analysis.
- **Summaries for decision-makers** summarize the results of the assessment and emphasize key results that relate to particular decisions, retaining some details on these particular results.
- **Executive summaries** provide a short summary of the assessment and highlight the most important and relevant findings in a straightforward way.
- **Slide presentations** make use of visual tools (e.g., charts, maps, illustrations) to demonstrate the results of the assessment. The level of detail depends on the needs of the audience.

Techniques to present complex information:

- **Figures:** Figures can be used to show relationships among different elements of a system, trade-offs or synergies among multiple ES, trends that are immediately recognizable by the slopes of lines or how different values compare between populations or alternative management options. *Figures 2.2, 2.3, 2.4,* and *2.5* are examples of the kind of graphic tools that can be used to quickly and easily communicate complex information about ES.

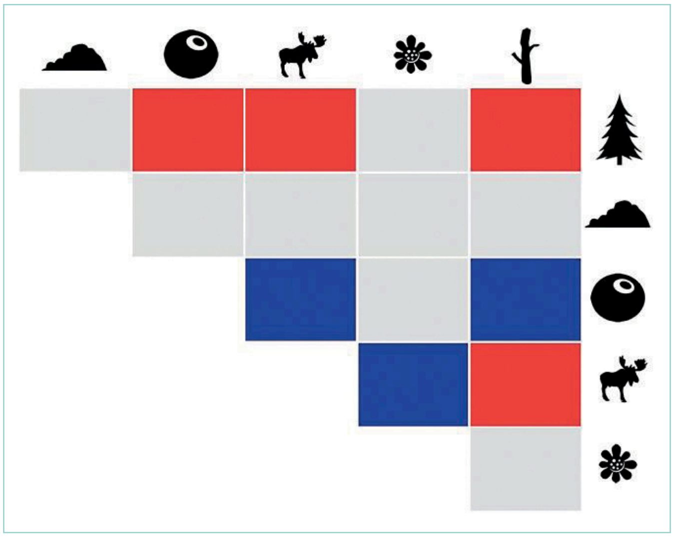


Figure 2.2. *Pairwise relationships between ES. Blue reflects positive relationships and red reflects negative relationships. Grey reflects relationships with no established inter-relationship. The six ES are labelled by their respective symbols (in order from left: soil carbon storage, bilberry production, game production potential, understory plant species richness, dead wood occurrence, and tree biomass production). (Source: Gamfeldt et al. 2013)*

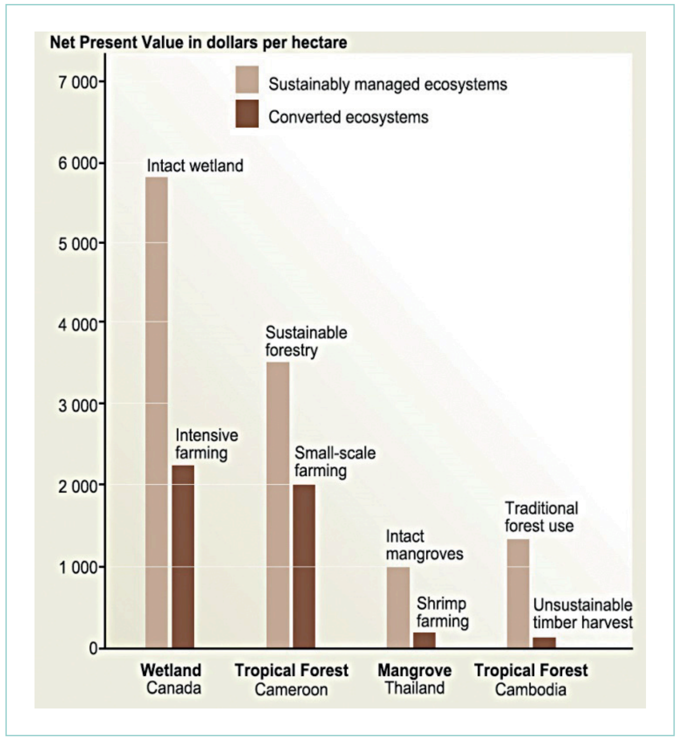


Figure 2.3. *Intact and healthy ecosystems are often worth more to society than ecosystems optimized for the production of one or a few goods or services. The private benefits are, however, often greater from the converted ecosystem. (Source: MA 2005)*

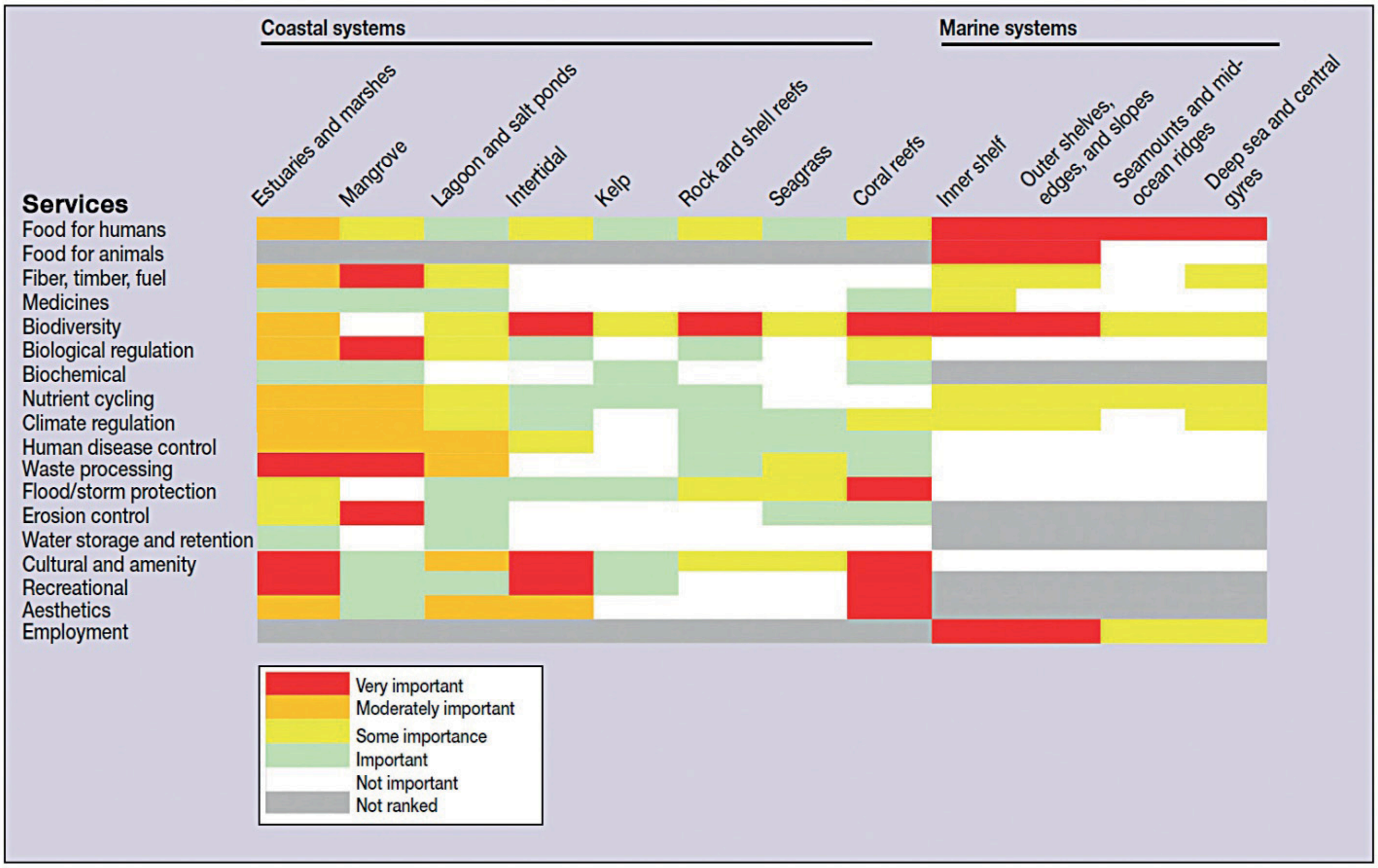
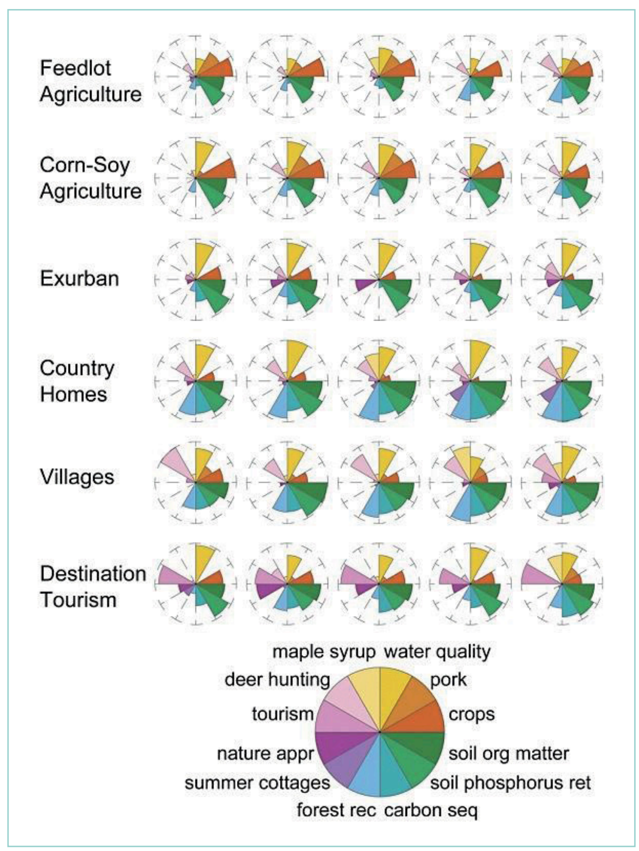


Figure 2.4*. ES provided by coastal and marine ecosystems, ranked in terms of their importance to coastal communities. Rankings of ES importance can be based on quantity of ES or benefits produced (in biomass or economic returns), perceived importance to societies (determined using participatory approaches or expert opinion) or irreplaceability or risk measures. (Source: Leslie and McLeod 2007)*[72]

Figure 2.5*. Flower diagrams illustrating the quantification of each ES by petal length. Each flower represents the set of ES for one municipality, and they are organized by clusters that have been given descriptive names (i.e., groupings of municipalities that are more similar to each other than to other groupings of municipalities). (Source: Raudsepp-Hearne et al. 2010a)*



[72] Leslie and McLeod adapted this figure with permission from Tables 18.2 and 19.2 of the Millennium Ecosystem Assessment (MA 2005). Reproduced here with permission from John Wiley & Sons. Requests for permission to reproduce this figure should be addressed to: permissions@wiley.com.

- **Tables:** Tables are particularly useful for summarizing large amounts of information in a format that can be easily sifted through and comprehended. For example, if different management options are each associated with multiple benefits and drawbacks, these can all be summarized in table form and then easily compared.
- **Artwork or photographs:** Photographs or artwork representing the condition of ecosystems or humans living there can be both impactful and memorable, and may greatly enhance messages directed at decision-makers.
- **Quotes or narratives:** Similar to photographs, quotes or narratives from stakeholders directly affected by changes occurring on a landscape can make a lasting impression on audiences. Narratives can also capture the complexity of human-environment interactions that may be difficult to convey otherwise.

Modes of disseminating information include:

- **Web sites:** Unlike reports, web sites enable information to be displayed in a non-linear fashion and facilitate navigation to and between sections of information that are most relevant to the individual user. They also enable the use of digital tools such as video, interactive maps, links to other sections or sources of information, and more.
- **Mobile applications (apps):** Local and regional ES information resulting from the assessment may lend itself to dissemination through mobile apps for use by local residents and organizations or by environmental and natural resources managers on the ground.
- **Interactive maps:** Maps can enable the user to add, remove, and analyze different layers of information resulting from the assessment.
- **Workshops and meetings (to disseminate, explain, and discuss results):** These can be informal or formal, depending on the audience. The two goals are to enhance interest in the results to increase the possibility of information use, and to be available to answer questions about the findings.

CHAPTER 3 – ADDRESSING ECOSYSTEM SERVICES IN DIFFERENT POLICY AND DECISION CONTEXTS

In This Chapter:

- **Introduction to mainstreaming ES in policy activities**
- **How to incorporate ES considerations in the general procedures for 11 common policy contexts (supported by *Chapters 1* and *2* and the *Tool Tabs*)**
- **Relevance, "entry points," examples, and resources for each context**

3.1 Introduction

What Does It Mean to "Mainstream" Ecosystem Services?

Governments around the world are increasingly considering ecosystem service (ES) assessment and its associated analyses to inform their policies, decisions, and management practices.[73] An ES approach requires consideration of ecosystem functions, how those functions generate ES, and how the benefits from ES are distributed within society. This approach identifies the consequences of environmental change and how environmental management decisions can enhance, diminish or maintain the flow of ES benefits. Thus, the approach provides more information regarding costs and benefits of change which can assist in environmental management decisions. The ways that the ES concept can inform a decision or action will vary:

- In some cases, the emphasis will be *primarily* on **ecosystem components and processes**, for example, to understand how a change in an ecosystem will affect the natural processes and functions that generate ES benefiting human communities. In these cases, the analyses would depend on multiple biophysical sciences.
- Sometimes the emphasis will be more about **human well-being**, by considering, for example, the impacts to human health from certain changes in ecosystems, how different groups benefit from ES, and who has access. Such analyses would depend on a variety of social sciences and economics, but would also be informed by the biophysical sciences.[74]
- Considerations might include either, or both, economic and socio-cultural **values and valuation** of ES. The approach to valuation would first be based on defining scope, context, and issues using biophysical and social sciences and economics. The various types of valuation chosen would be informed by the social sciences, such as anthropology and sociology, and on economics.
- Often a combination of emphases will be deemed most useful, and require a fully interdisciplinary approach.

"Mainstreaming ES" in policy and decision-making means showing, through the use of technical analysis, the specific ways that human well-being is dependent on ecosystems, and how human well-being is affected by changes in the environment. Inclusion of ES-enabling language in policy can inform the scope of a regulation and how the regulation is interpreted. The following example shows how ES assessment and considerations are being used in different policy contexts, and how they use different analysis methods and metrics as relevant and appropriate.

[73] Refer to *Tools – Tab 9: Glossary* for core definitions, including the different types of ES. See answers to *FAQs 1* and *2* in *Tools – Tab 8: Answers to FAQs (Frequently Asked Questions)* for examples of Canadian and international activity.

[74] Several disciplinary approaches exist to assess well-being. This Toolkit highlights two such approaches: economic and socio-cultural. Others include measures of health and security. The choice of a particular approach or combination of approaches depends on decision context. *Tools – Tab 6: Values and Valuation: Economic and Socio-cultural* provide advice about valuation approaches.

EXAMPLE:
2015 US Federal Directive to consider ES

In October 2015, the President of the United States (US) issued a Directive to all US federal agencies to incorporate ES into planning, investments, and regulatory contexts.[75] The Directive states that "**this may be accomplished through a range of qualitative and quantitative methods to identify and characterize ecosystem services, affected communities' needs for those services, metrics for changes to those services and, where appropriate, monetary or nonmonetary values for those services.**" Agencies are specifically required to complete detailed policies within six months, using existing frameworks to describe how relevant ES assessments, including monitoring and evaluation, will be undertaken. Examples of the scope of applicability are stated as "activities such as natural-resource management and land-use planning, climate-adaptation planning and risk-reduction efforts, and, where appropriate, environmental reviews under the National Environmental Policy Act (NEPA) and other analyses of Federal and Federally-assisted programs, policies, projects, and regulatory proposals. For example, should an agency's analysis require consideration of costs, the agency should consider ecosystem services assessment methods, where appropriate and feasible." Interagency co-operation was important leading up to the Directive and will continue to be central to implementation. By the time the Directive was issued, numerous major ES initiatives in many agencies were in progress as a component of natural resource and infrastructure management.

Chapter Purpose, Structure, and Introductory Advice

This Toolkit is meant to help build capacity to use ES assessment and reflect ES considerations in environmental management and decision-making.

Chapters 1 and *2* and their associated *Tool Tabs* contain full details on how to complete a six-step ES assessment, including several of the most common types of analyses that can be part of an assessment. Together these resources provide technical guidance needed for "mainstreaming" ES.

Chapter 3 illustrates some of the many practical uses for ES considerations in different policy contexts. "Considerations" can range from particular measures or values, to how people may be affected by ecosystem change, to full assessment. No single optimal use or blueprint exists for incorporating ES considerations into decision-making.[76]

The policy areas discussed in this chapter are organized into five broad groups:[77]

- **Area-based planning.** Featured examples are regional strategic environmental assessment and land-use/spatial planning.
- **Regulatory decision analysis.** Featured examples are environmental (impact) assessment, strategic environmental assessment, and regulatory and policy development.
- **Environmental damages assessment.** Featured example is environmental damages assessment.
- **Environmental management.** Featured examples are establishing and managing protected areas, managing species and ecosystems, and managing invasive alien species.
- **Conservation instruments.** Featured examples are conservation incentive programs and conservation offsets.

For each of these five groups, the chapter offers examples and recommendations on:

- relevance of ES to the policy area;
- entry points in the policy process for considering ES and what some of those considerations might include; and
- additional information sources (abbreviated format—for full citation of each see *Sources Cited*).

75 Executive Office of the President of the United States, 2015. (Bold emphasis added.) The example also points to the need for capacity, especially expertise, among agencies and consultants.

76 This chapter provides general advice for how and when ES could be integrated in existing policy-related processes. It is not intended to address all possible policy areas. It is not intended to describe the full suite of processes associated with the policy areas that are presented.

77 This grouping does not reflect formal divisions and the activities could easily be organized differently. The groups are not mutually exclusive, and there is overlap in some of the activities, for example, several of the featured examples have regulatory components but are otherwise not closely related. Some of the examples are likewise relevant in two or more of the topic areas. Some opportunities to consider ES are similar in the different situations.

Key Message:

It is not feasible to complete a new, comprehensive ES assessment for every decision. However, ES analyses and considerations can still inform different decisions through a strategic approach.

Begin by determining if ES assessment is warranted by reviewing the advice in *Section 1.4* of *Chapter 1*. It includes completing the *ES Priority Screening Tool (Worksheet 2* in *Tools – Tab 4*). This will help to determine if there are any important ES at significant risk as a result of a decision or action, and what those ES are. This immediately helps to refine the focus on what to evaluate.

A more thorough ES assessment approach is likely to be very useful and appropriate for larger, high-risk development projects that pose significant threats to the environment. Such a fully developed assessment will provide results that can inform many decisions affecting an area.

In the case of numerous small, low-risk projects, it is realistic to complete more modest analyses while still using the analytically robust steps and tools in this Toolkit in a strategic way. *Table 2.2* at the start of *Chapter 2* offers tips on how this can be done.

A unique benefit of the approach developed in this Toolkit is that, even for a relatively simple "desk-based" analysis, users are shown how to consider the ecological, socio-cultural, and economic aspects of the case in an integrated way. This means the assessment team is much more likely to identify critical issues, and can then choose actions that can result in more equitable, positive outcomes (see *Step 4* in *Chapter 2*).

The choices for what can be done to include ES in a policy-related decision-making process will depend especially on the phase and timing in that process. Here are just a few generalized examples:

- Early stages in a process might benefit from exploratory or scoping questions about whether ES are likely to be affected or have been affected. Start by identifying connections between the objectives of a decision and how they could sustain or even enhance ES in the decision site or region. This would correspond loosely with *Steps 1* and *2* in an ES assessment as presented in *Chapter 2*.
- Depending on the policy activity, stages during which data are gathered and analyzed (including during monitoring after a decision) would be an opportunity to also gather and analyze data about how the decision is affecting or is affected by ES. Such analysis could focus on species and ecosystems, on the extent or flow of ES, how people are affected, or how people value the changes. This would correspond loosely with *Steps 3* and *4* in an ES assessment as presented in *Chapter 2*.
- If the policy activity involves developing recommendations for alternative decisions, the ES information generated in the earlier stages could be synthesized in the decision-support framework being used. This adds another dimension that can help avoid unintended negative consequences, and even optimize positive outcomes. This would correspond loosely with *Steps 5* and *6* in an ES assessment as presented in *Chapter 2*.
- If the activity involves an implementation, mitigation or compensation phase, ES considerations could be of several kinds, two of which are noted here. Ask questions about what should be optimized and ensure that ES are part of the field of options for consideration. Scientific analysis of ES conditions and trends at the decision site or in the region can be used to establish criteria for performance objectives or requirements associated with restoration or mitigation.

The worksheets in *Tools – Tab 4: Worksheets for Completing ES Assessment* that are used to complete the steps of ES assessment in *Chapter 2* clearly show what questions to ask to understand different aspects of the ES cycle shown in the Toolkit's *Conceptual and Analytical Framework* (*Figure 1.2* in *Chapter 1*). For additional detail, please review the previous chapters and the *Tool Tabs*.[78]

[78] Different qualified experts can disagree with each other for varied reasons, including because the approach (including the data) will influence the conclusions that are reached (see *Issue 7 in Tools – Tab 2: Cross-cutting Issues and Key Considerations* about uncertainty and data gaps). An essential way to avoid gridlock and/or misinterpretation is for the assessment team (whether in-house government staff or contractors on behalf of government) to provide full documentation with their assessment or analysis stating the parameters of their analysis. For details regarding assessment documentation, see *Step 6* in *Chapter 2*.

TIP: **Collaboration across government agencies to develop a *strategy for actioning ES* could expedite its integration in policy-related activities. A ready-access resource kit to support time-sensitive and cost-effective analyses could be a valuable asset and could include:**

- **this Toolkit for step-by-step advice and tools to complete ES analyses and assessment using existing data where possible and gather new data where necessary;**
- **list with name, area of expertise, and contact information for all *potentially* relevant subject-matter experts in ES (e.g., biophysical, socio-cultural, economic) in government, academia, or private sector, starting with front-line contacts (within the government department or ministry); and**
- **list with name, content, holder, and access requirements for all *potentially relevant* data sets (e.g., biophysical, socio-cultural, economic, geospatial) to support ES analyses.**

3.2 Area-based Planning

This section illustrates how ES considerations could be integrated into regional strategic environmental assessment (R-SEA or RSEA) and land-use or spatial planning. Due to the similar processes involved in R-SEA and land-use planning, those two policy activity areas are combined in one section.

3.2-1. Regional Strategic Environmental Assessment and Land-use/Spatial Planning

Relevance of ES to R-SEA and Land-use/Spatial Planning

R-SEA is defined as "a process designed to systematically assess the potential environmental effects, including cumulative effects, or alternative strategic initiatives, policies, plans or programs for a particular region."[79] R-SEA is an interdisciplinary, participatory, and multi-scaled approach for evaluating the potential outcomes of different development and land-use planning scenarios. Land-use planning at any scale (typically provincial, regional, watershed, coastal zone, and municipal) uses policy and regulation to order land use. Planning requires spatial information about built and natural resources, natural capital, the importance and value of land-cover types, features, and human uses.

ES assessment can contribute to R-SEA and land-use planning by adding information about the connections between the natural environment, the ES it produces, and benefits people receive from those ES. ES assessment can help to identify spatial aspects of these processes and effects across a landscape,[80] as well as information on cumulative environmental effects[81] that arise from planning and development scenarios.[82] Land-use planning can better anticipate and mitigate the costs of growth when ES and the natural capital that underpins ES are considered. For example, environmental features such as riparian areas, green belts, and urban forest canopy can be maintained to improve water and air quality.

Entry Points in R-SEA and Land-use/Spatial Planning Processes for Considering ES

Similarities between R-SEA and land-use planning are compared with steps in ES assessment in *Table 3.1*.

[79] CCME 2009. R-SEA is distinguished from strategic environmental assessment (SEA) by its *regional* (i.e., place-based) focus, while SEA focuses on policies, plans, and programs. SEA is addressed in this chapter in section *3.3-2*.
[80] See *Issue 2 in Tools – Tab 2: Cross-cutting Issues and Key Considerations* for more on spatial flows of ES.
[81] See discussion of *Cumulative Effects* in *Tools – Tab 2, Issue 4*.
[82] Scenario development is a key tool in ES assessment. See *Chapter 2, Step 4* and *Tools – Tab 7: Compendium of Data Sources, Analysis Methods, and Tools* for factsheet on scenarios.

Table 3.1. *Comparison of steps among land-use planning, R-SEA, and ES assessment demonstrates strong parallels and opportunities for mainstreaming ES into most steps of those policy applications.*

Action Orientation	Land-use Planning (Typical)	R-SEA (CCME 2009)	ES Assessment (Chapter 2)
1. Defining context and objectives	1. Define the vision, goals and objectives (often a five-year horizon) for the area	1. Develop a reference framework	1. Define the issue and policy context
2. Scoping current conditions	2. Inventory / scoping current conditions of the environment, society, economy, and governance structures; identify data gaps and resource needs	2. Scope the regional baseline	2. Identify priority ES and beneficiaries for assessment
3. Identifying gaps and needs	3. Analysis / identify constraints and opportunities	(Potentially continuation of step 2 above)	3. Identify what needs to be evaluated to answer assessment questions
4. Completing detailed analyses	(Potentially continuation of step 3 above)	3. Identify regional stressors and trends	4. Identify and use indicators, data sources, and analysis methods
5. Developing scenarios and alternative options, and evaluating	4. Develop alternatives / options or scenarios, usually at least three 5. Evaluate alternatives / this may include SIA, SEA and other types of analyses	4. Identify strategic alternatives for the region 5. Assess cumulative effects of each alternative	5. Synthesize results to answer assessment questions 6. Communicate assessment outcomes
6. Selecting preferred option (normally decision-makers)	6. Select preferred option	6. Identify a preferred strategic alternative	
7. Documenting path forward as result of analysis	7. Develop official plan document and, if relevant, associated policies 8. Develop implementation and monitoring plans	7. Identify mitigation needs and management actions 8. Develop a follow-up and monitoring program	
8. Implementing decision	9. Implementation, monitoring, and evaluation	9. Implement the strategy, monitor, and evaluate	

Table 3.1 shows how the steps in ES assessment closely parallel the first five phases of both R-SEA and land-use planning. It means that ES assessment could be integrated into the existing steps of R-SEA and land-use planning. But ES assessment can also be used to inform specific phases of R-SEA and land-use planning, for example, in the following ways:

- *All phases, incrementally*: The similarities between R-SEA, land-use planning, and ES assessment illustrate how ES considerations could be mainstreamed into urban, rural, and regional land-use/spatial planning and R-SEA on a step-by-step basis. This could involve fully integrating the activities of steps in ES assessment with the corresponding activities and steps in R-SEA or planning. For example, when defining context and objectives, consider expanding the questions that are asked to include anything in *Worksheet 1* that is not already covered. Likewise, in scoping current conditions, consider expanding the questions asked to include anything in *Worksheets 2* and *3* that is not already covered, and so on.
- Especially in *Steps 1* and *2* of *Table 3.1,* ES assessment can be used for spatial targeting to configure land-use areas to meet desired management objectives, for example, water-quality improvement or flood mitigation.
- *All phases, strategically:* ES assessment *results* based on completion of a comprehensive or targeted approach (see *Chapter 2, Tables 2.1* and *2.2*) could inform any step in the existing processes for R-SEA and land-use planning. If an ES assessment were completed as an early step in the planning process, for example, to document condition and trends of ecosystems and ES, this could be a major source of supporting evidence to inform the rest of the R-SEA or planning process. ES assessment results can reveal the links between changes in land use, their causes (drivers of change), how these affect ecosystem functions, and how these changes affect the human population. All of these variables are considerations in spatial planning, but they are not often understood in terms of the causal links between them.

Examples of How ES Is Being Incorporated in Land-use/Spatial Planning

There are many opportunities for public or private land managers to efficiently secure important ES such as erosion control, flood protection, water regulation, recreation, and more, through strategic investments in natural capital as ecosystem-based "infrastructure."[83] Examples below include large-scale, regional land-use planning in Alberta and green infrastructure planning in British Columbia.

EXAMPLE:
Alberta's Regional Planning

The Government of Alberta's 2008 *Land-use Framework* policy sets out the basis for a series of regional land-use plans across the province. The policy is committed to developing a strategy for conservation and stewardship on both public and private lands, including developing or identifying practices and tools that would result in the provision and maintenance of ES. The *South Saskatchewan Regional Plan* (completed in 2014) seeks to secure ES on private lands through a variety of voluntary mechanisms and economic instruments such as conservation easements and financial incentives. For example, voluntary conservation offsets were piloted in Alberta's southeast native prairie landscape beginning in 2011. Private landowners were contracted to convert marginal cultivated lands to native perennial species to offset new industrial development activity on the native prairie. This landscape is a natural asset with important social, ecological, and economic benefits to society. It provides seasonal breeding habitats for many bird species and critical habitat for a number of species at risk (SAR) listed under Alberta's *Wildlife Act* as well as the federal *Species at Risk Act* (SARA). Alberta Agriculture and Forestry led the Southeast Alberta Conservation Offset Pilot to explore the use of offsets to help maintain these benefits.[84] The pilot started with a plan to focus on a species-specific offset, but quickly found that a broader habitat focus would avoid possible unintended conflicts when habitat creation for one species could negatively impact other species.[85]

[83] Also referred to in this Toolkit as "green infrastructure," by which natural processes in ecosystems provide benefits that function as supporting systems that humans depend on, such as water purification—whereas an engineered solution would provide built infrastructure to serve the same function. Green infrastructure in this Toolkit is thus not the same as built infrastructure that is environmentally friendly.
[84] For details of the pilot, see http://www1.agric.gov.ab.ca/$Department/deptdocs.nsf/all/sag14846.
[85] Good and Haddock 2014. This case is an example for section ***3.5*** below for its account of a *voluntary* offset design.

EXAMPLE:
Infrastructure Strategy for Gibsons, BC

At the municipal scale, ES are the basis for an "eco-asset strategy" for the Town of Gibsons, British Columbia, an initiative launched in 2015. The strategy recognizes the high cost of replacing aging built infrastructure with new technology, and reorients thinking about solutions by looking at ecosystem-based infrastructure as part of the town's asset base. They apply the same objectives to both built and green assets: managing risk, saving costs, maintaining healthy ecosystems, and managing the asset. In practice, this is expressed through actions such as investing in maintenance of water quality in the town's aquifer; conserving natural creeks and ponds and their forested environments to manage storm-water runoff; maintaining a natural seawall to protect the shoreline from storm surge and sea-level rise; and conserving forested areas for the many ES they provide. Each of these green infrastructure choices is being maintained at far lower costs than replacement built infrastructure. The strategy emerged through a shift from spending in response to problems, to employing an evidence-based approach, developing a natural asset policy, adapting its financial statements to include natural assets, adopting team-based management, developing partnerships, and taking a long-term view of planning. After completing their natural asset inventory, practices established for the aquifer were applied to other natural assets and include (1) biophysical analysis of asset condition and the ES it generates; (2) economic analysis of asset worth and substitution or replacement cost; (3) impact analysis of increased demand; (4) determination of objectives for management; (5) development of operation and maintenance plan; (6) development of financial plan; and (7) conducting ongoing assessments (monitoring and evaluation).

Additional Considerations

Including enabling language about ES can be helpful in legislation or policy/regulations intended to operationalize legislation. In most cases, the scope of spatial planning allows for considering both environmental and social factors. Enabling language that specifically calls for ES analyses, considerations or protections can support a more holistic systems approach than can sometimes be possible with more narrowly defined or overly general planning mandates.

ES can be readily implemented into municipal planning activities, especially using GIS approaches to map and analyze ES values across space and time. In addition to the suite of tools available for analyzing ES that are documented in this Toolkit, a number of tools have been designed specifically with urban/municipal planners in mind. Some simple examples include the online calculator "my tree benefits" and empirical tools such as UFORE and i-Tree that help quantify the biophysical benefits of urban trees and forests.[86]

Additional Information Sources (See *Sources Cited* for details)

Policy examples: Government of Alberta 2012; Government of Alberta 2014; Town of Gibsons 2014. A broad-based review of policy options for municipalities is provided in Molnar 2011.

Guides: CCME 2009; *The Economics of Ecosystems and Biodiversity* (TEEB) 2010; TEEB 2011

Selected peer-reviewed journal articles: Gómez-Baggethun and Barton 2013; Larondelle and Haase 2013; McKenzie et al. 2014; Kumar et al. 2013

[86] http://www.yourleaf.org/estimator; http://www.nrs.fs.fed.us/tools/ufore/; http://www.itreetools.org/

3.3 Regulatory Decision Analysis

This section illustrates how ES considerations could be integrated into existing processes for (1) environmental (impact) assessment; (2) strategic environmental assessment; and (3) regulatory and policy development/analysis. Although most other sections in this chapter also have a regulatory or policy dimension, the focus here is on generic processes for developing or implementing regulations and associated policies.

3.3-1. Environmental (Impact) Assessment

Relevance of Ecosystem Services to Environmental (Impact) Assessment

Environmental assessment (EA) or environmental impact assessment (EIA) may include social impact assessment. EA considers the potential effects of a project on ecosystems[87] often through the lens of "valued components" (VCs). These components can include human dimension components such as recreation, viewscapes, and public health and safety. Ecosystem functions and processes for many of these human dimension components (e.g., water-quality impact) are already considered in EA. Jurisdictions may vary in the extent to which EA considers socio-cultural and economic factors. Incorporating ES considerations in an EA would extend the focus to consider, *in addition*, effects on ecosystem components and processes that are valued because they provide important ES benefits to people. In many cases, these ES-providing ecosystem components and processes already qualify for consideration in EA. To consider ES, the focus remains on environmental effects but introduces criteria for what is "valued" based on how it supports human well-being. A key point is that introducing ES considerations to EA should be understood as in addition to the priority given to ecosystems in their own right, rather than a redirection of priority.

ES assessment can help proponents to more readily evaluate the effects of projects and mitigation actions. It can also highlight how projects may *depend* on ecosystems and ES, as well as aid in the identification of stakeholders and potential mitigation measures.

Increasingly, governments need to be prepared to evaluate submissions from proponents or intervenors that include ES analyses or claims about ES impacts.

EXAMPLE:
EA Intervenors in Oil Spill Impacts

For example, evidence was submitted to the Enbridge Northern Gateway Pipeline Joint Review Panel by Coastal First Nations (CFN)[88] to assess potential impacts on ES in the event of an oil tanker spill in the area. Almost half of the area assessed, defined as the Pacific North Coast Integrated Management Area (PNCIMA), has been identified as ecologically and biologically significant. The coastal area includes important fish habitat and critical habitat for marine birds, and supports 95 percent of the total breeding seabird population in British Columbia. Important habitat for 39 rare or vulnerable species that have been listed by COSEWIC also exists within the PNCIMA. The marine-dependent resources that could potentially be impacted by an oil spill in the area that were considered included commercial fishing, marine tourism, scenic viewing, and the existence value of the marine ecosystem. The combined total economic value of ES and other marine-dependent activities, calculated using the "total economic value" (TEV) approach, was estimated to be between C$28–30 billion. Using data from the Exxon Valdez oil spill, the analysts estimated damage costs from a large oil tanker spill in CFN territory to be in the range of C$5.2–22.7 billion.

Entry Points in EA Processes for Considering ES

The earlier in the process that ES considerations are explicitly factored into any given EA, the more opportunity there will be to develop a common understanding of the scope of the assessment and the effects of the proposal. Possible entry points at different phases in existing EA procedures include:

- *Project design phase:* If a project proponent proactively undertakes ES assessment prior to seeking government approval, the results could be used in project design to minimize detrimental effects to the ecosystem structures and processes that underpin the ES flows, and to identify the benefits of ES to the proponent. The International Finance Corporation of the World Bank announced in 2012

[87] This is the first step in ES production—see *Conceptual and Analytic Framework* in *Chapter 1*.
[88] For details, see Gunton and Broadbent, 2012.

that all new funding they provide will be contingent on meeting performance standards that include assessing risks and impacts to ES.[89] The World Business Council for Sustainable Development and the World Resources Institute (WRI) have developed guidance for business in this regard.[90]

- *Environmental impact statement (EIS) preparation phase:* Proponents could be encouraged, or even required, to directly consider ES in their project documentation for submission to government. This could include scoping at the earliest stage of the process for possible effects on key ES-producing VCs. It could also include gathering baseline information on ES and anticipated changes to ES incurred by the project. ES assessment could be required by the responsible government as an element in a proponent's completion of an EIS. Guidelines for how to complete ES assessment could be included in these specifications to clarify requirements for reliability. This could be a standard practice for all EA, or used only when a human population is likely to be affected by the loss of ES as a result of the environmental change linked to the project. The ES assessment could identify project benefits from ES, project impacts to ES (and beneficiaries) and how to mitigate impacts and manage dependencies on priority ES.
- *Government review phase:* ES analyses—if not full ES assessments—are increasingly becoming part of the evidence prepared by intervenors and proponents (either initially or in response to intervenors). In this phase, the responsible government may opt to complete an ES assessment (whether strategically limited in scope as noted at the beginning of this chapter, or in whole, depending on the seriousness of assessed risk) to inform in its evaluation of the proponent's EIS. Governments may also find that undertaking independent ES assessments are a practical, valuable tool to identify *cumulative* effects of environmental change.[91]
- *Decision/mitigation phase:* Analyses generated by ES assessment could be used to inform mitigation strategies, identifying all the important aspects of ecosystems that communities depend on, to ensure that mitigation actions are realistic and comprehensive.
- *Decision/compensation phase:* Analyses generated by ES assessment could be used to inform compensation strategies (i.e., for the project proponent to compensate either the government or property owners) when full mitigation is not possible but a project is deemed sufficiently important to proceed (see sections on Enforcement and Offsets below for a discussion of this). This could, for example, include monetary compensation or offsets for biodiversity, habitat or ES (see section *3.5* for more about ES offsets).

Other Considerations

The nature of ES can pose challenges when determining suitable boundaries for the ES assessment that align with those used for the EA.[92] The specific legislation and policies under which an EA is conducted will influence the nature and range of effects that may be considered in the process. Even if ES is not explicitly referenced in jurisdictions' existing frameworks and policies pertaining to EA, most Canadian jurisdictions would allow for consideration of effects on ES. In any of the phases identified in the "entry points" section above, views of Indigenous communities and other ES beneficiaries and stakeholders will be beneficial.[93]

Additional Information Sources (See *Sources Cited* for details)

Guides: Landsberg et al. 2013; Landsberg et al. 2014; Slootweg et al. 2006; Climate, Community & Biodiversity Alliance 2011

Selected peer-reviewed journal articles: Baker et al. 2013; Karjalainen et al. 2013; Rosa and Sánchez 2015; Satz et al. 2013

[89] International Finance Corporation 2012; Rosa and Sánchez 2015 evaluate implementation in five cases.
[90] Hanson et al. 2012; Landsberg et al. 2013; and Landsberg et al. 2014. There are also increasing numbers of academic expert publications that identify key considerations reflecting ES in EA.
[91] See *Issue 4* in *Tools – Tab 2: Cross-cutting Issues and Key Considerations* for discussion of cumulative effects and ES.
[92] See *Issues 1* and *2 in Tools – Tab 2* for more on scale and spatial flows of ES.
[93] See *Tools – Tab 3: ES Assessment Involving Indigenous Communities*, and on stakeholder engagement see *Chapter 2*.

3.3-2. Strategic Environmental Assessment

Relevance of ES to Strategic Environmental Assessment

Strategic environmental assessment (SEA) is a systematic, iterative tool that aims to identify and consider the potential environmental impacts of policy, plan, and program (PPP) proposals.[94] SEA is considered a form of risk assessment. It is intended to identify possible policy options and alternative scenarios that may minimize environmental impact and support achievement of sustainability objectives. A goal of SEA is to ensure that decision-makers are aware of the full range of potential consequences and opportunities associated with each option. SEA can range from informal but prudent analysis to highly detailed formal evaluation and reporting.

In Canada, federal departments and agencies are required to conduct SEA for initiatives destined for Minister or Cabinet decision when circumstances warrant, as specified in the *Cabinet Directive on the Environmental Assessment of Policy, Plan and Program Proposals*.[95] Provincial and territorial governments vary in their adoption of SEA through existing environmental legislation, at the level of strategic decision-making, or informally.

Because the subjects of SEA analyses are not necessarily specific to a particular area (aside from the jurisdiction's political boundary), and ES *are* inherently place-based, it may initially be difficult to identify how ES assessment or its component analyses can enhance or inform SEA. Extending the scope of analysis within the existing SEA framework can reveal ES dependencies and potential impacts. Many PPP have direct or indirect connections with ES, for example:

- trade agreements, such as for softwood lumber agreements in British Columbia, may impact the management of the forestry sector which is directly dependent on ES and has a direct impact on forest-based (or forest-mediated) ES; and
- pesticide regulation/deregulation may directly impact agricultural and surrounding ecosystems, pollinators, and waterways with a direct impact on the associated ES.

If the PPP depends on or impacts, either directly or indirectly, any of the following, consideration of ES is likely relevant to the SEA (note, this list highlights examples, but is far from comprehensive):

- agricultural lands
- freshwater or marine ecosystems
- fish and other wild-harvested biological resources
- forests
- water supply
- important wildlife habitat (e.g., habitat for SAR)
- significant cultural landscapes (e.g., spiritually important areas, scenic views)
- outdoor recreation and tourism

Entry Points in the SEA Process for Considering ES

Ideally, ES will be considered at the outset to ensure that decision-makers are fully aware of the broader environmental and social consequences of decisions. ES assessment or ES considerations can be useful in several phases of SEA. The phases shown here are based on the federal approach and may vary among different jurisdictions:

- *Preliminary scan phase:* The SEA process typically begins with a preliminary scan to identify any potential important environmental effects of a PPP to determine if a full SEA is required. Any potentially affected ES should be identified in the scan. This preliminary exercise is a critical entry point for integrating ES considerations into the full SEA. Identifying priority ES and ES beneficiaries and considering whether these may be affected by the PPP can be done using *Worksheets 2* and *3* in this Toolkit.
- *Full SEA:* This phase builds on the information gathered in the preliminary scan and is a deeper analysis of the potential direct and indirect outcomes of the proposed changes and how the environment will likely benefit from a deeper consideration of ES. Analyses generated by ES assessments can support comparison of options with respect to, for example, whether the expected outcomes of the option are vulnerable to changes in ES; whether measures are in place to manage the risks to ES associated with the option; whether the option is likely to result in activities that may increase the degree of risk to ES; and whether the options can enhance ES. The Organisation for Economic Co-operation and Development (OECD) and the United Nations Environment Program (UNEP) have published guidance on integrating ES into SEA (see *References* below).

[94] This segment focuses on SEA as distinct from R-SEA, which is discussed above in *3.2-2*.
[95] http://www.ceaa-acee.gc.ca/default.asp?lang=En&n=B3186435-1

- *Consideration of public and stakeholder concerns:* At all phases of a SEA, analyses generated by ES assessments can be key to understanding and articulating public and stakeholder concerns about possible changes to ecosystems and about possible changes to the ways people depend on or benefit from those ecosystems. Some SEA processes include a requirement to publish a public statement of environmental effects. If ES considerations were included in the SEA analyses, they could be reflected in the public statement.
- *Follow-up phase:* The SEA could include a recommendation to monitor the effects of the PPP on ES if impacts, whether positive or negative, are anticipated as a result of the recommended option. This is likely to be most effective if a system-health perspective is adopted rather than focusing only on individual components of the system.

EXAMPLE:
ES in SEA for Rural Programs

A mid-term SEA of a rural development program in Italy explored the relationship between the program's on-farm measures (through planned agri-environment schemes, or AES) and ES. Measures in the SEA case study included application of integrated production techniques, organic farming techniques, increase in organic matter in soils, and extension of pasture systems. Program officers responsible for implementing the program measures first completed desktop assessments and then participated in semi-structured interviews. The assessment identified the ES targeted by each measure and established a common understanding of the positive and negative impacts of each measure on associated ES. The aim was to support and improve program implementation. This includes innovations in data collection to assess changes in ES resulting from program implementation. Among the case study conclusions were that (1) program measures to increase the value of agricultural products, such as financing to purchase lower emission machinery, had a positive impact on air-quality regulation; (2) financing to build new agricultural structures had a negative impact on water regulation by increasing the extent of impervious surfaces; and (3) measures to increase integrated and organic farming had positive impacts on all identified ES. The integration of ES into the SEA helped program managers evaluate the program's effectiveness and adapt its implementation to improve results. Further, it highlighted opportunities to improve managers' ability to measure changes to ES to support future program renewal.[96]

Additional Information Sources (See *Sources Cited* for details)

Guides: OECD 2010a; UNEP 2014 explains how to integrate ES into SEA.

3.3-3. Regulatory and Policy Development

Relevance of Ecosystem Services to Regulatory and Policy Development

All Canadian jurisdictions require some type of analysis to inform development of policy and regulations and, typically, to inform their implementation. Policy and regulations directly *affecting* the environment—biodiversity, species, and ecosystems (or parts of ecosystems)—are the most obvious targets for ES assessment (in full or in part, as per *Chapter 2*). These may not always appear to be about the environment, for example, when their focus is grey infrastructure, urban development or human health. In some jurisdictions, environment-based analyses are based wholly on biophysical scientific evidence. In others, the biophysical evidence may be accompanied by social and economic analyses. ES assessment or its component analyses do not replace strictly biophysical or social impact analyses. They can, however, add to policy and regulatory analysis by revealing the dynamics of dependence, benefit, and impact between the biophysical and social considerations.[97]

96 Rega and Spaziante 2013.
97 *Step 5* in *Chapter 2* outlines different types of decision-support approaches that can be used to integrate ES information.

Entry Points in Regulatory and Policy Development Processes for Considering ES

- *Monitoring (continuous)*: Ongoing monitoring of the environment can include observations oriented to how ecosystems—and thus the ES they produce—are being affected by human activities. It can identify undesirable changes to ecosystem structures and processes that underpin ES. This can prompt a policy or regulatory response. It can provide justification for collecting baseline or trends data about environmental conditions and drivers of change to the environment. Conditions and drivers of change are directly tied to the extent and quality of ES flows to society and their significance to people. If an issue of concern is identified for possible management action within a jurisdiction's existing scope of authority, an ES "lens" may be applied if suitable enabling language exists in the relevant authorities. A preliminary desk-based completion of *Worksheets 1, 2* and *3* could be highly informative for next steps.
- *Issue analysis and instrument choice*: This phase includes further analysis of the issue, stakeholder, and technology considerations, and cost-benefit or cost-effectiveness analysis of various policy options as well as possible funding requirements to support implementation. Consideration of ES within each of these analyses would inform and strengthen the policy approaches being developed, and the instruments chosen, by demonstrating the connections between the environment, economy, and society as interrelated parts of one system. Stakeholder analysis and engagement (collecting their views) in regulatory development is an established opportunity to solicit information specifically about stakeholders' need for, use of, appreciation for, or values about ES. *Chapter 2* explains how valuable expert stakeholders can be in providing relevant information about environmental conditions and change, especially in cases where published data are not readily available for the subject area. Inclusion of ES-enabling language in policy can inform the scope of a regulation and how the regulation is interpreted.
- *Policy and regulatory design phase*: In the drafting of regulatory proposals, common elements often include a "triage" or preliminary assessment of all possible impacts of the regulation to the environment, stakeholders, and society in *general* terms (such as low/medium/high); a cost-benefit or cost-effectiveness analysis of some type; and an overarching regulatory impact analysis. Provided that enabling language is present in the authorities governing policy and regulation development, ES considerations can be included among the conventional aspects of these analyses as relevant and appropriate.

TIP: Enabling language in legislation, regulations or policies might refer to "nature's benefits to society," "natural capital," "use values and non-use values," "ecosystem services," "public interest" or "human well-being." Each of these can be addressed, at least in part, by ES assessment.

- *Compliance promotion and enforcement phase*: Consideration is normally given to regulatory compliance mechanisms in regulatory design. Compliance promotion and enforcement are focused on ensuring that what is written in regulations is complied with. Some or all aspects[98] of ES can be further considered *if* enabling language exists within regulations. Relevant aspects of ES—and impacts to them—could then be among the criteria guiding compliance inspections. They could also be part of the investigations to develop evidence of full extent of impacts from non-compliance. Further, ES-based evidence could be used when assessing penalties (see section *3.5* for details). In addition, some regulatees may be more responsive to compliance promotion materials knowing the potential ES impacts of non-compliance and that ES considerations would factor into penalties. For practical purposes, the compliance phase is detailed in the next segment of this chapter regarding environmental damages assessment.

[98] See the centre bar in the *Conceptual and Analytical Framework* diagram in *Chapter 1* for the five stages in the ES "cascade": ecosystem processes and structures produce ecosystem functions, resulting ES, which have benefits of ES to people, that are important to people.

EXAMPLE:
Federal RIAS Under Federal SARA

The Government of Canada requires that all new federal regulatory proposals be supported by a regulatory impact analysis statement (RIAS). Federal guidelines for completing a RIAS include, among other things, the requirement for a cost-benefit analysis (CBA). Initial federal efforts to include ES in RIAS have been primarily within the CBA component. In December 2014, Environment and Climate Change Canada developed a regulatory proposal to list three bat species under the federal SARA. The RIAS contained a summary of the biological and human-caused factors leading to the proposal for the listing and, in the required CBA, included a descriptive account of the bats' role in providing the regulating ES of "natural pest control" for both the agriculture and forestry sectors and in residential contexts, as well as its contribution to the cultural ES of recreation and tourism and the supporting ES of nutrient cycling and soil fertility. These were categorized in terms of the TEV framework in the CBA. This example illustrates that decision-making requires a multidisciplinary approach that connects ecosystem functions, how those functions generate the services to produce benefits, and how those benefits are distributed to society. The decision-makers can then use this information to make their decision.[99]

Other Considerations

A mainstreaming approach involves developing the standard practice of evaluating every regulatory instrument by asking whether there are likely to be changes to biodiversity, ecosystems, and ES as a result of implementing that instrument. This may be supported through creation of a policy document to advise more specifically how to incorporate ES into policy and regulatory development.

ES analyses may indirectly occur pursuant to existing policies and legislation. In developing new policies and legislation, consideration could be given to incorporating *enabling* language that explicitly encourages or supports the use of ES analyses and evidence. In some cases, there may be a decision to *require* ES analyses and evidence, as in the 2015 US Presidential Directive described at the start of this chapter.

Full ES assessment can be resource-intensive, but tools and approaches for "rapid" and targeted ES analyses are becoming more accessible. These efforts are particularly in recognition of the constraints on governments and their officials for the completion of regulatory actions that often have very tight timelines. Jurisdictions could facilitate their ability to integrate ES considerations in various policy-related activities by preparing a "ready access resource kit"[100] (see *Tip Box* in the *Introduction* to this chapter for suggested contents of the kit). Having an informal ES strategy or a formal policy in advance can help expedite the integration of ES considerations in policy activities.

Even a desk-based completion of *Worksheets 2* and *3* can provide significantly focused information about ES to inform a process. If the results from the two worksheets point to serious risk of an important ES loss, a more complete ES assessment should be given strong consideration (see *Chapter 2* and associated worksheets for this activity).

3.4 Environmental Damages Assessment

This section illustrates how ES considerations could be integrated into government processes for assessing environmental damages in both regulatory and civil cases.

Relevance of ES to Environmental Damages Assessment

Many governments have laws protecting the environment against damages, for example, those caused by unauthorized pollution events. When an event is identified and confirmed, governments may undertake an assessment of the resulting damages to the environment and to human well-being. Understanding the connections between ecosystem components that produce flows of ES can provide a foundation for defining the *scope* of environmental damages and resulting penalties in the contexts of both regulatory enforcement and civil claims.

[99] http://canadagazette.gc.ca/rp-pr/p2/2014/2014-12-17/html/sor-dors274-eng.php

[100] Much of the ES assessment relies on analysis of the biophysical environment (natural capital) as a proxy for ES, and what makes it possible to interpret the effects on ES is the approach to analysis taken—see *Chapter 2* and the list of Indicators in *Tools – Tab 5: Indicators of Natural Capital, Ecosystem Services, and Benefits* for more on this. Knowing in advance what kind of data can be used to analyze ES, where existing data are housed, and how to access them will support timely and relevant analysis.

Entry Points in Environmental Damages Assessment Processes for Considering ES

Baseline data on environmental conditions are important in both regulatory and civil cases of environmental damages, and are essential to enabling analysis of damages to ES as well. Baseline data provide a frame of reference, help to specify risk, and are essential to proving the extent and severity of damages to inform penalties.[101]

Regulatory. Enforcement of environmental regulations flows logically from the regulatory development process, beginning with compliance and promotion. Non-compliance with regulations can cause damages to ecosystems (including biodiversity and wildlife) and the ES that they provide or support. Although the specific procedures may vary across jurisdictions, there are generic aspects that apply to most or all, and ES considerations are relevant in each phase.

- *Planning and priority setting*: This includes deciding where to conduct compliance verification activities, with analysis of the likelihood of non-compliance and risks to environmental protection and to conservation due to non-compliance. Considering potential damages in terms of risks associated with damages to ES can help to clarify the biophysical extent and nature of damages from an ecosystem process perspective and from the perspective of impacts to society from loss of ES. This involves intelligence gathering and inspections. Intelligence gathered to target enforcement activities and evidence gathered during compliance verification inspections can be used to support the assessment of damages to ES. The ES focus in an inspection could be informed by awareness of the ES most likely being produced in an area combined with awareness of the character of potential impacts to the ecosystem structures and functions that produce those ES. If planning can identify areas with high risk of ES damage, efforts for baseline data collection could be focused on those areas. Inspections are also an opportunity to promote awareness of regulations and ES.[102]
- *Post-incident evidence gathering*: Inspections are conducted to verify compliance with regulations. If there are reasonable grounds to believe non-compliance has occurred, an investigation is launched. If non-compliance is proven and there is a need to demonstrate the severity of damages, it will be important for enforcement officers to be aware of what information should be collected and what aspects related to non-compliance should be documented. Impacts to ecosystems may impact ES. The worksheets in this Toolkit (especially *Worksheets 1, 2, 3,* and *5*) may provide a helpful framework during an investigation to assess impacts on ES.
- *Sentencing and penalties*: Quantification or characterization of damages is essential in this step and is a key entry point for ES evidence. Evidence about the ES produced and their importance and values, as well as the extent to which they are degraded by the non-compliant action, must all be analytically specific and robust. In such cases, a scientifically thorough ES assessment could be advisable, considering completion of *Worksheets 1* through *9* inclusively, and supported by the guidance in *Chapter 2*. A key to sentencing is the determination, potentially through stated preference and revealed preference approaches to valuation of use and non-use values, of interim losses to society due to the damage.[103] ES values may inform the amount of a fine, and can be contributing criteria for determining any additional penalties to be paid into special programs such as the Federal Environmental Damages Fund. ES assessment can also be very useful when penalties include physical remediation and restoration of damaged ecosystems, by helping to identify the particular ecosystem structures and processes that produce ES and the pathways of those ES flows. In cases where remediation is not possible, offsets based on ES may be considered (see section *3.5* for discussion of offsets).

Civil. As recognized by the Supreme Court of Canada, governments in Canada are legally able to bring civil claims for environmental damages on behalf of the public. Specifically, the Court has recognized that loss of "use values and non-use values" (as characterized in economic analysis) of the environment could be used to assess a claim.[104] This enabling language sets the precedent for considering, at least, economic measures associated with ES in these situations.

[101] See *Chapter 2, Step 4*, for advice on analyzing ES conditions and trends.
[102] See *Compliance Promotion* in previous section.
[103] Interim losses are those that accrue to society from the time the damage occurs to the time that the ES are remediated or replaced, if possible. Certain losses may be incurred for very long time periods, or in perpetuity (for example, with irreplaceable natural assets), which should be reflected in the cost analysis.
[104] In British Columbia v. Canadian Forest Products Ltd. S.C.R. 274, 2004 S.C.C. 38, 2004 the Courts recognized TEV as a suitable framework for economic analysis. See *Tools – Tab 6: Values and Valuation: Economic and Socio-cultural* for explanation of use values, non-use values, and TEV.

A comprehensive, robust damage assessment would be required to support a government civil claim following a significant pollution event. In those situations, a reliable description of the ecosystem structures and functions that have been impacted, the ES they are believed to produce, and the benefits and significance of those ES to people, in qualitative and quantitative format, can all support the damage assessment.

Other Considerations

Considering the environment from an ecosystem perspective helps to reveal site and downstream effects, and an ES perspective can help to identify which jurisdictions and stakeholders should be included.

ES assessment could be used to estimate the value of ES loss or reduction due to the damage incurred. This would ideally include economic, socio-cultural, and biophysical values in their relevant formats. A full accounting of these values could inform possible sentencing/ compensation options and site restoration options.

In the US, the BP Deepwater Horizon oil spill damage assessment explicitly included ES (see *Additional Sources* below). Canadian courts have, in a few cases, recognized that wild species and ecosystems have important value to society beyond any established markets, that sometimes these values can be estimated in monetary terms and other times they cannot,[105] and that both market and non-market values are relevant.

To expedite economic estimation of environmental damages for setting fines, some authors recommend using pre-set damage schedules or tables of generic values often derived from replacement costs. Replacement costs are not necessarily indicative of environmental damages. Due to these limitations inherent in replacement cost approaches, a number of researchers suggest developing schedules using paired comparison and ranking surveys that focus on preference.[106] Schedules can make it possible to consider ES values when there is no time for more direct ES assessment or primary economic valuation, and can be made to be very conservative and confidently within acceptable levels. However, such an approach may not always be less time-intensive than a benefit transfer exercise, which could be a more direct reflection of actual economic values. Pre-set schedules are unable to account for the specific conditions in each case at each location, so considerations for their use should include whether their generalized measures would likely introduce or increase a risk of unintended negative effects on the case, human well-being, and the environment. Schedules may be best suited to informing decisions on replacement- or restoration-related fines, and less so for determination of interim losses.

To the extent that it is possible, ongoing collection/ accumulation and management of baseline data can be highly valuable for possible use in prosecution or civil claims should a pollution event occur. The data could focus on the condition and trends of known ecologically sensitive areas, and areas of high ES production and flow.[107] Without baseline data, it is difficult to assess the extent of incident-caused ES degradation.

Additional Information Sources (See *Sources Cited* for details)

Committee on the Effects of the *Deepwater Horizon* Mississippi Canyon-252 Oil Spill on Ecosystem Services in the Gulf of Mexico 2013; Olszynski 2012 provides a review and interpretation of case law recognizing ES in North America.

3.5 Environmental Management

Environmental management could, in its broadest sense, be understood to encompass all sections in this chapter. For present purposes, however, in this section we focus specifically on the following three subjects: (1) establishing and managing protected areas; (2) managing species and ecosystems; and (3) managing invasive alien species.

3.5-1. Establishing and Managing Protected Areas

Relevance of ES to Establishing and Managing Protected Areas

Different types of protected areas may have different policy and program objectives, including nature conservation or restoration, conservation of a specific species, conservation of a specific or representative ecosystem, public recreation, public education, or a combination of these. Assessing the ES provided from a proposed (or established) protected area can help determine the extent to which the site's objectives are likely to be met, and describe or even quantify the ES most closely linked to supporting those objectives. An ES assessment can also identify additional or ancillary benefits or costs that may accrue beyond the primary purpose of establishing the site. Considering ES in each step of the decision-making involved in selecting,

[105] Justice Robinson in 2005 SKPC84, 272 Sask R 13 [*Carrière*].
[106] Quah et al. 2006 explain benefits of using damage schedules and methods for using paired comparison ranking as the basis for schedules, which they claim are more reliable and less costly and time consuming than other methods.
[107] See *Tools – Tab 2: Cross-cutting Issues and Key Considerations, Issue 2,* on ES flows.

establishing, and even managing protected areas can help ensure the optimal site and type of protected area are chosen, and maximize the ongoing or long-term benefits that result. ES assessment may also be a trigger for consideration of formal protection of an area by identifying extremely high-value or irreplaceable ES.

The ES associated with protected areas are generally well known, and can include a wide variety of provisioning, regulating, cultural, and supporting services. Including ES assessment in the process of establishing new protected areas can focus attention on the benefits of protected areas to local residents as well as to other stakeholders at larger scales who may benefit as visitors to the protected area or in more indirect ways. Having a better understanding of the ES associated with a given area and the tools to articulate these clearly can be invaluable in securing public and political support for protected area establishment. It can also help to ensure that protected areas are designed and managed to maintain high-priority ES and that the values of local communities are reflected. For example, the Gwaii Haanas National Park Reserve, National Marine Conservation Area Reserve, and Haida Heritage Site were designed, established, and co-operatively managed to preserve the irreplaceable ES that have provided a source of sustenance and cultural connection with the land and sea for generations of Haida communities living there.

Entry Points in Protected Areas Processes for Considering ES

- *Selection of candidate sites:* As part of protected area network planning, the selection of candidate sites typically includes consideration of at least some ES, even if they are not described using the "ES" terminology. The *National Framework for Canada's Network of Marine Protected Areas*[108] explicitly identifies ES in the second of three overarching network goals: *To support the conservation and management of Canada's living marine resources and their habitats, and the socio-economic values and ES they provide.*
- *Design phase:*
  - *Delineating boundaries:* ES assessment results can help identify which ecosystem components and specific geographic areas provide essential or highly valued ES benefits, and their interdependencies (e.g., headwaters or wetlands that are crucial to freshwater provision, water purification or recreational use of a lake). Boundaries might, therefore, include the "point of use" as well as the area of ecological activity that supports the ongoing viability of that use.
  - *Determining allowable on-site activities and conservation measures:* Some activities will enhance ES while others may reduce them. Trade-offs may be necessary between desired but competing activities, for example, recreational trails will increase accessibility but may decrease wildlife habitat quality. An ES assessment can help clearly identify the range of values and beneficiaries and confirm the extent to which various uses are, or are not, compatible with the objectives. Describing and understanding different interests can also reveal options and make it easier to avoid or resolve conflicts.
- *Designation phase (including socio-economic and cost-benefit analysis):* Monetary valuation of ES is typically part of the cost-benefit analysis associated with protected areas establishment. These analyses normally generate very conservative estimates of value due to primary data shortage; challenges of capturing the full breadth of ES in any analysis (this applies to all methods); and incompatibility of some (particularly cultural) ES with monetization. A multi-criteria approach that incorporates quantitative, monetary, and qualitative analyses can produce a more complete understanding of the broad range of services provided and their associated values.
- *Management phase:*
  - *Developing site management plans:* If priority ES have been identified, described, and mapped during the design phase, the site management plan can specify measures to maintain these. Cultural ES are especially relevant in protected areas with public access or where encouraging visitation is a principal objective. Including the preservation of ES as an objective of the management plan and developing ecosystem management actions to deliver the objective helps reinforce the link between ecological integrity and human benefits.
  - *Promoting awareness of existing protected areas:* Communicating the ES of the site helps build public awareness of the overall values of a protected area. This can be particularly useful in establishing or maintaining support for protected areas where public access or recreational opportunities (i.e., more tangible benefits) are limited.

Several governments and non-government organizations in Canada have undertaken different types of analyses focused on aspects of ES in support of habitat conservation as well as protected area designation and planning. Three examples are given here to illustrate some possible approaches.[109]

[108] Government of Canada 2011a.
[109] Including organizations such as Pembina Institute, IISD, Ducks Unlimited Canada, David Suzuki Foundation, and the Nature Conservancy of Canada. See *Tools – Tab 10: Canadian ES Assessments and Analyses Reference List.*

EXAMPLE:
Kwets'ootł'àà Candidate Protected Area ES Assessment

The Pembina Institute completed an ES assessment in 2013 on the Kwets'ootł'àà Candidate Protected Area in the Northwest Territories (NWT). The team first developed an ecological profile using information from ecological and natural resources assessments completed for the study area in combination with studies of similar ecological areas. Their profile used the MA/TEEB ES typology to identify more than 20 ES and 16 associated benefits derived from the four main ecosystems present.[110] Drawing on a wide variety of information sources, the team characterized the benefits from provisioning services (using information on the use of country foods from the NWT Bureau of Statistics); the importance of habitat or supporting services (e.g., for wildlife harvested by local people); the importance of regulating services such as carbon sequestration (information on the disproportionate rate of warming in the NWT and the impacts experienced by northern residents); and the irreplaceable cultural services specific to the area, including spiritual connections to the ancestral land and educational services for community youth provided by a healthy landscape (information on the cultural benefits of ES was accessed in a meeting with Tłįchô elders who use the area).

The project used the TEV framework[111] to define use and non-use values and then estimated monetary values for a subset of ES for which qualitative and quantitative data were available. The team made note of important attributes of the study area that could not be quantified, such as cultural values, and identified these as data gaps limiting the valuation exercise. Local valuation data were prioritized where available, but for many ES the benefit transfer method[112] was used. Transferred values were applied by both ecosystem type and ES using the *Environmental Valuation Reference Inventory* (EVRI) as well as literature reviews and other ES valuation database searches. For ES that could be assigned a monetary value, the team estimated a total average annual value for the study area of C$(2011) 35.5 million. A sensitivity analysis identified the possible range of values that could be assigned to each of the ES under different assumptions. The lower and upper ends of the range are useful as an indication of the level of certainty attributed to each of the value estimates, and also help determine the overall range when describing the total estimated values. The range for the total estimated average annual value was between C$(2011)25 million and C$(2011)47 million.

[110] See *Tools – Tab 1: Ecosystem Service Descriptions* for the ES typology used in this Toolkit, which is based on combining the MA and TEEB typologies.
[111] See *Tools – Tab 6: Values and Valuation: Economic and Socio-cultural* for description of the TEV framework.
[112] See *Tools – Tab 7: Compendium of Data Sources, Analysis Methods, and Tools* for a factsheet describing benefits transfer method.

EXAMPLE:
Off-site Benefits of Protected Areas (Ontario)

In 2013, Ontario's Ministry of Natural Resources and Forestry (MNRF) undertook a study to assess and map the benefits associated with protected areas.[113] It was noted that while Ontario's provincial parks system provide a wide range of services, quantifying these remains challenging, in particular because the beneficiaries of ES are often "off-site" and mapping the flow of benefits has been difficult. The project tested two approaches to quantifying, assessing, mapping, and valuing ES in and around several provincial parks in three defined study areas. It illustrates some of the ES that can be evaluated, examples of methods that can be used, and products that can be developed in these cases to help support planning and decision-making. The first approach used ARtificial Intelligence for Ecosystem Services (ARIES)[114] to map and model the spatial connection between ecosystems and beneficiaries for recreation and carbon sequestration associated with Algonquin Park and sediment transport, and water provision associated with the Lake of the Woods region. The Algonquin Park study produced maps identifying locations of, and barriers to, scenic views, among other outputs. The carbon analysis estimated a total sequestration value for Algonquin Park of 1.3 million tons of CO_2 per year and identified sequestration hotspots. The water supply analysis for Lake of the Woods mapped the supply and flow of surface water and, in combination with value transfer estimates, produced an estimated water supply value of C$845,000. The ARIES approach also produced a series of maps that can help managers understand the sources, sinks, flows, and beneficiaries of ES. The second approach used value transfer (also known as benefit transfer) to estimate the economic value of ES benefits in the target area by comparing it with known estimates from other areas with similar land cover. The second approach was applied to a large region on the north shore of Lake Huron, and resulted in detailed land-cover typology with 18 classes which were assigned value estimates. The resulting value estimate of benefits for the *study area* was C$9.3 billion per year. The ES benefits generated from the *parks in the area* were estimated to be worth C$1.1 billion per year.

MNRF found the exercise of ES assessment to be useful in improving the understanding of how provincial parks contribute to human well-being and in providing valuable information to support protected area management decisions. MNRF noted that the value transfer approach they used was a simplified "back of the envelope" approach, but concluded that spatial-modelling tools such as ARIES, while requiring considerable time and expertise to develop, are highly valuable and flexible management tools that offer a much richer understanding of the sources, sinks, and flows of ES to distinct beneficiary groups.

[113] Voigt et al. 2013.
[114] See *Tools – Tab 7* for a factsheet describing ARIES.

EXAMPLE:
Rouge National Urban Park

An ES assessment was completed by the David Suzuki Foundation in 2012 which focused on a study area centred around Rouge National Urban Park.[115] Using a combination of land-cover data (SOLRIS 2000–2002), local information where available, and benefit transfer, the study provided an inventory of natural capital and identified ES for each land-cover type. It generated estimates of non-market and market values for 14 ES, including, among others, stored carbon, drinking water, waste treatment, pollination, biological control, and recreation. The study used the ES typology and valuation methodology established by TEEB. Maps of natural capital values provided a visual model to complement the report findings. Valuation results provide a useful starting point for developing a deeper understanding of the benefits provided by this region; however, the authors acknowledge several limitations including the inability to monetize many ES benefits, uncertainties in values determined through the benefit transfer approach, and the inability to reflect the changes in values over time, concluding that the valuation provided is a conservative estimate. The economic value analysis determined that the Rouge Park area and surrounding watersheds provided an estimated C$115.6 million in non-market benefits to residents in the Greater Toronto Area. On a per hectare basis, wetlands provided the greatest value. The ES that contributed most to the area's natural capital assets were stored pollination services, carbon storage, and wetland habitat provision.

Other Considerations

MNRF noted in their assessment of ES and the flow of benefits in provincial parks that "remote parks characterized by small visitation and long distance to human communities do pose a significant challenge for application of the ecosystem services framework, largely because their weak connectivity to humans makes their contribution to human well-being extremely difficult to quantify, except in the case of globally-realized services like carbon sequestration. While society highly values these parks, it is often in ways that defy quantification."[116] In these situations, the "use values" could be low (see *Tools – Tab 6: Values and Valuation: Economic and Socio-cultural,* section *T6.2-4,* for explanation of use values and non-use values), but non-use values may be extremely high precisely because the areas are remote and more likely to contain pristine, iconic or undisturbed ecosystems and species. In these cases, however, approaches that focus primarily on biophysical science will be essential, while ES approaches can add an important dimension. Decision-makers are likely to benefit from understanding both the ES values and the ecological processes and functions being targeted for protection.

Because protected areas serve multiple functions, including ecological conservation and connecting humans to nature, the values attributed to them tend to be diverse. These range from critical ecosystem functions and processes that ensure clean drinking water, to recreational opportunities for local and distant visitors, to psychological and spiritual experiences.

A study of public perceptions found that visitors to Pinery Provincial Park in Southern Ontario and Gatineau Park in the National Capital Region rated social, psychological, and physical benefits of the parks as most important, and benefits to the local economy as least important to them personally, when chosen from a list of 10 possible types of benefits.[117]

Additional Information Sources (See *Sources Cited* for details)

Kettunen and ten Brink 2013.

3.5-2. Managing Species (Wildlife) and Ecosystems

There are many different policy-related areas of activity that involve managing species and ecosystems. This chapter does not attempt to address them all. This section provides illustrative suggestions for how ES considerations could be incorporated in some of the processes associated with the following: wildlife and ecosystems management; SAR; ecosystem restoration and rehabilitation; and natural hazard risk assessment.

Relevance of ES to Managing Species and Ecosystems

In combination with analyses focused on biological resilience, ES considerations can be useful in a wide range of policy-relevant activities associated with managing wildlife species and ecosystems. These include (but are not limited to) decisions about species for which hunting or fishing will be allowed; numbers

[115] Wilson 2012.
[116] Voigt et al. 2013, p.3
[117] Lemieux et al. 2012.

of hunting licenses to issue for different species in different areas; identifying actions in SAR recovery planning; and addressing human-wildlife conflicts.

A *species* is not an ES but may *provide* one or more ES that provide benefits to people (e.g., pest control, pollination, food, medicines, viewing, recreation, ecotourism). For example, game species are important for the "provisioning" ES of "food," and (for some people) game species are also important to multiple "cultural" types of ES, including spirituality, cultural identity, and knowledge (e.g., Indigenous traditional knowledge). Many people attach importance to just knowing that a particular species exists, even if they never personally see it or have direct benefit from it.[118]

Wildlife species depend on ecosystems for habitat and also are essential in creating and modifying ecosystems. As a result of these ties between species and the ecosystems they inhabit, ES considerations focused on species will have implications for ecosystems and vice versa.

ES assessment or its component analyses can demonstrate how managing ecosystems as viable wildlife habitat can simultaneously provide many important benefits to humans. It can help to clarify the biophysical basis for how ES from species and ecosystems are produced and sustained, and the spatial pathways through which the benefits they provide are accessed. ES assessment can also clarify how people are benefiting, who is benefiting and who is not, and how human activity is affecting the availability of these benefits. Finally, ES assessment can evaluate these benefits in descriptive, ranked or monetary terms through socio-cultural and monetary valuation methods. All of these types of information can help wildlife managers to identify what and where management actions should be taken to maintain healthy wildlife habitats and functioning ecosystems while reducing or avoiding ES loss, whom to engage and why, and to prioritize and justify actions to benefit wildlife species, ecosystems, and people.

ES considerations can be compatible with the ecosystem approach and related ecosystem-based management (EBM) approach.[119] ES assessment can include spatial and temporal dimensions through mapping, scenario analysis, and other tools that can be of use to conservation planners. It is important to note that ES assessments do not replace the scope of analyses that strictly address the needs of species and the sustainability of ecosystems. Instead, ES considerations can be integrated with those analyses and thus broaden understanding of the dynamics involved.

Entry Points in Managing Species and Ecosystems Processes for Considering ES

- *Wildlife species and ecosystems management generally*: Increasingly, wildlife agencies and initiatives seek to understand the many ES values generated by the natural capital (which provides habitat) needed to sustain target species.[120] For example, landscapes with a high proportion of natural lands provide habitat for wildlife *and* enhanced co-benefits to ecosystems, species, and people through ES, such as crop pollination, forage production, flood attenuation, and provision of clean water. At the same time, it is important to understand the functions that wildlife species have in ecological systems that contribute to ES. The ES values of individual species may vary greatly between geographic areas and stakeholder groups, and ES assessment can help identify the beneficiaries of different, potentially contrasting or competing ES.

  In the context of diverse policy-related activities, managing species (or wildlife) and ecosystems through an ES lens could consider:
  - the suite of ES that one or more species and/or ecosystems may provide or significantly contribute to;[121]
  - how people benefit from those ES, who is benefiting, and where beneficiaries are;
  - how people value those benefits—in socio-cultural and/or economic terms;[122]
  - the species' habitat requirements, and ecosystem conditions where those requirements are met, including the biophysical environment and relationships among diverse species;
  - threats to the species/habitat/ecosystems (including relationships with other species) and thresholds of species/ecosystem health;[123]
  - how threats to species/habitat/ecosystems may impact ES; and
  - potential effects on people due to changes in ES benefits derived from those species and ecosystems.[124]

[118] In economics, this type of importance is called "existence value." See *Value, Values, and Valuation* in *Tools – Tab 9: Glossary*. The many types of values associated with ES benefits are explained in *Tools – Tab 6: Values and Valuation: Economic and Socio-cultural*.
[119] The CBD defines EBM as "a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way."
[120] See *Conceptual and Analytical Framework* in *Chapter 1*, and *Tools – Tab 9: Glossary*, especially the terms highlighted in red.
[121] Identifying interrelated bundles of ES is an optimizing strategy for ES planning and management, and corresponds well with the idea of considering interdependent species within a habitat or ecosystem. See *Steps 4* and *5* in *Chapter 2* for explanation of ES bundles.
[122] These first three bullets can be addressed using the *ES Priority Screening Tool (Worksheet 2)* in *Tools – Tab 4: Worksheets for Completing ES Assessment*.
[123] The fourth and fifth bullets in this list could involve a condition and trends analysis, see *Step 4* in *Chapter 2* for explanation.
[124] The last two bullets on this list could involve a scenario analysis, see *Step 4* in *Chapter 2* and factsheet in *Tools – Tab 7: Compendium of Data Sources, Analysis Methods, and Tools.*

There are additional possible considerations, but the above list would be the foundation from an ES perspective. ES considerations can also be incorporated into ongoing, existing environmental or ecosystem management processes by simply integrating guiding questions about how ES may be affected by current conditions or proposed decisions. It may also include modifying current practices to restore or secure ongoing provision of ES, or adapting implementation plans to protect or even enhance current and future flows of ES while still meeting decision or project objectives. While making trade-offs between different outcomes is often a consideration, an ES assessment can help to optimize equitable, positive outcomes.[125]

- *Species at risk*: While SAR identification is based on the survival of a species, identifying direct and indirect benefits to people from the species or from the habitat on which the species depends (i.e., co-benefits) can provide useful analysis to support regulations and recovery plans, including evaluating the ES implications of different recovery approaches or specific recovery actions. Approaches to SAR that consider multiple species in shared habitats introduce an ecosystems view that may be more likely to sustain target species, their habitat, *and* the associated ES. Integrated approaches to conservation planning could use ES assessment of alternatives, for example, identifying which conservation actions provide the greatest benefit to target species (whether at risk or not) and simultaneously generate the most optimal combination of ES benefits.
- *Ecosystem restoration and rehabilitation:* Restoring and rehabilitating degraded ecosystems can enhance the quality and quantity of ES, and hence their benefits to human well-being. Degraded ecosystems do not supply the same quality and quantity of ES. Considering the value of "lost" ES benefits can strengthen the case for rehabilitation, as well as inform the choice of remediation techniques and design details. Deliberately considering ES when developing detailed restoration plans can also help ensure that all ecosystem components and their functions are properly reflected. Restoring lost or degraded ecosystems is generally very costly and can take many years, but it can be a "high-yield" investment. Research has shown for a variety of different types of ecosystems that the costs associated with restoration projects, including maintenance, are much less than the potential value of the ES benefits.[126] Examples of documented benefits from ecosystem restoration include improved job opportunities and livelihoods in rural areas, mitigating some effects of anthropogenic climate change, and increasing the adaptive capacity of biotic communities.[127] Drained wetlands can be restored to help restore water quality, water regulation, and habitat functions. Larger-scale projects tend to be more cost-effective and also enhance ecosystem resilience.
- *Natural hazard risk assessment:* The potential cost of dealing with natural disasters after they have occurred may outweigh the financial costs involved in assessment, mitigation, and management of risks. There is an opportunity for ES assessment to support and inform hazard assessment, helping to make investments in risk reduction more defensible and comprehensive. There is also a risk associated with failing to take into consideration the ES that play a key role in capacity to cope with potential disturbances. Monitoring ES that are critical to risk reduction (e.g., slope stabilization, erosion regulation, water storage, flood protection) can help to demonstrate the biophysical values of these services in the context of disaster avoidance and inform risk and hazard assessment. ES assessment can help identify strategic management interventions to build resilience and strengthen the capacity to cope with disturbance events and avoid potential disasters.[128]

125 Particularly when using bundle analysis—see *Chapter 2, Steps 4* and *5*.
126 For example, Marbek 2010; Pattison et al. 2011.
127 de Groot et al. 2013.
128 Some risks are non-linear such that disturbance can occur in an abrupt manner if thresholds are crossed. A broad systems-based approach can help with understanding potential threshold dynamics.

EXAMPLE:
ES Values in Ecosystem-based Management

During marine spatial planning for the PNCIMA in British Columbia, research on the benefit of an ES perspective was completed to show the potential to account for a more complete range of the ecological processes that provide benefits to people.[129] The research tested methods for identifying values associated with the study area as inputs to marine and terrestrial EBM, focusing on challenges in the elicitation and representation of intangible values related to cultural ecosystem services (CES). Through 30 semi-structured interviews, Sarah Klain tested a protocol for verbal description and quantitative measure of monetary and non-monetary values held by local people. Interviewees held a wide range of marine-related occupations. They were asked to identify specific locations of the ocean that were important for their economic livelihood and allocate tokens representing monetary values to these areas. They were asked about connections between marine ecosystems and CES such as their heritage, identity, spirituality, and well-being of themselves and their community. Using maps of the study area, they were asked to indicate locations associated with the CES they identified, and to allocate tokens representing non-monetary values to these places. All interviewees identified intangible benefits and values pertaining to ES, but 30 percent refused to assign quantified non-monetary value to specific locations and 16 percent chose not to identify specific locations of non-monetary importance. The researcher concluded that studies that attempt to isolate and quantify CES will likely not have substantial traction at a community level, and other means of expressing non-monetary value should be explored (e.g., through a deliberative decision-making process). Moreover, when respondents were asked about one particular type of CES, their answers generally referred to multiple types of services. This demonstrated the links between services, leading researchers to conclude that analysts completing ES valuations should not assume independence of ES types.

EXAMPLE:
ES Assessment of Wetlands for Flood Control

As part of their Ecosystem Services Pilot Project, the Government of Alberta assessed water storage and flood control ES. The aim was to develop an approach for assessing ES associated with wetlands in a standardized, systematic way that would also enable assessing cumulative impacts associated with wetland disturbance. The pilot study used GIS data to identify more than 6,500 wetlands (many very small or temporary) within an area of 267 km^2 in the Shepard Slough, east of Calgary. Land-cover data from various datasets were used to estimate wetland water storage capacity, and data on impervious surface values were used in a GIS model with eight separate predictor variables to assess flood control. Analysis revealed detailed information about the storage capacity of wetlands in the study area, including the water volume capacity of different classes of wetlands, and found that most wetlands only reached full capacity in the spring. Changes in water storage from a large number of wetlands that had been drained were mapped and linked to the main beneficiaries in the area of wetland water storage and supply services (e.g., cattle farmers). The flood control assessment also included maps of trends across the area for each of the seven predictor variables. This information was used to show how even smaller wetlands at high landscape positions could provide flood control benefits. The study also showed that it was possible to calculate increases in peak flows of the Bow River with the drainage of wetlands.[130]

[129] Klain 2010. The study area focused on the Regional District of Mount Waddington, spanning across 20,288 km^2 of British Columbian land and 9,880 km^2 of ocean.
[130] 02 Planning + Design 2011.

EXAMPLE:
ES to Inform Conservation Planning

Researchers have adapted systematic conservation planning procedures to include ES. Using a case study based in eastern Canada, Cimon-Morin and colleagues focused on 10 key ES across 16 types of wetlands. By considering and mapping both the source of these 10 ES as well as where the benefits are received, the study authors suggest that conservation planning can be more effective when important ES are identified, and also when the spatial location and arrangement of both the source and beneficiaries of these ES are taken into consideration.[131] Participatory approaches that elicit the values of ES to different stakeholder groups can help to identify conservation options that are more transparent and likely to be more acceptable to these user groups.[132]

Other Considerations

Multiple ES benefits and bundles of ES can shift the focus of management from a single species to the interactions between species at an ecosystem scale. For example, the Whitebark Pine and Limber Pine are two endangered tree species in Alberta threatened by both an introduced fungus (*Cronartium ribicola*) and by mountain pine beetle. Both tree species can grow on steep cliffs where they contribute to soil stabilization and also accumulate snow thereby regulating water flows. The seeds from these pine trees are an important food source for animals such as squirrels, bears, some small birds, and rodents.[133] Through these system interactions, the Whitebark Pine and Limber Pine demonstrate how some ES are bundled together and how common threats have potential impacts and cumulative effects at a regional level.

Additional Information Sources (See *Sources Cited* for details)

Selected examples of ES analyses related to ecosystem and species management in Canada:

- Molnar 2015, Wilson 2014 and others from the David Suzuki Foundation; and Pattison et al 2011, and Anielski et al. 2014 use ES to make the case for conservation in Canada.
- Credit Valley Conservation regional watershed authority http://www.creditvalleyca.ca/watershed-science/our-watershed/ecological-goods-services/ has a multi-year, multi-project initiative to understand ES and their economic values to support policy and land-use decisions.
- Kulshreshtha and Knopf 2003, and Bellet 2013 researched the ES benefits of shelterbelts in agricultural landscapes to help inform management practices.

3.5-3. Managing Invasive Alien Species

Relevance of ES to Managing Invasive Alien Species

Invasive alien species (IAS) are a major cause of biodiversity loss.[134] Since biodiversity underpins the ability of ecosystems to generate ES, IAS are, by extension, a threat to ES. Species can become IAS problems through intentional introduction by humans (e.g., ornamental horticulture, pets) or unintentional introduction by humans (e.g., "hitch hikers" on road and marine vehicles). Once introduced and established, IAS can spread as a result of species migration associated with, for example, climate change and major land-use changes. In all cases, introduction of IAS can interrupt the ecosystem processes that generate ES, making ES assessment relevant.

IAS can displace native species by aggressively colonizing habitat, leading to potentially large changes in ecosystems and the ES they provide. The Invasive Alien Species Strategy for Canada, for example, observes:

> Invasive alien species can alter habitats and essential ecosystem functions, including hydrology, nutrient cycling, contaminant absorption, natural fire regimes, and energy flows and cycles. Essential ecosystem functions can be placed at risk, including greenhouse gas absorption by forests, pest control by native species, water filtration by wetlands, and the use of native biodiversity for the bio-based economy (including pharmaceuticals and other biotechnology).[135]

131 Cimon-Morin et al. 2014.
132 Ban et al. 2013.
133 Alberta Whitebark and Limber Pine Recovery Team 2014.
134 CBD https://www.cbd.int/invasive/
135 Federal, Provincial, and Territorial Governments of Canada 2004.

Research to develop a European Union framework for IAS risk assessment included, among its criteria for minimum standards, that such assessment "can broadly assess environmental impact with respect to ecosystem services."[136] The framework analysis states that "the identification of impacts on biodiversity and ecosystem characteristics clearly forms the basis for impacts on ecosystem services whereas identifying the impacts on ecosystem services form a key conceptual basis for assessing the foreseen socio-economic impacts of IAS invasion."[137] For example, ES (and by extension human well-being) are directly affected by IAS as a result of impacts to food and water security, natural hazard mitigation, climate change mitigation and adaptation, recreation, cultural and natural heritage, and education, among others.[138]

Entry Points in Managing IAS Processes for Considering ES

ES assessment can be useful in IAS risk assessment and justification for prevention measures such as regulatory or policy controls on the transportation of potentially invasive species, or activities that might facilitate the "natural" movement of species (such as eliminating natural predators). ES assessment is equally valuable in identifying and prioritizing response and management measures in the field, in mitigation actions, and ongoing monitoring.

- In conducting risk analysis, impacts of IAS to ES can be assessed using a protocol that begins by identifying IAS impacts to an ecosystem's structures and processes. These are the "ecosystem service-providing units." This enables estimates of the magnitude of impact to the ES that were being provided.[139] ES assessment can help show the link between IAS impacts to ecosystems and resulting impacts to human well-being.
- In early detection of IAS, and monitoring ecosystems for IAS impact, the early signs of problems may be identified by a reduction in one or more ES in a region. These changes could alert officials to the need for more thorough investigation and possible mitigation actions.
- Once an IAS has become established, ES analyses can help reveal the possible spatial route of diminished ES resulting from the IAS, and point to landscape features and places that may need mitigation to restore degraded or lost ES. An ES assessment may help inform the degree of effort that should be invested in IAS control or eradication.

The Global Invasive Species Program's Toolkit for the Economic Analysis of Invasive Species uses an ES lens as the basis for estimating monetary values for the impacts of IAS in terms of costs, helping to understand economic causes of IAS introduction and spread, and to inform policy. Their toolkit explains and illustrates the potential uses of various economic methods in the IAS context.[140]

EXAMPLE:
Scenario Analysis of IAS Impact on ES

Researchers in Europe developed a standardized, consistently reproducible approach to assess the impacts of IAS on ES using scenario analysis.[141] The scheme was tested using the Citrus long-horned beetle's impacts on the ES in Europe as an example. The beetle originates in Asia and feeds on many woody plant species that are common in Europe and North America, threatening forests, landscapes, and associated commercial sectors. The assessment scheme considers key biophysical, spatial, and temporal factors to identify ES that are most at risk of being negatively affected by the beetle, thereby contributing to refine and expand the scope of existing risk assessments for IAS.

[136] Roy et al. 2014: 11.
[137] Roy et al. 2014: 12.
[138] Roy et al. 2014: 70.
[139] Gilioli et al. 2014.
[140] Emerton and Howard 2008.
[141] This example is summarized from Gilioli et al. 2014. See also factsheet on scenario analysis in *Tools – Tab 7: Compendium of Data Sources, Analysis Methods, and Tools.*

Other Considerations

The UN *Millennium Ecosystem Assessment* (MA) examined IAS as a major driver of ecosystem change—and thus ES change. The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) program of work for 2014–2018 includes a thematic assessment on IAS and their control, focusing on the threats that IAS pose to biodiversity and ES (Deliverable 3b).[142]

Additional Information Sources (See *Sources Cited* for details)

Gilioli et al. 2014; Roy et al. 2014; Emerton and Howard 2008; Katsanevakis et al. 2014.

Alberta Agriculture and Forestry Online Risk Assessment Calculator addresses exposure, environmental, economic, and social variables http://www.agric.gov.ab.ca/app19/calc/risk/riskcalculator.jsp.

3.6 Conservation Instruments

Much as "environmental management" (section *3.5*) could be understood as relevant to all sections of this chapter, various conservation instruments could be applicable in nearly all of the policy-relevant areas discussed in the previous sections of this chapter. Suggestions are provided here for including ES considerations in conservation incentive programs and conservation offsets.

3.6-1 Conservation Incentive Programs

Relevance of ES to Conservation Incentives

Conservation incentive programs are particularly relevant in area-based planning (section *3.2*) and environmental management (section *3.5*). They are often used in combination with regulatory approaches that restrict some uses. Provincial, territorial, and federal government agencies in Canada have used a wide range of incentive measures for ecosystem conservation. Approaches to using conservation incentive measures[143] can be direct or indirect. The CBD describes these two approaches:

> Direct approaches typically (but not always) provide monetary incentives which seek to emulate market prices — they generally involve 'paying' relevant actors to achieve biodiversity-friendly outcomes or, conversely, to not achieve biodiversity-harmful outcomes. Examples include long-term retirement (or set aside) schemes; conservation leases, covenants or easements; and schemes providing payments for ecosystem services. In many countries, such incentives are also generated through the use of breaks on governmental levies such as taxes, fees or tariffs that grant advantages or exemptions for activities that are beneficial for conservation and/or sustainable use.
>
> Indirect approaches seek to support activities or projects that are not designed exclusively to conserve or promote the sustainable use of biodiversity, but have the effect of contributing to these objectives. Many of these incentives are non-monetary (or 'non-market') in nature (although they may have financial implications for the provider); for instance, the official recognition of the role of local communities in the context of community-based natural resource management programmes.[144]

Payments for ecosystem services (PES) is an umbrella concept for a suite of compensatory tools. Although not widely used in Canada, it is the only conservation incentive mechanism that is explicitly framed as focusing on ES, so a brief account of its use is included in this chapter.

Entry Points for Considering ES in Conservation Incentives

ES considerations are a particularly strong fit with conservation incentive programs of all kinds, offering a sound analytical basis (in association with other factors such as strictly biophysical science) for:

- identifying *target landscapes* for a conservation incentive or funding program;
- establishing *criteria for conservation behaviour* within an incentive program;
- identifying *specific outcomes* for incentive programs;
- determining *which incentive mechanism* is likely to have the greatest success;
- establishing *criteria for monitoring and evaluation* of incentive programs and their outcomes;

[142] The scoping document is listed as a Working Document IPBES/4/10 at http://www.ipbes.net/plenary/ipbes-4.

[143] Kenny et al. 2011:1. Their report summarizes nearly 40 conservation incentive programs under Canada's FPT governments and the challenges, advantages, and disadvantages of many different economic instruments for biodiversity conservation, as well as selection criteria for their use.

[144] CBD 2011a: 14. Additionally, the CBD Secretariat (CBD 2011a:5) affirms that: "The new Strategic Plan for biodiversity for the period 2011–2020, which was adopted by the Conference of the Parties to the Convention at its tenth meeting, held in Nagoya, Japan, in October 2010, acknowledges that there is now some understanding of the linkages between biodiversity, ecosystem services and human well-being, but also recognizes that the value of biodiversity is still not reflected in broader policies and incentive structures. The Strategic Plan reflects the urgent need to act on incentive measures by calling for the removal, phasing out, or reform, by 2020, of incentives, including subsidies, that are harmful to biodiversity, and for the development and application of positive incentives for the conservation and sustainable use of biodiversity."

- determining the *extent of the incentive* such as the price for a tax credit or payment as compensation for forgone uses of private land in the public benefit using performance criteria and/or economic valuation;
- justifying *renewed investments* in incentive programs based on specific conservation practices and/or outcomes; and
- projecting *anticipated outcomes* of proposed or potential investments in new programs.

Biophysical, socio-cultural, and economic analyses about ES can be useful to inform each of these entry points, to varying degrees, and the most reliable results will come from using all three kinds of analyses together. ES assessment provides a robust means to more systematically evaluate the benefits of conservation incentive programs. ES assessment can contribute to the design of more efficient and effective incentives by identifying a more complete set or "bundle" of ES that are supplied across a landscape. Taking into consideration multiple benefits and the different ways they are valued (i.e., by different beneficiaries and/or for different purposes) can help to calibrate the allocation of resources.[145]

There are a variety of ways to calculate adequate level of compensation required to properly incentivize landowners for their donations of land for conservation. For example, some programs, such as Canada's federal Ecological Gifts Program, use real-property assessment based on assessed market value of the land.[146] This provides a standardized and replicable methodology. However, the assessed market value may not capture the value of social benefits provided by ES generated on a property or to which the property contributes.

One way to apply a standardized, replicable methodology for incorporating measures of ES benefits associated with a given property or site is to use an evaluation grid. This approach could be useful with most of the entry points listed above. The first step is to establish a scoring system with a standard set of criteria in which each criterion encompasses one ES, or a key indicator of ES that can be assessed based on site conditions and current land-use or management practices. The relative extent to which an ES is estimated to be secured by the natural capital on site could be ranked with a simple gradient.[147] The scoring could be further refined through ES prioritization using *Worksheets 2* and *3* in *Tools – Tab 4: Worksheets for Completing ES Assessment* to identify the relative importance of each ES to local or regional beneficiaries. The final scoring outcome could be stated as a percentage of a possible credit or funding envelope, or inform a different type of calculation (e.g., calibrated relative to property tax). A monetary value could reflect the combined ES either as a bundle or in what is called "stacking."[148]

145 Worksheets in *Tools – Tab 4: Worksheets for Completing ES Assessment* can be used to focus in on objectives, identify priority ES, reveal significant issues, and focus data gathering and analysis.
146 http://www.ec.gc.ca/pde-egp/default.asp?lang=En&n=AB7425E1-1
147 For example, three or five points from high to low. The process would be comparable to current practice of using an evaluation grid to score proposals received in competitive contracting. See also the factsheet on *Constructed Scales* in *Tools – Tab 7: Compendium of Data Sources, Analysis Methods, and Tools*.
148 See Robertson et al. 2014 for details on stacking ES; and Banerjee et al. 2013 comparing stacking and bundling.

Example of Economic Instruments for ES Conservation Across Canada

- In Manitoba, the provincial government is seeking to prevent soil erosion and improve water quality by offering a *Riparian Tax Credit* to farm operators who take action to improve the management of lakeshores, riverbanks, and streambanks on their property.
- In Saskatchewan, Ducks Unlimited Canada led a "*reverse auction*" to pay landowners for restoring wetlands in their fields and pastures in an effort to restore 56,000 hectares of wetlands over a period of 20 years.
- In Ontario, the South Nation Conservation Authority has instituted a water-quality *trading program* designed to reduce phosphorus discharge to the watershed.
- The federal Ecological Gifts Program seeks to protect ecologically important areas across Canada, by providing *tax reductions* to landowners who donate ecologically sensitive lands to a qualified recipient, such as an approved land trust.[149]
- Prince Edward Island's Alternative Land Use Services (ALUS) program pays farmers to retire agricultural lands or to establish and/or maintain beneficial management practices that protect soil and water quality or improve fish and wildlife habitat.[150]
- Paid conservation easements are delivered by agencies such as The Nature Conservancy of Canada and Ducks Unlimited Canada.
- Ontario has programs that involve property tax credits on managed forests, private lands with provincially important natural heritage features, species-at-risk farm incentive and stewardship programs, and water-quality trading.
- Ducks Unlimited Canada has also used ES analyses to demonstrate the value of wetlands conserved through its programs for the regulating ES of carbon sequestration, source water protection, and flood attenuation.

EXAMPLE: FPT Pilot Project on ES Incentives in Agriculture

A federal-provincial working group was established by Ministers of Agriculture in 2004 to examine policy options for "ecological goods and services" incentive mechanisms, including regulation, annual payments, one-time payments, education and awareness, reverse auctions, tradable permits, tax incentives, community consensus-building, and peer pressure.[151] The working group tested different schemes across the country through pilot projects using reverse auctions, annual payments, community target setting, transferable credits, and offset trading. Lessons learned are summarized here in *Table 3.2*.[152]

[149] These first four examples are quoted (with corrections) from Kenny et al. 2011: iii.
[150] www.gov.pe.ca/growingforward/ALUS2
[151] See "Lessons on Ecological Goods & Services from Canadian Pilot Projects" by Ian L. Campbell, at: http://nfwcc.com/presentations/presentations/138_Ian_Campbell.pdf.
[152] Pilots were discussed at a workshop—see Prairie Habitat Joint Venture 2009.

Table 3.2. *Lessons learned from ES pilot studies in Canadian agricultural systems. (Reproduced from Ian L. Campbell, n.d.)*

Categories of Lessons	Lessons Learned from ES Pilot Projects
Pitfalls	• National ES funding program will not reflect local conditions • Annual payments are effective only under particular conditions (e.g., regulatory measures in place, transition to fiscally sustainable tool), severe ecological risks • Regulations are efficient only in special circumstances (e.g., may be needed for market-based instruments to function) • ES programs to subsidize farm incomes are inefficient for income and environment
Scale	• Best mechanisms are local or place-based (spatial variation in demand for ES, efficiency of farm practices, and government structures) • Local engagement is needed for consensus on environmental targets and compensation • Local initiatives are best for bundled services provided by the same landscape
Compensation	• Unnecessary for practices that are neutral or economically beneficial to producers • May be needed when public value exceeds cost to producer • Funding should draw on users of the ES
Overall Principles	• Accountability (measurable, efficient, and accountable to funding providers) • Place-based (local conditions, flexibility, and public support) • Efficiency (market-based instruments) • Partners (involve other stakeholders) • Integration (with other agri-environmental objectives)

Other Considerations about Conservation Incentives

Payments for Ecosystem Services. The essence of PES is that beneficiaries of ES (or their representatives, e.g., community organizations, governments, or buyers through PES banking mechanisms) compensate the stewards (landowners) of environments that produce those ES.[153] The payment "secures" the ongoing protection of targeted ES by compensating the owner for both their conservation practices and their forgone options to use the property in ways that would reduce or eliminate the ES it currently produces or contributes to.[154] Several of the conservation incentive mechanisms listed above have also been used under the banner of PES when the explicit focus is on ES as the conservation goal.

Numerous guides to incentive mechanisms, including those classed as PES, have been developed in recent years. With an increasing number of pilot projects and full programs implemented, analysts can now provide more precise advice based on lessons learned.[155] For example, researchers have defined a concise set of natural science principles and guidelines for PES interventions that address ecosystem dynamics, baseline conditions, multiple ES, monitoring, metrics, and ecological sustainability.[156] Recent reviews have found that two of the key shortcomings of PES programs internationally to date have been a failure to confirm additionality and to address the inequity that can often accompany the implementation of these programs.[157] These findings demonstrate the importance of a robust instrument design that includes these two and other core principles in a meaningful way.

Additional Information Sources (See *Sources Cited* for details)

Kenny et al. 2011; Banerjee et al. 2013; Naeem et al. 2015; CBD 2011a; Forest Trends et al. 2008; OECD 2010b; Smith et al. 2013.

153 Three main types of PES are (1) public payment for private landowners to maintain or enhance ES; (2) formal markets with open trading between buyers and sellers (e.g., carbon trading); and (3) self-organized private deals between "sellers" and "buyers"—see Forest Trends et al. 2008 for a primer on the different types and how to use them, with examples for each approach.

154 This "additionality" is a key principle of offset design as well. A primary distinction between PES and biodiversity offsets is that PES are oriented to a "beneficiary pays" principle and offsets are oriented to a "polluter pays" principle.

155 See for example, Smith et al. 2013 (the UK government's best practice guide to PES); and Forest Trends et al. 2008. See also Banerjee et al. 2013 on key issues in PES design.

156 See Naeem et al. 2015.

157 Calvet-Mir et al. 2015; and, Hejnowicz et al. 2014. Additionality is a standard criterion for PES and offset design, in which a project must produce [ES] benefits in addition to (i.e., over and above) the benefits that would have occurred without the intervention.

3.6-2 Conservation Offsets

Relevance of ES to Offsets

Conservation offsets can be used in different policy areas for remedial action under regulatory authority, for example, in EIA.[158] They can also be used as a voluntary conservation incentive.[159] Numerous critiques and guides with specific criteria are readily available to inform offset design and use.[160] Offsets share some characteristics with other instruments discussed in the previous section, such as reliance on incentives to motivate action. A key distinguishing characteristic is that offsets are a market-based instrument that operate under government regulations, and are used to meet regulatory requirements. Typically, offsetting is undertaken after an activity has occurred. "Advance offsetting" is when an offset is created before the impact occurs. In advance offsetting, third parties may develop offset credits that can be sold to entities that are required to offset their impacts. In Canada, examples of offset requirements are the federal fish habitat compensation and the Alberta Wetland Policy requirement to offset wetland impacts.

The central idea of offsetting is to measurably compensate in one location for detrimental effects of development or other activities in another location. With their focus on environmental impacts, offsets are directly implicated in the flows of ES. This section does not delve into the components of offset design and principles generally, but focuses on how ES considerations can be factored into offset use.

Entry Points for Considering ES in Offset Processes

Offsets should be understood as a last resort to address impacts that cannot be avoided or minimized. The intention to minimize the net loss of ES, or achieve a net benefit, follows a "mitigation hierarchy" of decreasing preference: (1) avoiding impacts; (2) minimizing impacts that cannot be avoided; and (3) offsetting residual impacts that cannot be avoided and minimized.[161] Importantly, some ES are not able to be offset.[162]

A key consideration is that mitigating ES losses does not substitute for mitigating ecological losses, although there are likely to be synergies from considering both concurrently. ES may be measured in ways that are different from directly ecological, habitat or natural capital measures. Synergies are likely because mitigating the loss of ecosystem structure and functions is likely to sustain its capacity to provide ES. One way to resolve this is to require an ES assessment prior to habitat loss and ensure that compensation habitat yields similar ES. In all cases, it is essential to be clear about which ES are being offset and, if possible, to state which ES are not being offset.[163]

Offsets are typically area-based, for example, one hectare of wetland loss might be offset by three hectares of wetland (3:1). This area-based requirement does not sufficiently take into account ecosystem function between the lost and offset habitat. In recognition of this limitation, some offset programs have begun to require function-based offsetting. For example, the Alberta Wetland Policy requires assessment of wetland area and function during regulatory evaluation of impact and offset. There is also recognition that placement of environmental features back onto the landscape through offsets needs to be informed by relevant concerns, for example, water quality, flood hazard minimization, fisheries or species management. ES assessment provides a method to guide the design and placement of offsets.

Whereas some approaches to offsetting might focus on distinct land-cover types, for example, a wetland or a deciduous forest, an ES approach to offset design would address the flows of ES across a landscape. These flows may be in the visible landscape or underground, as in subsurface hydrology. Spatially, this would include:

- locations of biophysical structures, processes, and functions that produce one or more ES;
- where these flows move through the landscape;
- locations of impediments or enhancements to those flows; and
- locations of human beneficiaries of the ES.

Spatial considerations are described in *Tools – Tab 2, Issue 2.* Equally, the temporal aspect of offsets must be a factor in relation to ES flow. Depending on the nature of the offset action, the replacement of ES benefits could take many years after the "offset action" is taken. The implication of this dynamic is that to consider ES in offset design:

- the impact (or loss) location must be analyzed in terms of its ecosystem dynamics;
- ES that (1) are produced on site; (2) flow through the site; and/or (3) are received at the site must be identified;

[158] For example, Environment Canada 2012.
[159] See example of the Southeast Alberta Conservation Offset Pilot in section *3.2-2* of this chapter.
[160] Examples listed in Additional Sources in this section but for details on offset design, including metrics, multipliers, and mechanisms, see especially ICF and IEEP 2014. Laitila et al. 2014 provide a method for calculating multipliers in offset design.
[161] See "Mitigation Hierarchy" in *Tools – Tab 9: Glossary*. See also Brownlee 2014.
[162] Poulton 2014. See also "critical natural capital" in *Tools – Tab 9.*
[163] See Brownlee 2014 Table 1 for a concise presentation of offset design principles. On metrics, see Gonçalves et al. 2015.

- a prioritization process may be needed (see *Worksheets 2* and *3* in *Tools – Tab 4: Worksheets for Completing ES Assessment*) to identify ES that are (1) "critical" and cannot be offset; (2) not a high priority to beneficiaries or can be substituted without offsetting; and/or (3) a high priority to beneficiaries and can be offset; and
- a suitable offset site must be located at which the availability of the chosen ES flows is secured.

When offsets are deemed to be appropriate, a measure or a set of measures is needed to evaluate gains relative to losses. The choice of a specific metric or set of metrics is a trade-off between what is measurable and what would ideally be measured. Since multiple ES are typically provided as a bundle from ecosystems, a measure of one or just a few services could be targeted as a proxy for the set.[164] The effectiveness of this approach will depend upon the extent to which the targeted ES can be protected or enhanced without undermining other services of the set. In practice, authorizations to offset are usually provided on the basis of specific actions that are believed to result in desired future outcomes.

EXAMPLE: Biodiversity Offsets for a Powerline Corridor

This example of the Hydro One – Bruce to Milton Biodiversity Initiative is excerpted from Poulton 2014. Hydro One initiated a project in 2008 to construct a new double-circuit 500 kV transmission line running 180 kilometres from the Bruce Nuclear Generating Station to the Milton Switching Station in southern Ontario. The company estimated that the project would affect approximately 280 hectares of woodland habitat through clearing or conversion to low-growing habitat considered compatible with overhead transmission lines. Whereas the traditional compensation approach of the industry required a hectare-for-hectare replacement of this habitat through tree planting, the company committed to a more ambitious goal of no net loss of habitat and net gain where practicable. To accomplish this, the company worked in consultation with local communities, provincial agencies, environmental interest groups, and First Nations and Métis communities to develop a methodology for quantitatively valuing and ranking the habitat lost due to the project, as well as habitat creation and enhancement opportunities. The valuation methodology was applied independently to each watershed that was traversed by the Bruce to Milton project to ensure that the habitat created in each watershed was proportionate to the habitat lost. Strictly ecological values were applied to the comparison of habitat lost and habitat created or enhanced to ensure no net loss. However, social factors (such as educational opportunities, recreational benefits, and involvement of First Nations and/or Métis communities) were also considered when ranking the habitat creation opportunities. Hydro One reports that the goal of no net loss has been achieved, and that a net gain of habitat has been achieved with approximately 380 hectares of habitat created or enhanced.

Other Considerations

Environmental offsetting is becoming more popular as a way to manage unavoidable impacts of development in EA and some emerging conservation policies (e.g., agricultural drainage policy). One approach to offsets involves ecosystem banking and ecosystem markets, relatively new mechanisms that to date have limited uptake.[165] While offset design criteria have improved, there remain several serious practical challenges. Offsetting relies on the assumption that equivalent values can be identified and protected or restored at a different location to compensate for the loss.[166] Ecosystems are highly complex in terms of species populations and their dynamics and the dynamics of ecosystem structures, processes, and functions that generate ES. This means that one wetland cannot simply be exchanged for another wetland and produce the same ES, and one 100-hectare forest is not equal in ecosystem functions to another 100-hectare forest elsewhere. Limitations of scientific knowledge and the limited use of that knowledge to inform offsetting in practice are further challenges.[167] Monitoring of individual offset areas over time is one of the big challenges for offset programs. Experts are developing

[164] See *Chapter 2* for technical guidance on measuring ES, including ES bundles.
[165] See, for example, the Ecosystem Marketplace: http://www.ecosystemmarketplace.com/. For an expert critique of market-based instruments and ecosystem services, see Gómez-Baggethun and Muradian 2015.
[166] On equivalence and trade-offs, see Brownlie et al. 2013.
[167] On structures, processes, and functions see *Chapter 1, Framework*; on limitations see *Tools – Tab 2, Cross-cutting Issues and Key Considerations*. On risks—notably time lags, uncertainty, and measurability—see Maron et al. 2012, and Curran et al. 2014. On numerous specific challenges, see Bull et al. 2013. See also *Tools – Tab 2*, all *Issues*.

specific guidelines, criteria, and frameworks to address the various challenges and risks of offsetting.[168] Only recently have meta-analyses of cases that document offset performance begun to be undertaken and published. Examining the ES outcomes of offset programs could prove very useful for future offset design.

Additional Sources on Offsets for ES (See *Sources Cited* for details)

Brownlee 2014; Brownlie et al. 2013; Bull et al. 2013; Curran et al. 2014; Environment Canada 2012; Gardner et al. 2013; Gonçalves et al. 2015; ICF and IEEP 2014; IUCN 2014; Maron et al. 2012; Noga and Adamowicz 2014; Pilgrim et al. 2013; Poulton, D.W. 2014; Tallis et al. 2015.

[168] Avoidance criteria are summarized in Tallis et al. 2015, see especially their Figure 4. A framework for achieving no net loss is presented in Gardner et al. 2013.

TOOL TABS

Contents

Note: Abbreviated citations are provided in footnotes as necessary in these Tools; full bibliographic references for the sources cited in the footnotes are provided in the final section of the Toolkit: *Sources Cited*.

TOOLS – TAB 1 – ECOSYSTEM SERVICE DESCRIPTIONS

Table T1.1. *ES typology with examples of ES benefits.*

Ecosystem Service (ES)	How Benefits to Humans Are Derived from the ES
Provisioning services – ***the result of ecosystem processes and functions that provide goods or products that humans obtain and rely upon***	
Food • Crops • Livestock • Capture fisheries • Aquaculture • Wild foods	Edible products derived from plants, animals, and fungi that humans require for biological sustenance or commercial use (e.g., fruits, nuts, seeds, meat, vegetables, fungi, tubers/roots, herbs, oils). Ecosystems produce many wild foods and also provide soil, nutrient, microbiological, and climatic conditions that enable humans to cultivate food. These occur through natural gross primary production and conversion of solar energy into biomass, secondary productivity through energy transfer in food chains, and water and nutrient cycling.
• Timber and other wood products • Fibres, resins, animal skins, and ornamental resources	Ecosystems produce raw materials from plants and animals that are used by people in many different ways. Plant fibres are used for building (e.g., wood) or are broken down for other products (e.g., pulp for paper), and are also woven to make fabric and other pliable materials (e.g., rope). Raw material derived from animals is also used by people (e.g., fur and wool for clothing, blankets and other textiles, down filler, and sinew for a variety of purposes).
Biomass fuel	Biological materials are used by humans as sources of energy, typically burned to create heat for warmth, fuel machinery, and cook food. For example, fuel may be derived from wood, dung, grasses, oil/fat, hydrocarbons, and ethanol.
Fresh water for human consumption and use	Fresh water is fundamental to life and is consumed by humans for drinking, irrigation, sanitation, waste management, and industrial use. Fresh water is a necessary input to the production of foods and fibres, and used for many essential and non-essential activities.
Genetic material	All living organisms contain genetic information that encodes their essential characteristics, which is an important resource to people. This information has been the basis of animal and plant breeding for millennia to improve desired qualities such as taste, resistance to pests, and drought tolerance. Genetic material from wild relatives continues to be necessary to maintain cultivated plants and domestic animals. Genetic material is also used in biotechnology, including medical research.
Biochemical and medicinal resources	Biological organisms produce chemicals, known as "biochemicals" which are the basis for most medicines and pharmaceuticals, and are also increasingly used in various industries, including pest management and food processing.

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Ecosystem Service (ES)	How Benefits to Humans Are Derived from the ES
Regulating services – ***the result of ecosystem processes and functions that regulate all aspects of the environment, providing security and habitable conditions that humans rely upon***	
Air-quality regulation	The maintenance of good air quality relies on ecosystems to exchange chemicals with the atmosphere through bio-geochemical cycles. Human health is directly impacted by air that is polluted, for example, through burning or industrial emissions. Air-quality regulation by ecosystems ensures numerous benefits, including clean, breathable air and the prevention of respiratory and skin disease. Ecosystems influence air quality by emitting chemicals to the atmosphere (i.e., serving as a "source") or extracting chemicals from the atmosphere (i.e., serving as a "sink"). Lakes serve as a sink for industrial emissions of sulphur compounds. Vegetation fires emit particulates, ground-level ozone, and volatile organic compounds. *(UNEP)*
Climate regulation and carbon sequestration • Global climate regulation • Regional and local climate regulation	Ecosystems play an important role in moderating local weather and influence climate locally, regionally, and globally. Ecosystems influence global climate by emitting greenhouse gases or aerosols to the atmosphere or by absorbing greenhouse gases or aerosols from the atmosphere. Topography, vegetation, decomposition (by animals, fungi and microbes), albedo, and water bodies interact with regional and global climate processes to regulate climate. The reflective properties of the Earth's surface, affected by ecosystem properties, such as the amount, type and structure of the vegetation and the amount of surface water, influence the amount of incoming solar energy that is absorbed or reflected back to space. Certain types of ecosystems (e.g., prairie grasslands, forests, wetlands, bogs) serve as important stores that lock up greenhouse gases from the atmosphere. Plants and marine algae remove and sequester carbon dioxide in their tissues thus influencing global temperatures. How the climate is regulated by ecosystems impacts humans in a variety of ways, for example, by altering food production conditions, controlling humidity levels, and influencing storm intensity.
Water-flow regulation	Maintaining natural water-flow regimes in a watershed through intact ecosystems provides numerous benefits to people by mitigating drought and extreme flood events, for example, through buffering extreme discharge from rivers and streams and providing natural irrigation and water storage. Changes in land cover can influence the timing and magnitude of runoff, flooding, and aquifer recharge. Permeable soil facilitates aquifer recharge. River floodplains and wetlands retain water, which can decrease flooding during runoff peaks, reducing the need for engineered flood control infrastructure. *(UNEP)*
Erosion regulation	Vegetative cover and, in particular, the structure of vegetation both above and below ground, plays an important role in soil retention and in the stabilization of slopes. Plant roots help to stabilize soil, thus minimizing land degradation and sediment loads in rivers and streams and helping to conserve water quality.

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Ecosystem Service (ES)	How Benefits to Humans Are Derived from the ES
Water purification and waste treatment	Vegetation, soils, and soil biota can help to filter out and sequester or decompose organic wastes, including those introduced in production landscapes. Water filtering by wetlands involves the breakdown of nutrient-rich waste from human and animal sources and the removal of disease-causing bacteria such as *E. coli*. Bioremediation of soils and water relies on the metabolic activity of plants and microorganisms to absorb pollutants from soil or water and, in some cases, to digest toxins. The purification of fresh water for drinking and other purposes as well as the removal of microbes and other toxins provide an important benefit to human health.
Disease regulation	Changes in ecosystems influence the incidence and abundance of human pathogens (e.g., cholera, malaria) in the environment. Ecosystem biodiversity helps to regulate predator-prey relationships and parasite lifecycles that affect vector-borne diseases and directly impact human health. Many different species of birds, bats, flies, wasps, frogs, and fungi act as natural control agents. Bird diversity, for example, can be a contributing factor dampening the occurrence of viruses carried by mosquitoes and minimizing human exposure to the disease.
Pest regulation	Changes to ecosystems, including pest management interventions, can alter the capacity of the ecosystem to naturally regulate pests, thus potentially influencing the production of harvestable goods. Natural pest regulation supported by healthy ecosystems significantly reduces impacts of unwanted predation, for example, on crops, and the monetary and (in the case of pesticide use) health costs associated with implementing engineered controls.
Pollination	Most plants require pollination to reproduce. Natural pollination occurs primarily by insects, and also by wind, birds, and bats. Changes to ecosystems and impacts to pollinator species from human or other activity alter the abundance and distribution of pollinators and hence their effectiveness.
Natural hazard regulation	The impact of extreme weather events and natural hazards such as floods, avalanches, and landslides can be ameliorated by intact ecosystems. For example, coastal dune ecosystems can dampen the impact of storm surges, thus minimizing harm to people and damage to infrastructure. Ecosystems also play a role in regulating natural disturbance regimes such as forest fires. Changes to forest ecosystems, for example, through fire suppression, can lead to more intense fires caused by higher fuel loads that can damage seed banks and be more difficult to control. *Continued on next page…*

Ecosystem Service (ES)	How Benefits to Humans Are Derived from the ES
Cultural services – ***the result of ecosystem processes and functions that inform human physiological, psychological and spiritual well-being, knowledge and creativity*** Some authors refer to these as "information services" because they *inform* human experience. Cultural services are tightly bound to human values and behaviour, as well as to human institutions and patterns of social, economic, and political organization. Thus perceptions of cultural services are more likely to differ among individuals and communities than, say, perceptions of the importance of food production. *(Adapted from MA)*	
Cultural identity and heritage	Ecosystems influence the types of social relations that are established in particular cultures. Fishing societies, for example, differ in many respects in their social relations from nomadic herding or agricultural societies. Many societies place high value on the maintenance of either historically important landscapes ("cultural landscapes") or culturally significant species. *(MA)* Identity and heritage are grounded in experience everywhere, in every type of ecosystem, and are informed by relationships with nature that are distinctive to each place. Ecosystems thus support social cohesion through shared experience and shared understanding of the world.
Spirituality and religion	Many religions, cultures, and individuals around the world attach spiritual and religious values to the earth and ecosystems or their components, or find deep spiritual inspiration in their experience of nature. These values are found everywhere in the world, in industrialized as well as traditional and Indigenous societies. These beliefs and experiences provide a sense of deep purpose and profound meaning to human life.
Knowledge systems and education	As the primary context of human existence, perception of the Earth's ecosystems and their processes and functions are the foundation for all human knowledge systems. Ecosystems influence the *types* of knowledge systems (traditional and formal) developed by all cultures and societies. Ecosystems and their components and processes are the basis for both formal and informal education. Observation of ecosystems at all scales is increasingly the basis for technological problem-solving, for example, through biomimicry. Language, knowledge, and the natural environment have been intimately related throughout human history. *(TEEB)*
Cognitive development, psychological and physical health and well-being	Direct contact with nature is essential to support human cognitive development and psychological health. Two key benefits are decreased incidence of crime and improved socialization. It is also proven to support physical health and healing (in addition to benefits that come through physical exercise). (*see WHO-CBD 2015*)
Aesthetic experience	Humans experience the world through sensory perception and cognitive interpretation. Aesthetic experience refers to the cognitive and associated emotional response to perceived beauty in any form. The appreciation of beauty in the sounds, sights, scents, and sensations of nature is of recognized importance to the human condition and is documented throughout history, across cultures and traditions. While aesthetic experience can be a powerful source of inspiration for creative works or spiritual beliefs, the experience of aesthetic appreciation itself is highly significant in human quality of life by supporting emotional, psychological, and (by extension) physical health. ***Continued on next page…***

Ecosystem Service (ES)	How Benefits to Humans Are Derived from the ES
Inspiration for human creative thought and work	Nature has always been and continues to be an important source of inspiration for much human art, literature, folklore, music, architecture, industrial design, symbols, and science. *(Adapted from MA and TEEB)*
Recreation, ecotourism	Nature-based recreation and leisure are highly valued aspects of life for people around the world, whether in urban, rural or remote wilderness settings. These activities, and ecotourism, are all dependent on the direct experience of nature and engagement with it in some form. They provide significant quality-of-life benefits, including physical, psychological, and emotional well-being. These activities generate direct economic benefits to society, but can be a contributing factor to ecosystem degradation if not wisely managed.
Sense of place	Sense of place is experienced by individuals and can be shared collectively within groups and whole communities based on common and shared experiences of a place. It is informed strongly by characteristics of that place which may be both natural and human-modified or built. Within communities, the sense of place can further inform a sense of community identity.
Supporting or habitat services – *the underlying ecosystem processes and functions that are necessary for the production of all other ecosystem services, creating the biological environment*	
Soil formation	Soil is formed through long-term processes of rock weathering and the accumulation of organic matter. Soil provides a substrate for the growth of plants, including on cultivated land, and also contributes to the natural filtration of water for human use.
Primary production	Primary production involves the formation of biomass through the conversion of solar energy (photosynthesis) and nutrient uptake by plants, contributing to plant growth and animal food webs.
Nutrient cycling	Many nutrients that are essential to life flow through ecosystems (e.g., nitrogen, sulfur, phosphorus, carbon). These nutrients are decomposed and recycled, changing forms and making them available to plants and animals, for redistribution within the system.
Water cycling	Water flows through an ecosystem in all forms (i.e., gas, liquid, solid). Within a watershed, water is absorbed by plants and transpired, returning water moisture to the atmosphere where it can cycle back to the land and oceans through precipitation. Water is thus made available to humans for a variety of uses.
Habitat	Habitats provide everything that an individual plant or animal needs to survive: food, water, and shelter. Each ecosystem provides different habitats that can be essential for a species' lifecycle. Migratory species, including birds, fish, mammals, and insects, all depend upon multiple ecosystems during their migrations. (TEEB)

TOOLS – TAB 2 – CROSS-CUTTING ISSUES AND KEY CONSIDERATIONS

Contents of Tab 2

Introduction

After initiating an ecosystem service (ES) assessment and defining the central issue to address, the assessment lead team members (see *Step 1c* in *Chapter 2*) may quickly find that they have different understandings of what ES are, the role of ES in society, and how ES can be measured and understood. The team may also have different views of how their assessment fits with other ongoing projects and issues. It is important to develop a shared understanding of ES concepts to move forward. The following cross-cutting issues and key considerations are essential to an understanding of ES dynamics.

Issue 1. Assessment Scale

An important and sometimes challenging issue when assessing ES is determining at what scale the assessment should be conducted. The answers to assessment questions are often scale sensitive, that is, the answer received depends on the scale (in both space and time) at which the question was posed. Some patterns or processes are evenly distributed through space and time, and therefore observable at any scale. More frequently, phenomena are not equally distributed in space and time; they are "lumpy" and therefore patterns will look different depending on the scale at which they are being observed. Some processes or patterns related to ES may only appear at certain scales. This issue is closely tied to how the boundaries of an assessment are defined—as noted in other issues below, the production and consumption of ES are not neatly defined in the way that jurisdiction boundaries are.

Choosing the scale of the assessment actually means considering multiple issues. First, what are the boundaries of the assessment? The boundaries will be chosen based on the area that will potentially be impacted by a decision, including the area containing stakeholders that may be affected and the area in which affected ecosystem processes will be impacted. To determine the boundaries of the assessment, the scale of production and consumption of each ES must be looked at. Second, what is the spatial grain at which data will be collected? This will depend on how detailed the results need to be, as well as data availability for each ES.

Three broad approaches[169] to consider for choosing the scale of an assessment are:

1. Choose the "right" scale, one that is relevant to policy-makers but still at fine-enough resolution to be able to capture system variability and processes. An assessment scale would be two to three times larger than the grain of important underlying processes, and the resolution two to three times smaller.

[169] Scholes et al. 2013. Full citations for references in these footnotes are provided in *Sources Cited* at the end of this Toolkit.

2. Conduct a "multi-scale" assessment, which means doing a study at several scales. Multi-scaling is often necessary because the assessment is interested in several processes that may operate across widely different characteristic scales. Alternatively, it may be because there are several important stakeholders operating at different scales, or because ecosystem processes occur at several scales. With this approach, it is important to harmonize methods and datasets across scales. This approach may require significant resources.

3. Conduct a "cross-scale" assessment, which focuses on drivers of change and their impacts across scales, or on how changes in the system percolate across scales. This is also a multi-scale assessment, but there is a particular focus on how variables in the system interact across the scales. Examples of cross-scale interactions include the impacts of international-scale policies on the collapse of local fisheries and the effects of a global market on local-scale management practices, or the effects of region-scale drought on global food prices.[170]

The UN *Millennium Ecosystem Assessment* (MA) found that a multi-scale approach is necessary when any or all of the following apply:

- the problem being addressed, or objectives to be met, intrinsically require a multi-scale approach;
- the responses require syntheses of data across scales;
- analysis of causality and trade-offs are important to users; and/or
- a sense of ownership of the assessment is required from stakeholders at different scales.

Four reasons for going multi-scale

- Permits individual ecological and social processes to be assessed at the scale at which they operate and to be linked to processes at different scales and levels of social organization.
- Allows progressively greater spatial, temporal or causal detail to be considered as the scale becomes finer.
- Allows for independent validation of larger-scale conclusions by smaller-scale studies and creates a context at larger scales for findings at smaller scales.
- Permits reporting and response options to match the scales at which social decision-making occurs, with which people can relate, and on which they can act—the local community, the province, the nation, the regional bloc, and the planet.

(quoted from Scholes et al. 2013: 21)

Issue 2. Flows of ES Across Time and Space

Scale issues extend to how ES and their benefits to people are produced, distributed, and received across space and time. The schematic diagram shown in *Figure T2.1* was developed for the ARIES modelling tool.[171] It illustrates the spatial dynamics of ES production, flows, and uses. Note that the *sources* of ES are not necessarily in the same locations as the *beneficiaries*. Multiple ES can flow from the same source to beneficiaries in one or more locations. Multiple benefits can flow from different sources to the same beneficiaries simultaneously. Interruptions (or leakages) in the flow may occur anywhere along the line, implying that not all of the ES produced at a source reaches the beneficiary population. A *decision site* that is in a separate location from human populations may still have significant impacts on the delivery of essential and valuable ES benefits to people "downstream" by altering the flow of ES along its pathways from source to beneficiary. These flows, leakages, and decision sites and their connections may not always be visibly apparent, so understanding them requires mapping from both biophysical and social science perspectives. Political and administrative jurisdiction boundaries rarely correspond to ecosystem dynamics, with the exception of watershed agencies which are haracteristically bounded by natural hydrological systems. An ES assessment, and any policy or decision-making process that incorporates ES considerations, may achieve the most useful and robust results by focusing on the ecosystem *serviceshed*—that is, the area in which the ES are produced and the pathways through which the benefits of those ES are received by people.[172]

When considering the area to include in an assessment, the following should be taken into account (these issues are included in *Worksheet 1*, through which the

170 Scholes et al. 2013 provide a list of tools that may be helpful for conducting multi-scale assessments of ES.
171 See *Tools – Tab 7: Compendium of Data Sources, Analysis Methods, and Tools* for a summary factsheet about ARIES.
172 Tallis et al. 2015 explain that focusing on the ES serviceshed will "more accurately reflect cumulative impacts and variation in environmental quality, social needs and value preferences."

assessment team defines the assessment context):

- policy and jurisdiction boundaries at all scales (e.g., municipal, regional, watershed, province/territory, federal);
- area anticipated to be directly affected by the problem or decision;
- areas that contribute to the production of ES; and
- area beyond the site of direct effect that may also be affected by the problem or decision due to air and water flows, and movement of animals and insects into and out of the area that is believed to be *directly* affected; these processes are likely to expand the zone of impact beyond the immediate problem or decision site.

ES flows across time are important to consider as well. ES that are not considered to be important by society today may be important in the future or may be important for the *resilience* of desired ES across time. Changing values and priorities, and even increasing and migrating human populations, may result in changes to perceptions regarding which ES are considered important. In addition, consideration of how ES may change across time and how to manage for the resilience of the entire system in the long term is always warranted. A precautionary approach may apply in relation to the dynamics of some ES that are important to the functioning of the entire system, especially as there are limits to knowledge about the functioning of complex systems.

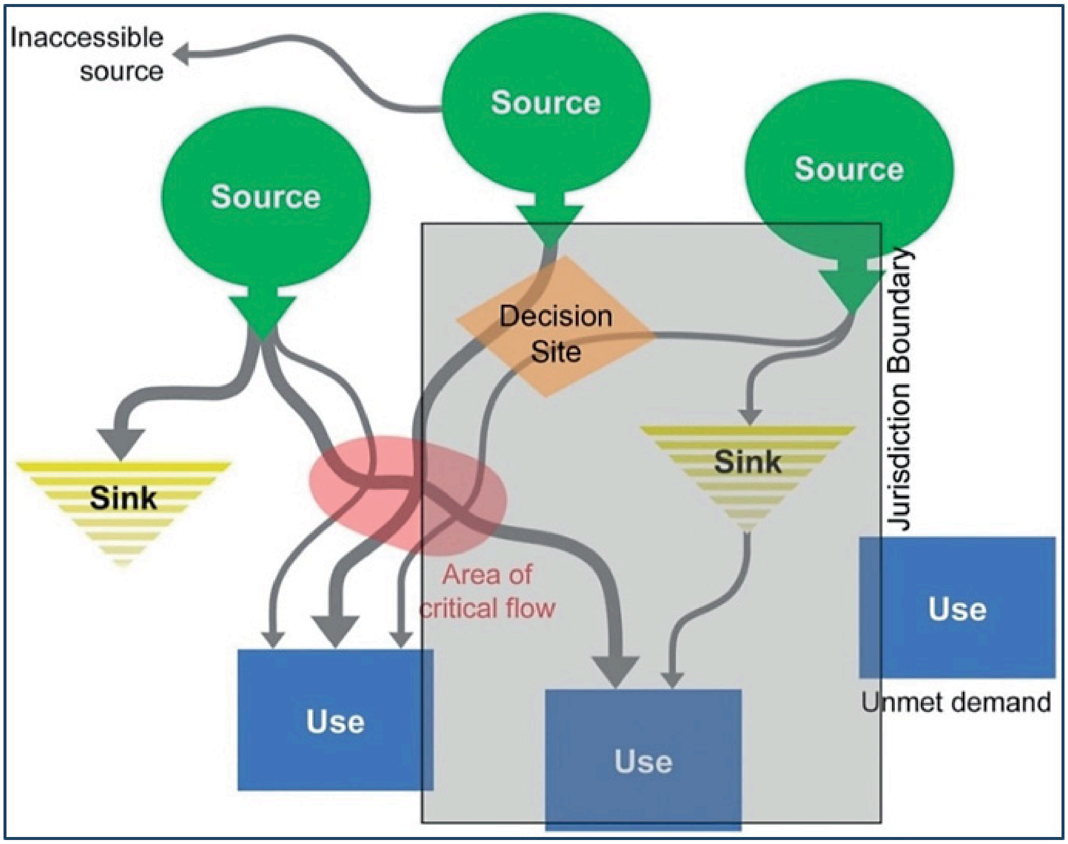

Figure T2.1. *Schematic diagram to illustrate spatial relationships between ES sources, flows, policy boundaries, and the influence of decision site placement on ES flows. The ARIES conceptual model of ES flow dynamics. Reproduced and adapted from Villa et al. 2014. Jurisdiction boundary added for illustration.*

Issue 3. Resilience and Social-Ecological Systems

In the context of ES, "resilience" relates to a system's capacity to sustain a desired set of ES in the face of disturbance, ongoing stress from different impacts, and change. When a system loses resilience, it may not be able to continue to provide the desired ES, which in turn is very likely to impact human well-being. Understanding how elements within a system are connected can help in the management of ES resilience. For example, the long-term resilience of crop production may rely on healthy soil formation, nutrient cycling, erosion control, and other, less obvious, ES. It is, therefore, important in ES assessments to make sure that all important aspects of the system are taken into consideration.

Seven generic policy-relevant principles have been identified[173] for enhancing the resilience of desired ES in the face of disturbance and ongoing environmental change:

- **Maintain diversity and redundancy.** Diversity in a social-ecological system (SES) context may relate to biodiversity, spatial heterogeneity, livelihood strategies, and institutional diversity. Combined with redundancy of system components and processes, diversity provides buffering capacity and "insurance" against ongoing stress and shocks, and supports the provision of multiple benefits.
- **Manage connectivity.** Connectivity among system components, including resources, species, and social actors, can influence the resilience of ES depending on the strength and structure of linkages.
- **Manage slow variables and feedbacks.** Slowly changing system variables are often key components of a system. Changes in slow variables and the system feedbacks they are associated with can lead to abrupt threshold effects and the sudden loss of desired ES.
- **Foster an understanding of SES as complex adaptive systems (CAS).** Understanding the interdependent and tightly coupled nature of human and natural systems has implications for their management. CAS are characterized by dynamic behaviour and a capacity to self-organize. ES are nested within these systems at multiple and interacting spatial scales.
- **Encourage learning and experimentation.** Uncertainty, change, and surprise are inevitable in complex SES, hence there is a constant need to add to and revise existing knowledge and enable adaptation.**Broaden participation.** Participation of diverse groups of stakeholders who may benefit in a variety of ways from ES is central to facilitating collective action in response to disturbance and changes in the supply of ES.
- **Promote polycentric governance systems.** Having multiple governing authorities at different scales enables governance to better match the scale of the problem and offers a degree of modularity, providing some redundancy when needed, as well as enhanced opportunities for learning and experimentation to better govern ES.

Issue 4. Cumulative Effects of Change and Thresholds of Ecological Resilience

"Cumulative effects" refers to the incremental effects of multiple, interacting stressors on ecosystems and social-ecological systems through time. The concept of cumulative effects builds on the recognition that a single, incremental action may have minimal effects but when combined with other actions in the same geographic area, there is an accumulation of effects that may become significant. The accumulated impacts weaken the ecosystem's ability to function normally, which also reduces the ability of the ecosystem to provide ES. *Figure T2.1* illustrates how impacts in one area can affect ES in other areas by interrupting the flow of natural processes.

When decisions are made that can affect the provision of ES, responsible practice can include analysis of cumulative effects to address how the current decision contributes to processes already underway as a result of previous events or activities and, in light of current trends and probable activities, in the foreseeable future. Procedures for cumulative effects assessment, or cumulative impact analysis, have been evolving since the 1970s, and users of this Toolkit are referred to current publications for that advice.[174]

Multiple stressors are not simply additive. They can behave in synergistic or dampening ways, and result in unexpected outcomes. The point at which a system loses the ability to maintain normal system dynamics is referred to as a threshold, or a tipping point. Once a threshold is reached, further impacts will cause major system change that is often abrupt and can include the loss of critical ecosystem functions, and the ES associated with them.[175]

173 Adapted from Biggs et al. 2012.
174 See the review article by Duinker et al. 2013; also for a focus on biodiversity, see Burton et al. 2014; and for ES, see Halpern and Fujita 2013. The Canadian Environmental Assessment Agency produced a guide to cumulative effects—see Hegmann et al. 1999.
175 Scheffer and Carpenter 2003.

Anticipating *precisely* how much stress a system can handle is nearly impossible,[176] so the precautionary principle[177] should be applied. In systems approaching critical thresholds, assessment methods should focus on the resilience of ES, their proximity to thresholds, and associated risks for people.[178] Research is advancing on the subject of thresholds, tipping points, and limits in the context of ES, among the mandated issues for the European Union's (EU) OpenNESS project.[179]

EXAMPLE: Cumulative Effects Management (CEM) and ES in Alberta Policy

"Cumulative effects" are defined in the 2008 Alberta Land-use Framework (p. 51) as "the combined effects of past, present and reasonably foreseeable land-use activities, over time, on the environment." This can occur, for example, when new development begins in an area that already has environmental impacts from previous activities. Cumulative effects also result when multiple activities occur across an area and lead to synergistic and sometimes rapid impacts on the environment. Wetland loss is a prime example of cumulative impact on ES, because the loss of many small basins collectively results in large cumulative effect.

CEM aims to set environmental objectives in consideration of their social, economic, and environmental consequences and to manage activities through a process of continuous improvement to achieve those objectives. It is not an add-on to Alberta's current management system, but an evolution of that entire system.

ES considerations can support CEM by providing:

- physical science-based and social science-based evidence of society's benefits and dependence on ES for human well-being (e.g., clean water, fresh air, food);
- qualitative and quantitative data on the cultural and economic benefits derived from the environment in a place-based context; and
- integrated information on the biophysical, economic, and socio-cultural dimensions of environmental resources to support trade-off discussions in decision-making, policy, and planning.

Issue 5. Drivers of Change

The UN *MA* examined how different external factors directly and indirectly contribute to change in ecosystems, and thus ES provision (as shown in *Figure T2.2*). "A direct driver unequivocally influences ecosystem processes, while an indirect driver operates more diffusely, by altering one or more direct drivers. The indirect drivers are underlying (root) causes that are formed by a complex of social, political, economic, demographic, technological, and cultural variables. Collectively, these factors influence the level of production and consumption of ES. The causal linkage is almost always mediated by other factors, thereby complicating statements of causality or attempts to establish the proportionality of various contributors of change."[180] Interactions among drivers, ecosystems, ecological functions, and ES can take place at more than one scale and can cross scales. For example, an international demand for timber may lead to a regional loss of forest cover, which increases flood magnitude along a local stretch of river.[181]

176 Especially since stresses to ecosystems are many and wide ranging, highly variable in nature and intensity, and their synergistic effects have rarely been measured.

177 Using the precautionary principle means that "where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation" (United Nations General Assembly 1992). For a full discussion of the precautionary principle, see Iverson and Perrings 2011, and Gardiner 2006.

178 Farley 2012; see www.regimeshifts.org for more information on regime shifts. See also Weber et al. 2012 special issue of *Ecology and Society* on diverse aspects of cumulative effects.

179 See Jax 2014.

180 Tomich et al. 2010: 88.

181 *UN Millennium Ecosystem Assessment* 2005, from description of Figure B, p. iv.

Drivers of change are important to include in ES assessments as they lead to changes in ES and human well-being. For example, an impact assessment focused on the impacts of housing development on soil erosion could also take into account the other drivers of change that are impacting erosion. This could help to understand and manage all the key variables and to understand whether impacts from housing development will be small or large in comparison with impacts from other drivers. It is a good idea to consider which drivers are important in a system at the beginning of an assessment and determine how they should be incorporated into the assessment. Even if a quantitative assessment of all drivers is beyond the scope of an assessment, listing important drivers and how they may be impacting the system is still an important step towards better understanding of the system.

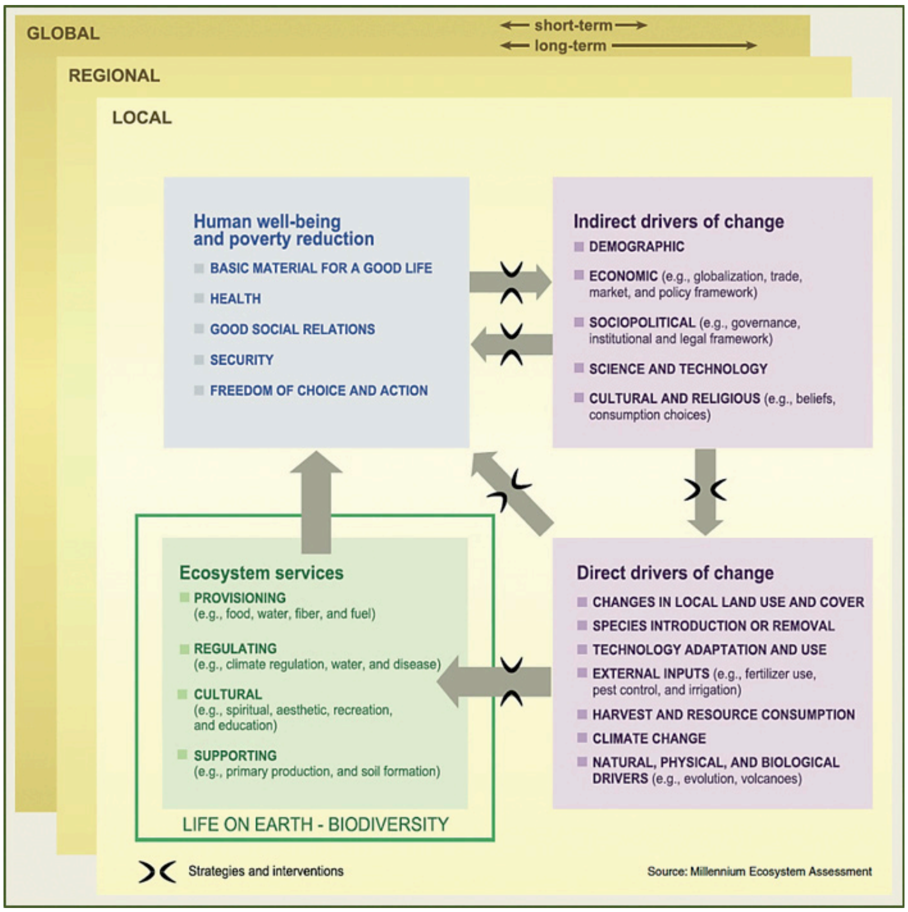

Figure T2.2. *Conceptual framework for the UN Millennium Ecosystem Assessment, showing the main indirect and direct drivers of change to ecosystems and ES. (MA 2005: Figure B, p. iv)*

Issue 6. Biodiversity and ES: Compatibilities and Trade-offs

The relationship between biodiversity and ES is of interest to many people and organizations, because existing biodiversity programs within governments are seen as a natural fit for initiating ES programs or incorporating ES concepts. Further, the policy connection between biodiversity and ES has been formalized by international work and commitments made under the UN *Convention on Biological Diversity* (CBD), and by the UN Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES).

Biodiversity conservation and ES management can be complementary, but they are not the same thing. Biodiversity experts may or may not be familiar with ES concepts, and may or may not agree with the values or philosophy behind ES concepts. The ES concept was developed by conservation biologists in response to what they recognized as a lack of traction in their attempts to promote biodiversity conservation. They believed that appealing to people's self-interest could boost interest in management and conservation. It is important to recognize that while biodiversity and ES issues can sometimes be addressed and managed simultaneously, context-specific assessments of their linkages, associated values, and incompatibilities are key to identifying when this is possible, and when separate management approaches are necessary.

Biodiversity and ES (see *Tools – Tab 9: Glossary*) are not the same thing, but they are interdependent. The relationship between ES and biodiversity is the subject of much academic work, but there is still much to be learned.[182] Biodiversity is known to be directly important in the provision of some ES, and is important to the resilience of many ES through the redundancy of ecological functions (i.e., multiple species within an ecosystem perform (some of) the same functions, and this provides an insurance against loss of function if one of the species disappears or can no longer perform the function).

Due to the difficulty of collecting data on ES at particular sites, biodiversity data can sometimes be used as proxies for certain ES. While ecosystem components (such as the structure and composition of ecosystems and, particularly, biodiversity measures) are difficult to measure directly, more information about them is available than for many ecological functions at any given site, because the structure and composition of ecosystems are more readily observed and measured than the dynamics of ecosystem processes.

Practically speaking, many of the tools and principles of biodiversity assessments, as well as the lessons learned by conservation planners, provide valuable insights and starting points for ES planning. For some ES, the data, techniques, and software provided by biodiversity assessments already exist and are well suited for planning for ES.[183] In particular, mapping software and land-cover proxies that are used to estimate biodiversity may also be used to estimate some related ES. Since decision-makers sometimes want to assess both biodiversity and ES for conservation planning, many of the new tools being developed for the assessment and modelling of ES also include biodiversity assessment. For example, InVEST and other ES models provide mapping tools for comparing biodiversity and ES distributions and impacts.[184] Many of these models also facilitate valuation of ES.

In terms of policy, there may be synergies or trade-offs between biodiversity conservation interests and ES management. Knowledge about ES is likely to make clearer and more direct the connections people have with ecosystems on many levels. However, the importance of ES and ecological processes do not always align (e.g., fire may be needed for long-term sustainability, but has immediate negative effects on humans). An ES approach should not obscure the importance of biodiversity and other variables important for the long-term sustainability and resilience of social-ecological systems, or impede public understanding of these things. As many advocates point out, ES approaches should be *one of a set of tools* used in pursuit of conservation or ecosystem management.

182 This relationship is the subject of one task area in the EU OpenNESS initiative; see also de Groot et al. 2014.
183 For example, van Jaarsveld et al. 2005 used an irreplaceability analysis (Ferrier et al. 2000) to generate maps of priority areas for ES. Software such as C-Plan (Pressey 2009) and Marxan (Ball et al. 2009), which are underpinned by explicit targets for biodiversity features and generate maps of irreplaceability, lend themselves easily to ES assessments.
184 Nemec and Raudsepp-Hearne 2012. See *Tools – Tab 7: Compendium of Data Sources, Analysis Methods, and Tools* for a factsheet about InVEST.

Issue 7. Uncertainty and Data Gaps

Complexity and uncertainty arise from a number of sources, such as:

- incomplete and imperfect data;
- uncertainty about the course of future events and about the effectiveness of responses to those events;
- uncertainties about how complex systems work in general; and
- uncertainty about how key ecosystem components interact (e.g., how important drivers of change impact key ES and, in turn, aspects of human well-being).

It is fundamental to good scientific practice to accompany key assertions with some measure of the confidence in those findings. The treatment of scientific uncertainty within assessments is an important factor influencing the credibility of the process. Clear statements of what is unknown are often as influential for policy makers as statements of what is known with relative certainty. The assessment of the state of knowledge should reflect both the type and amount of evidence (e.g., observations, interpretation of model results, expert judgment) and the level of peer acceptance or consensus. Certainty and uncertainty can be presented in a number of ways, including statistical approaches (e.g., presenting confidence limits) and qualitative approaches (e.g., attaching specific language to findings, such as "well-established" for outcomes that have a high level of agreement and amount of evidence, graded through to "suggested but unproven" for outcomes with a low level of agreement and amount of evidence). Examples of ways to communicate uncertainty are shown in *Box T2.1*, below.

Uncertainty is not a reason for not acting on issues where there is potentially significant risk of negative consequences for ecosystems or society. It is nearly always the case (not just for ES) that decisions are made with a degree of uncertainty and limited knowledge. ES assessment helps to reduce uncertainty through new knowledge and the ordering of complex information around environment-society linkages.

Toolkit users are encouraged to follow steps in *Chapter 2* on identifying data needs even if there are not sufficient data to fill those needs. A high degree of uncertainty about the extent of potential impacts to beneficiary groups or ecosystems can be used as an indication that a particular ES is a priority for assessment (see the *ES Priority Screening Tool – Worksheet 2* in *Tools – Tab 4: Worksheets for Completing ES Assessment*). Identification of data needs can also guide new research and monitoring programs.

In the key statements of high-level summaries, it is helpful to use agreed and calibrated language to express your level of certainty and uncertainty.

For quantitative analyses that lend themselves to formal statistical treatment, or for judgments where the experts are comfortable assigning broad probability ranges, the following reserved language can be used:

Virtually certain	Greater than 99% chance of being true or occurring
Very likely	90–99% chance of being true or occurring
Likely	66–90% chance of being true or occurring
Medium likelihood	33–66% chance
Very unlikely	1–33% change of occurring or being true
Exceptionally unlikely	Less than 1% chance of occurring or being true

For more qualitative statements, this language could be used:

		Amount of evidence		
		Limited	Medium	High
Level of agreement	High	Agreed but unproven	Agreed but incompletely documented	Well-established
	Medium	Tentatively agreed by most	Provisionally agreed by most	Generally accepted
	Low	Suggested but unproven	Speculative	Alternate explanations

Source: Moss and Schneider 2000.

Box T2.1 Communicating Uncertainty. *Reproduced from Ash et al. 2010, Box 4.4*

TOOLS – TAB 3 – ECOSYSTEM SERVICE ASSESSMENT INVOLVING INDIGENOUS COMMUNITIES

Contents of Tab 3

T3.1. Introduction: Purpose and Orientation of This Tool Tab[185]

This Toolkit is not a policy document, but rather is intended to provide helpful, flexible advice to support policy, management, and decision-making. This section therefore offers non-prescriptive practical advice about working on ecosystem services (ES) assessment or ES considerations that involve Indigenous communities. **The advice in this Toolkit does not supersede activities required to fulfil any legal and Constitutional obligations the jurisdiction may have. This advice does not supersede responsibilities for engaging and consulting with Indigenous communities on any issues. It does not supersede any protocols established by Indigenous communities,** even if/when such protocols are not considered legally binding. Toolkit users should consider the role and need for approval and involvement by Indigenous communities when seeking access to information with those communities for ES assessments. This is particularly so for Indigenous traditional knowledge (ITK) and the unique perspective held by Indigenous communities with respect to nature and ES. Toolkit users need to be aware of Indigenous and Treaty rights, the common law duty to consult given well established conditions, and of relevant obligations in modern treaties, including consultation obligations. In these cases, users should be guided by their jurisdictional policies and legal advice.[186] Contemplated Crown conduct that has the potential to create adverse impacts on Aboriginal or treaty rights triggers a duty to consult and, where appropriate, accommodate. An ES assessment that informs such conduct must therefore consider this duty.

The potential breadth of engagement with communities, experts, and stakeholders that is possible in the course of completing an ES assessment will vary in every case depending on many factors as discussed in *Chapter 2* and its associated *Tool Tabs*. Likewise, the potential breadth of sources of expert information, whether from peer-reviewed literature or traditional and practitioner knowledge, will also vary in every case. Indigenous communities may be among the ES beneficiaries or among those who may potentially be affected by a change in the environment for which an ES assessment is being considered or undertaken. They may be sources for documented or held ecological, socio-cultural, and economic information that could contribute meaningfully to an ES assessment or to factoring ES considerations into decisions, for example, planning for the identification of protected areas (e.g., see section *3.5* in *Chapter 3*).

[185] This Tool Tab is subject to revisions pending additional feedback from National Indigenous Organizations.

[186] Federal guidelines (Government of Canada 2011b) define **Aboriginal rights:** Practices, traditions and customs integral to the distinctive culture of the Aboriginal group claiming the right that existed prior to contact with the Europeans. In the context of Métis groups, Aboriginal rights means practices, traditions and customs integral to the distinctive culture of the Métis group that existed prior to effective European control, that is, prior to the time when Europeans effectively established political and legal control in the claimed area. Generally, these rights are fact and site specific. **Treaty rights:** Rights that are defined by the terms of a historic Treaty, rights set out in a modern land claims agreement or certain aspects of some self-government agreements. A treaty right may be an expressed term in a Treaty, an implied term or reasonably incidental to the expressed Treaty right. **Aboriginal title:** An Aboriginal right to the exclusive use and occupation of land. It is possible that two or more Indigenous groups may be able to establish Indigenous title to the same land. Additional federal guidelines (Government of Canada 1995) further explain that **Self-government agreements** set out arrangements for Indigenous groups to govern their internal affairs and assume greater responsibility and control over the decision-making that affects their communities. Broadly stated, the scope of Indigenous jurisdiction or authority likely extends to matters that are internal to the group, integral to its distinct Indigenous culture, and essential to its operation as a government or institution. The self-government arrangements operate within the framework of the Canadian Constitution; are tailored to meet the unique needs of Indigenous groups and are responsive to their particular political, economic, legal, historical, cultural and social circumstances.

This *Tool Tab* provides practical advice, including checklists of considerations that should be addressed in attempting to work effectively with Indigenous communities to identify the relevant ecosystem and social dynamics involved in the provision of ES in a region, and the importance of those ES to Indigenous communities.

This *Tool Tab* also draws special attention to *cultural* ecosystem services (CES) and how CES are intertwined with other types of ES. In particular, CES are considered both a class in their own right, and a set of services that are derived from or linked to others (e.g., harvesting wild foods is a "provisioning ecosystem service," but might also be an important CES because of the transmission of knowledge that occurs as part of that provisioning). Most CES are not widely represented in literature on ES-specific theory, methods, and case studies, and so particular care is exercised here to assist the representation of this category of ES for a more balanced approach.

T3.2. Ecosystem Services and Indigenous Communities

In the context of Indigenous communities (and some other non-Indigenous traditional communities) whose day-to-day lives and livelihoods are closely tied to the environment through their customary practices, the overlap of benefits from different ES can be especially strong.

All types of ES are potentially relevant for Indigenous communities and this may include relying on certain ES to support commercial activities such as logging, trapping or nature-based tourism, among others. Contemporary economic activities may or may not have a basis in traditional cultural practices, but will likely be informed by them. Identifying such economic benefits as well as the socio-cultural benefits of ES to Indigenous communities can provide information to support decision-making. Understanding how different ES benefits should be analyzed and represented in an assessment can benefit from the advice of relevant knowledge holders in those communities. Different worldviews give rise to different ways of thinking and talking about nature. An assessment team has to be mindful of how this can affect their understanding of information shared with them or found in documents.

T3.3. Traditional Knowledge As an Information Source for ES Assessment

Traditional and contemporary Indigenous knowledge can include detailed information about the dynamics, status, and trends of biodiversity and ecosystems within traditional territories and, as a result, the holders of such knowledge can be beneficial sources for an ES assessment. For example, working with individual hunters, hunter and trapper associations or wildlife management boards, it is possible to identify and map

EXAMPLE: Hunting involves regulating, provisioning, and cultural ES

For example, hunting activity results in the benefits of the provisioning ES of wild food and materials for ceremonial activities and regalia, as well as clothing, material goods, and art. At the same time, for most Indigenous cultures, hunting is recognized as a sacred activity that is as much about material subsistence as it is about their reciprocal and spiritual relationships with animals, rivers, seascapes, landscapes, and the environment more broadly. It is also an essential activity through which ITK and cultural identity are shared from one generation to the next and societal cohesion and cultural identity is maintained. From an ES assessment point of view then, the importance of hunting *cannot* be represented only through the value of food.[187] History itself is written on the landscape, and is recalled and maintained by being present on the landscape through the retelling of both oral tradition and stories in situ. The ways that ecosystems support and inform cultural identities and knowledge systems—in this case the transmission and continuation of ITK—are core CES.[188]

[187] For a deeper explanation of this, see Chan, Satterfield, and Goldstein 2012. Full citations for references in these footnotes are provided in *Sources Cited* at the end of this Toolkit.

[188] See *Tools – Tab 1: Ecosystem Service Descriptions* for explanation of all types of ES including CES, and see discussion on CES in *Tools – Tab 6: Values and Valuation: Economic and Socio-cultural.*

the areas of many different species of flora and fauna, including migratory routes and times of year; animal behaviour, including health; changes in habitat due to, for example, fires and floods as well as industrial activities; water quality and quantity over time; and much more. ITK can also be a primary information source about how a culture or community interacts with, and benefits from, biodiversity and ecosystems—and all types of ES.

The use of ITK by governments, research organizations, and others to better understand the environment is becoming increasingly common. For example, ITK is referenced in the federal *Species at Risk Act* and *Canadian Environmental Assessment Act*. As the Canadian Biodiversity Strategy highlights:

> *Many communities, families and individuals have accumulated traditional knowledge that is relevant to the conservation of biodiversity and the sustainable use of biological resources. This knowledge may relate to harvesting resources, planting crops, using natural herbs and other material for medicinal purposes, and understanding changes that have occurred to local biological features and landscapes. Traditional knowledge can provide an excellent basis for developing conservation and sustainable use policies and programs.*

Two main considerations when accessing ITK and other ES-related information from Indigenous communities are (1) appropriate protocols for access or engagement; and (2) sharing of benefits that may arise as a result of the use of their knowledge. These are the subjects of the following two subsections.

T3.3-1. Appropriately Accessing ITK and Other ES-related Information from Indigenous Communities

As far as possible, Toolkit users should engage Indigenous groups prior to commencing an ES assessment, that is, in the proposal/design phase. This is a key element of working effectively with Indigenous communities.

Relevant authorities in an Indigenous community as described in the checklist below should be recognized as having the authority to determine whether access will be granted, and to control access. It is important for the assessment team to find out whether there are existing engagement protocols to be observed. Indigenous communities may hold documented sources of ITK and other ES-related information in reports or publications. As with verbal information, appropriate permissions should be sought when seeking access to such sources. ITK and other ES-relevant information have also been documented and published by both Indigenous and non-Indigenous researchers and may be located through conventional literature searches (e.g., in university libraries). There may be an interest in seeking community agreement and interpretation as necessary for any given cultural context with the content of existing ITK documents.

Access to some or all information contained in ITK may not be granted, despite the intentions or assumptions of an assessment team. Researchers need to be prepared to invest time in relationship building with the community to build genuine trust necessary to gain access in certain places. Maintaining effective relationships between Indigenous peoples and other parties involved in conservation management decisions is required to facilitate a meaningful exchange of knowledge. Individuals seeking access to ITK need to respect the pertinent protocols.[189] This is likely to include agreement on any information that must be held as confidential and on clarification on what mechanisms exist to guarantee confidentiality. There may be some information for which governments cannot guarantee confidentiality, and such limitations should be clearly stated before any information is accessed from Indigenous communities.

The following checklist illustrates a possible process for accessing information about the benefits of many types of ES (from all ES categories) to an Indigenous community, and how important those ES are to the community.

1. **Decision-making authority.** Understand and confirm who has decision-making authority over what information is shared and how it is used. This may be leaders in Métis, First Nation or Inuit communities or organizations. It may be an elected official, chief or council, hereditary chief(s), or individuals who are "keepers of the knowledge." Sometimes it is family groups in reference to specific use sites, and "family" may be differently defined across communities (e.g., immediate family, lineage, clan). In self-governing First Nations, it may be administrators (e.g., band managers, natural resources officers, staff). Where possible, seek written confirmation from communities that the individual whom the team is speaking to is the appropriate representative. In addition, there are often multiple groups who need to be aware of the requests for access to ITK, such as Indigenous development corporations, renewable resource or hunter trapper committees, tribal councils, and/or self-government representatives.

[189] The advice in this segment pertains to Indigenous peoples in Canada. Most of it is drawn from many years of anthropological experience working with First Nations on the west coast. It is structured so as to be applicable to most Indigenous communities who live in or access (at least part of) their traditional territories and/or who maintain many of their traditional cultural practices. The section includes text provided by Terre Satterfield, based on Satterfield et al. 2011.

2. **Expectations and objectives.** Work with the community to clarify the expectations and objectives for engagement of each party, including practices or protocols that ensure mutual respect for working with Indigenous communities.[190] In certain cases, the federal, provincial, and territorial governments have legal obligations with prescribed procedures for engaging with Indigenous communities—particularly when a treaty or comprehensive land claim agreement is in place. At the very least, designate in advance and be transparent about (1) what the information collected will, can, and cannot be used for; (2) who owns the "data" or knowledge collected; and (3) what kinds of things legally or otherwise the information cannot be used for or applied toward. Clarify in advance the nature of any agreement, including whether there is a need for an agreement signed by all necessary authorities, as well as consideration of how the knowledge will be used by the party accessing that knowledge.

3. **Knowledge authority**. Identify ITK holders and understand who has knowledge authority. This may be leaders in Métis, First Nation or Inuit communities or organizations. It may be an elected official, chief or council, hereditary chief(s), or individuals who are "keepers of the knowledge." It may be family groups however defined (e.g., clan, lineage).[191] ITK holders or community representatives may be any community members, such as harvesters, elders, women or youth. It is important to acknowledge that persons recognized within their communities to be experts (i.e., appropriate representatives) may be chosen by community leadership to participate in the ES assessment. Indigenous communities are likely to include one or more individuals who are respected as experts in ITK, and this expertise should be recognized appropriately by the assessment team. The assessment team should, from the start, seek to understand the community's views about ownership, control, access, and possession of their ITK and discuss with ITK holders how best to address these views in line with 1. and 2. above. Assessment team members must also respect and support community discretion to share or withhold ITK. In some Indigenous communities, the relevant wildlife or renewable resource management boards and councils can be potential sources of ITK, as some of them may collect, support or commission the collection of ITK for use in meeting their management goals, which could be disseminated if requested.

Protocols or policies for research involving ITK have been developed by Indigenous, governmental, and intergovernmental organizations.[192] The community may have already developed protocols on the specific processes for accessing ITK and ITK holders.

T3.3-2. Sharing of Benefits Arising from the Use of ITK

A second key consideration when accessing ITK is how the Indigenous community will benefit from sharing their knowledge, such as, among others:

- through increased environmental protection of the local environment;
- collaboration, co-operation and contribution in scientific research;
- collaboration, co-operation and contribution in education and training;
- capacity building (e.g., to preserve ITK);
- access to scientific information relevant to conservation and sustainable use of biological diversity;
- institutional and professional relationships; and
- remuneration for expert advice and services.

Benefits should be communicated to the community in advance of the work.

Indigenous communities may be apprehensive about the use of their knowledge to complete an ES assessment. It is essential to inform them about why this information is being requested, how it would be used, with whom it would be shared, and to agree with them on how they would be involved if they chose to do so. Indigenous groups need certainty that sensitive information will not be appropriated or used in a manner they do not deem acceptable.

190 Before engaging any Indigenous community to collect data, read the *Tri-Council Policy Statement on Ethical Conduct for Research Involving Humans*, (TCPS 2010). Chapter 9 addresses research involving Indigenous people in Canada. http://www.pre.ethics.gc.ca/eng/policy-politique/initiatives/tcps2-eptc2/chapter9-chapitre9/#toc09-1

191 See Davis and Wagner 2003 for more explanation on the importance of identifying "experts."

192 For example, Deh Cho First Nation 2004; Fedirechuk et al. 2008a; Fedirechuk et al. 2008b; Gwich'in Tribal Council 2004; Government of the Northwest Territories 2005; Government of the Northwest Territories n.d.; Inuit Circumpolar Council Canada n.d.; Mackenzie Valley Environmental Impact Review Board 2005; Sambaa K'e Dene Band 2003; Assembly of First Nations Quebec-Labrador 2014; and Armitage and Kilburn 2015.

T3.4. The Importance of Nature and Ecosystems in Indigenous Communities

ITK is increasingly recognized as an important source of information for understanding the environment and for understanding the relationships that Indigenous cultures have with the environment. ITK is important in ES assessment for understanding the complex dynamics of ecosystems, including environmental change seasonally (e.g., hydrological cycles associated with freezing and thawing in the north) and as a result of irregular events (e.g., forest fires), species behaviour (both flora and fauna), and other biophysical characteristics.

ITK is unique in also importantly helping to understand the ways that Indigenous communities interact with other species and the ecosystems they live in. Based in their worldview, ITK helps others to understand Indigenous views about human responsibilities. It also reveals the social and cultural importance of species and ecosystems in terms of the benefits people receive and practices that may enhance, reduce or mitigate the processes generating ES. Further, through documented sources, ITK, and appropriately respectful ethnographic interviews, it can be possible to learn from Indigenous communities about how important these relationships are in their lives.

ITK can help people to understand how the worldview held by different cultures is integrated into their practices, beliefs, and knowledge systems, but also written onto the landscape itself (e.g., some histories can only be told at the locations where events occurred). Many Indigenous cultures have what is sometimes referred to as a "relational" worldview, in which all life is understood to depend on and succeed through maintaining respectful, reciprocal relationships. This is not just a "school of thought," but a foundational way of understanding life in the world. Assessing the importance of "nature" in the context of cultures holding such worldviews requires respect for the ethical and moral values, beliefs and epistemological frameworks, and principles that inform how people live, including these relationships that are sometimes referred to, and thought of, as kin relationships (family).

An approach that oversimplifies these connections, or that focuses on only a single type of ES benefit or use, would not be logical or culturally appropriate and would most likely be considered disrespectful. For example, Indigenous communities may object strongly to applying a monetary value to nature or its components. It is important for any government officials or their contractors who are requesting this information to understand the sensitivity behind it. Other ways of documenting importance, such as description, may be preferred by the community.[193]

The checklist below illustrates a possible process for completing a cultural ES assessment in Indigenous communities.[194]

In all cases below, recognize that these kinds of information might be important, even if it is unlikely that the "ES beneficiaries" (the Indigenous community members) would be willing to share some of it, especially the locations, with an ES assessment practitioner. Some of the hoped for information may be already available in document form. While there are available publications containing information sourced from ITK, in most cases this information is not publicly available in the peer-reviewed sources that are most often used to complete an assessment. Yet multiple important sources do exist and can greatly enhance the quality of an assessment. These generally exist in the ethnographic, ethno-botanical, ethno-zoological, ethno-ecological, and anthropological record and literatures.[195] In other cases, interviews, transect walks, place mapping, and so on, will be necessary.[196] Ethnographic research in Canada's northwest has demonstrated that people are sometimes more able to discuss their knowledge of the environment, including cultural stories and meanings, when they are present in that environment.[197] This can be an important consideration when planning information gathering.

Flexibility for designating critically important no-go zones is key, not just because of the material needs that might be met by those sites (e.g., harvesting food) but also because those particular activities allow the nourishment of cultural continuity and well-being and may be associated with potential or established Indigenous and Treaty rights and related interests.[198]

[193] Communities may also be receptive to alternative trade-off methodologies such as the analytical hierarchy process, which uses pair-wise comparisons of outcomes to determine preferences. For a description of this method, see Martin-Ortega and Berbel 2010.
[194] Checklist and advice on ranking in this segment provided by Satterfield, based on Satterfield et al. 2011.
[195] The use of "ethno" as a prefix refers to culture, e.g., ethno-botany is the study of a culture's knowledge about botany, typically grounded in their cultural identity, including traditional practices and language.
[196] For description of some of these methods, see *Tools – Tab 7: Compendium of Data Sources, Analysis Methods, and Tools.*
[197] Cruikshank 2005.
[198] For explanation of the extra-material importance of valued ecosystem components, see Garibaldi and Turner 2004 on cultural keystones.

The list below assumes that some mapping/designation of the geographic area associated with traditional activities has already occurred. In all cases below, the instruction to "identify" should be understood as the outcome of either a literature search or an appropriately respectful interaction with knowledgeable members of an Indigenous community. ➔ Remember, **these are questions that an assessment team should ask of the *documents* that they are reviewing.** If an Indigenous community consents to participate in the assessment, these points would be the basis for designing appropriately respectful interview questions. The role of the community in specifying how and when the activities below will be included should be discussed and agreed upon at the beginning of the assessment. Existing literature should be used as a reference point or for background, but community representatives should always have the opportunity to validate it before it is used as it may be outdated or incorrect.

1. Based on existing current expert literature or through new data collection with recognized community experts (see point 3 in section *T3.3-1* above on identifying ITK holders with knowledge authority), list **species and where they are harvested** for fresh water, medicinal plants, food plants, edible grasses and marine plants, terrestrial and marine mammals, fowl, bird or other.
2. Identify which species, sites or nature-derived materials in item 1 (above) are used when transacting any kind of **cultural practices**—naming ceremonies, potlatching of feasting, events that witness key relationships and decisions between groups or with the Crown and/or other governance parties, events that recognize births, deaths, marriages, adoptions, assignation of hunting or fishing rights, recognition of educational, legal, civic or athletic achievements, community celebrations and hosting of outside guests and dignitaries, and so on.
3. Identify which of the species, sites or nature-derived materials identified in item 2 (above) are most commonly, widely or importantly used for **knowledge transmission** and teaching future generations—which are key to potent moments for one-to-one or group-based learning.
4. Identify which species, sites or nature-derived materials are key for **trading and transacting** with other groups, nations or community members.
5. Identify which species, sites or nature-derived materials are key for **commercial livelihood**, if applicable.
6. Identify, in general, what **places** are important even if they are not visited (or not supposed to be visited). There are likely to be restrictions on the circulation and identification of place names, and information associated with these sites may be deemed culturally sensitive.
7. Identify where **ancestors** lived, are buried or reside in afterlife (this can include important middens, burial sites or natural features such as trees said to be occupied by spirits of ancestors).
8. Identify where **important sites** are (named or unnamed) and, if possible and relevant, the place names and their meanings.
9. Identify where **history "lives on the land,"** meaning where stories of ancestors, origins or other historical or oral histories are told and/or what places are linked to those stories, whether one goes there or not. Ask where any objects are that have been modified by past groups or ancestors (e.g., petroglyphs, culturally modified trees or landscapes).

While virtually all information generated by responding to this list will likely be important, some things will be critically important because, for instance, the same species, site or nature-derived material might be key to all of these cultural practices or a subset of them, or because they will be implicated by Indigenous or Treaty rights. At the very least, this allows for some ability to conduct a relative ranking of the importance of key species and sites. Indigenous communities may reject the idea of ranking elements of nature as incongruent with a holistic and relational worldview, and therefore unacceptable. If it is agreed to, constructed scales can be used where necessary or where indicators do not exist.[199]

[199] On how to create "constructed scales" see Keeney and Gregory 2005; Gregory et al. 2012, and factsheet in *Tools – Tab 7: Compendium of Data Sources, Analysis Methods, and Tools*.

To illustrate, the stages of assessment of impacts on cultural values from a project or decision would include:

- A broad-scale listing of all species, sites, and nature-derived materials.
- Relative importance of these species, sites, and nature-derived materials as first-order (most) versus second- or third-order importance by knowledge authorities, where importance here often means that all species are important but some are important, very important or crucially important. As well, be careful to recognize different experts and different divisions of labour by gender, family line, and so on. Most communities know who their experts are, and can identify these people for different knowledge domains.
- A linking of these species, sites, and nature-derived materials to different cultural practices (e.g., what is above referred to as cultural business, knowledge transmission, historical and oral history sites or "cultural landscapes" (site of meaning) given things that have occurred there, be they events, histories, and so on), and cultural relationships (e.g., things important for trading, securing relations, acts of reciprocity).
- Distinguish which species, sites, and nature-derived materials above are key to more than one aspect of cultural business, practice, landscape or relations.
- Link this subset of inferred important things to potential physical impacts where some designation of low, medium to high probability of a physical impact or change will result in a significant cultural impact precisely because it affects negatively the things distinguished in bullet 4 above.
- Specify which physical and socio-cultural impacts are irreversible. That is, which involve immediate (one season to one year) versus longer-term recovery where recovery involves "self-recovering" systems and so is not dependent on large-scale remediation or restoration that cannot be assured.

TOOLS – TAB 4 – WORKSHEETS FOR COMPLETING ES ASSESSMENT

Step 1: Defining the Issue and Context	
Worksheet 1 **Define the Issue and Context** **p. 105**	Identify all issues driving the question of need for an ecosystem services (ES) assessment, and consider them in light of their geographic, environmental, policy, social, and economic contexts. Note any critical issues.
Step 2: Identifying and Prioritizing ES	
Worksheet 2 **ES Priority Screening Tool** **p. 108**	Identify all possible ES in the study area, the benefits they provide, beneficiary groups and magnitude of benefit, likely impacts, and risks associated with the issue driving the assessment.
Worksheet 3 **Summarize Screening Results and Confirm Priority ES** **p. 113**	Summarize results of *Worksheet 2* to rank ES relevant to the area and situation, which helps to decide whether an assessment is needed and, if it is needed, which ES to focus on and what issues are likely to require attention.
Step 3: Planning the ES Assessment	
Worksheet 4 **Characterize the Priority ES** **p. 115**	Build on results from previous worksheets to identify and describe each ES to be assessed, focusing on ecological, socio-cultural, and economic dynamics, ES interactions, benefits, drivers of change, and key questions.
Worksheet 5 **ES Cascade Tool** **p. 117**	For each ES being assessed, identify the elements of natural and human capital that produce ES, their benefits to people, drivers of change, and specific indicators for measuring each. Refer to *Tools – Tab 5*.
Worksheet 6 **Develop Detailed ES Assessment Plan** **p. 118**	Develop a detailed technical plan for the remainder of the assessment, including specific questions to be answered, who will answer them, what information will be needed, and how it will be developed.
Step 4: Identifying and Using Indicators, Data Sources, and Analysis Methods	
Worksheet 7 **Select Relevant Indicators to Assess ES** **p. 120**	Identify indicators to be used to represent measures of ES provision, benefit, and change, linking especially to *Worksheet 5*, and explore data availability to report against the chosen indicators. Revisit *Worksheet 6* as needed.
Worksheet 8 **Determine Approach to Analysis Methods and Tools** **p. 123**	Determine the bundle of analysis methods and tools to use (the approach) based on information needs, available data, and available resources, and considering factors such as degree of specificity, scale, and time. Review *Tool Tabs 6* and *7* to identify sources, methods, and tools.
Step 5: Synthesizing Results and Completing Decision-Support Analysis	
Worksheet 9 **Synthesize Analysis Results** **p. 125**	Assemble the collected data and analysis to answer the assessment questions, and summarize all results and support as needed with descriptive text, statistics, tabulations, maps or other materials.
Step 6: Communicating Assessment Outcomes	

Introduction to the Worksheets

The series of nine worksheets presented in this *Tool Tab* have been developed to walk Toolkit users through each step of an ES assessment by providing a sequence of straightforward questions to answer. The worksheets are aligned with the six-step assessment laid out in *Chapter 2*. Depending on the approach taken, all of the worksheets do not need to be completed. To make this determination, read through *Chapters 1* and *2* especially. The advice in *Chapter 3* is intended to help identify how ES considerations can be incorporated—whether component analyses or full assessment—into existing processes for different policy and decision contexts. *Table 2.2* near the beginning of *Chapter 2* provides suggestions of which steps to follow in a partial or strategic approach to ES assessment depending on the team's information needs and available time and resources. *Chapter 3* suggests some additional opportunities to use the worksheets.

Just as the steps in an ES assessment are simultaneously progressive and iterative—meaning that one keeps moving forward by looping back and building on what was accomplished in earlier steps—the understanding documented in the worksheets is cumulative, and they will be updated and refined as understanding improves. This is especially the case with the *ES Priority Screening Tool (Worksheet 2)*, the *ES Cascade Tool (Worksheet 5)*, and the *Detailed Assessment Plan (Worksheet 6)* and applies to others as well. Keep the completed worksheets on hand as progress is made through the chosen steps. They will be used to inform responses to subsequent worksheets, and become the basis for the final analysis and synthesis of results in *Worksheet 9*. The collected documentation held in the worksheets can make the communication of results robust and transparent, because, through the worksheets, the data sources, analytic methods, and tools used are kept track of, as well as those that were not used (and why)—see *Steps 5* and *6* in *Chapter 2*.

As the individual worksheets are completed, be sure to make use of the **many resources provided in the other *Tool Tabs*** to help answer the questions and build the assessment. For example:

- If there are unfamiliar terms, check in *Tools – Tab 9: Glossary*.
- If there are complicated concepts that the team has heard of but is unsure of how they might affect the responses in the worksheets, check in *Tools – Tab 2: Cross-cutting Issues and Key Considerations* to see if they are covered. The explanations in that Tab will help from the very first worksheet onwards.
- When the team starts identifying the groups of people who may be affected by a decision or problem that is driving its desire to gather information about ES, it can find information about stakeholders and beneficiaries in several parts of the Toolkit, beginning with the *core definitions* identified by red text in *Tools – Tab 9: Glossary*. *Tools – Tab 3: ES Assessment Involving Indigenous Communities* was especially developed to help Toolkit users to begin to understand and respectfully approach ES assessment involving Indigenous communities. Think about how the advice in *Tab 3* can help in the responses in each of the worksheets.
- If more clarity is needed about different kinds of *values and valuation*, turn to *Tools – Tab 6: Values and Valuation: Economic and Socio-cultural*. It provides a concise introduction to socio-cultural and economic values and valuation approaches, and explains why using both approaches can provide a richer understanding of the issues from a human well-being perspective.
- When the team needs to start identifying the indicators to be used for assigning measures to ES, natural capital or other variables, be sure to check the *Table of Indicators* in *Tools – Tab 5: Indicators of Natural Capital, Ecosystem Services, and Benefits from Ecosystem Services.* It was compiled from diverse publications to help in quickly populating the *Cascade Tool* in *Worksheet 5*.
- Even though team members may have clicked on the *FAQ* links and read their answers during the reading of *Chapters 1* and *2*, they may very well want to go back and double-check some of them while completing the worksheets. They are presented in the same sequence as the assessment steps, and if the team needs to check context, each FAQ answer in *Tools – Tab 8: Answers to FAQs (Frequently Asked Questions)* has a "back to chapter" link that takes them right back to where the question was posed in the first place.

Worksheet 1. Define the Issue and Context

Use this worksheet to define the problem or decision context that is leading the team to consider completing an ES assessment. Insert the answers in the boxes below and keep this worksheet on hand while progressing through the steps in this Toolkit. Add more pages as needed to answer each question.

1. **Describe the issue and clearly state the problem or challenge.** For example, "We are looking for low-cost approaches to improving water quality in a region. There are a range of stakeholders that are affecting water quality and who depend on good quality water."

2. **Assessment driver(s).** What is driving the assessment, specifically? Regulation? Development? Impact? Incentive? List all that apply. Be as specific as possible.

Why are you considering completing an ES assessment?	Notes
A.	
B.	
C.	

3. **Geographic context and scale.** For example, if the issue is whether or not to allow the construction of a new road in an area, the geographic context is the location of the road and the surrounding areas that include anyone who will be affected by the construction of the road.

Where is the assessment area? (name, description)	What is the scale of the issue?

4. **Environmental context.** What are the major natural characteristics of the assessment area? Use aerial photos, topographic maps, and other sources to list and briefly identify the biophysical elements or features such as rivers, creeks, lakes, forests, fields, slopes, and so on. Attach visual evidence (with any relevant notations) to the worksheet for ongoing reference.

5. **Policy and decision-making context.** It is important to have a specific understanding of the regulatory and policy environment to scope the ES assessment on the most relevant issues to decision-makers. Related questions include who has jurisdiction over what is—or what may be—impacted by the decision or problem? Is there a need to consult or collaborate with other authorities?

Policy, regulation, or other institutional structure (name)	Implementing authority (e.g., provincial government)	Focus of policy, etc. (e.g., agriculture; species at risk)	Notes
A.			
B.			
C.			

6. **Social / socio-cultural context.** Identify both the decision-makers and stakeholders relevant to the situation. **Decision-makers** include those associated with regulatory and policy structures, but can also include those who are working directly on the land (e.g., at the field scale). **Stakeholders** include everyone who cares about a particular issue. One set of stakeholders is the people who benefit from ES that may be affected by the decision or project (see *Beneficiaries* in *Chapter 1*); beneficiaries will be considered more thoroughly through the *ES Priority Screening Tool* (see next worksheet). Other stakeholders may not be direct beneficiaries of affected ES but may have interests that will be affected as a result of decisions made. Make a note about what type of information is perceived as most important by key decision-makers and stakeholders.

Who are the decision-makers?	Who are the stakeholders?
Notes on most relevant data/format and to which group:	

7. **Economic context.** What are the economic activities (i.e., business) currently occurring in the area that may be affected by the decision? What ES are these activities dependent on? What effects (positive or negative) are economic activities having that are impacting (or are likely to impact) the flow of ES to beneficiaries?

Economic activities	ES dependency? (see question)	Effects (see question)

8. Critical issues. What are the critical issues in the area that cannot be ignored? These may or may not appear to be directly related to the decision or project, but are clearly important to stakeholders in the area, or are identified as ecologically significant. Who is directly affected? Are there other people who are not directly affected but involved or concerned (e.g., agencies, community groups)? Are there drivers of change that cannot be controlled? Are there culturally sensitive issues? (and so on)

Critical issue name	Explain – why critical?	Who is affected?	Who is concerned?
A.			
B.			
C.			

9. Related decision time horizon. What is the time horizon for broader decision for which the assessment is being done? *Note: Temporal scale pertaining to the provision of ES is a consideration in later stages of the assessment.*

Click here to *Return to Chapter 2, Step 1*

Worksheet 2. ES Priority Screening Tool

Instructions

Item numbers in these instructions correspond with the column numbers on the worksheet. **In all cases, if the team completing the sheet does not know the answer, insert "DN."** Where there is disagreement among those filling in the worksheet, a process of participatory deliberation should be followed, where contributors explain their views and a negotiated answer is agreed upon. It is realistic to have to use *informed* best guesses. If no agreement can be reached, the different views should be noted. Use as much space as needed.

1. ES checklist. The first step is to identify *all* the ES that are or might be relevant to people in the anticipated assessment area. Beneficiaries include residents and visitors, for example, tourists who come to benefit from the area's natural benefits. Indicate Y (yes) or N (no) for each of the ES that are benefiting people within the primary affected area as well as the additional surrounding area as defined above in *Worksheet 1* and illustrated by *Figure T2.1* in *Tools – Tab 2: Cross-cutting Issues and Key Considerations.* Remember that *all* people may benefit from *all* types of ES, directly or indirectly.[200]

2a. Specify what the ES benefits are that people are or may be receiving in the study area, relative to each ES. Examples could include physical safety and security of person and property against flooding, as a result of maintaining sufficient vegetated buffers along rivers and creeks and on steep slopes.

2b. Specify what disservices people are or may be receiving in the study area as a result of natural ecosystem processes. Examples could include illness caused by mosquitoes or deer ticks as a result of forest habitat.

3a. List each group of beneficiaries[201] for each ES. Typically, groups are defined by location, ethnicity, socio-economic status, or other broad descriptors, such as "farmers," "Indigenous communities," "rural populations," "low-income urban core residents," and so on.

3b. Indicate in relative terms as well as possible what the magnitude of the benefits of each ES are to each beneficiary group. This is different from the significance or value of the benefit—this refers to the scale or extent of the benefit. Indicate the estimates as H (high), M (medium) or L (low).

4a. Will the policy or project decision under consideration be likely to have a *positive* impact on the provision of the ES? Indicate Y (yes) or N (no) beside each ES identified in step 1. Note that the impacts to some ES may be positive where impacts to other ES may be negative. *Provide separate responses for each beneficiary group.*

4b. Will the policy or project decision under consideration be likely to have a *negative* impact on the provision of ES? Indicate Y (yes) or N (no) beside each ES identified in step 1, with separate responses for each beneficiary group. This is because dependency on individual ES can vary from one beneficiary group to another, sometimes very significantly. For example, while everyone depends on safe, clean air to breathe, rural populations that obtain drinking water from wells may depend on water purification ES more than most urban populations whose water is filtered and purified by engineered infrastructure.

5. Are there realistic, comparable substitutes readily available for the ES? Indicate Y (yes) or N (no) beside each ES identified in step 1 of this worksheet. It is useful to indicate whether there are substitutes available even for ES that have been identified as not likely to be negatively impacted, particularly when considering opportunities for trade-offs later in the process. Substitutes should have the capacity to provide equivalent ES benefits, *with recognition of ecosystem dynamics through which one biophysical source of an ES is typically the source of other ES as well.* To avoid risk of exceeding thresholds for provision of any ES (and the ecosystem processes that generate the ES), it is vital to include these dynamics in the assessment screening.

6. If there are substitutes available, are they likely to be contested or disputable by either the beneficiaries or the experts (i.e., professionals, practitioners, or holders of local and traditional environmental knowledge)? Indicate Y (yes) or N (no) beside each ES identified in step 1 of this worksheet. In addition, estimate how contested or disputed the substitutes are and indicate H (high), M (medium) or L (low). This information will be critical in determining the appropriateness and acceptability of any substitutes to beneficiaries, stakeholders, and others, and will be important in deciding the path to choose.

[200] While *Worksheet 2* can be completed by the assessment team, results will be stronger when stakeholder participation – formal or informal – is included. Even asking a variety of stakeholders questions like 'what aspects of the environment are important to them that the team may not have considered?' can help represent ES that may be missed by the team. Beneficiary participation in identifying ES on the landscape using participatory GIS methods is described in Brown, Montag, and Lyon 2014. If the assessment issue involves Indigenous communities, see the advice in *Tools – Tab 3: ES Assessment Involving Indigenous Communities.* The other Tool Tabs can help, e.g. to identify sources.

[201] See *Beneficiaries* in *Tools – Tab 9: Glossary.*

7. Is the ES that may or may not be affected by the decision scarce relative to demand? Indicate a. Y (yes) or a. N (no) beside each ES to reflect scarcity in terms of the quality of the existing ES; and b. Y (yes) or b. N (no) to reflect scarcity in terms of the quantity of the existing ES in each case.

8. Are the thresholds for ES provision in this context known?[202] Indicate Y (yes) or N (no) beside each ES.

9. Based on knowledge of thresholds for the continued provision of each ES, indicate the extent to which the decision that is driving the assessment introduces the risk of breaching the threshold by noting H (high), M (medium) or L (low). A high level of uncertainty about this risk for any ES, particularly those of high significance to beneficiaries, can indicate that an ES assessment is very likely needed.

10. Can the anticipated impacts to the individual ES be mitigated effectively (realistically) and in a timely manner, so as to ensure the ongoing benefits to people who depend on the ES?[203]

11. Once the entire screening process has been completed and the chart filled in, highlight every instance of:

    - "H" responses to H-M-L options to 3b, 6b, and 9
    - "Y" responses to 1, 4b, 6, 7a, 7b, and 8
    - "N" responses to 5

Collectively, these will be the first suggestions of high-priority ES for further analysis. Where many such responses pertain to the same individual ES, the priority may be higher and will warrant further investigation. It is not a simple matter of counting up the totals, however, because issues reflected by the different steps in the Tool are not of equal importance. *Worksheet 3* walks the team through these complexities.

TIP: **The use of ES by one group may limit or enhance the use of ES by another group, or it may have little to no impact. This dynamic can result in conflict or co-operation and is important to identify.**

[202] For information on thresholds and uncertainty, see *Tools – Tab 2: Cross-cutting Issues and Key Considerations.*

[203] The "mitigation hierarchy" for environmental sustainability has as its primary objective the avoidance of impact and, if that is not fully possible, to minimize impact through careful design. If residual impacts cannot be avoided, the impacted ecosystem should be rehabilitated or restored. When that is completed but still insufficient, the damage may be offset by *enhancing* ecosystem viability in another location to achieve no net loss, and potentially taking other additional conservation actions.

Worksheet 2. Ecosystem Services Priority Screening Tool

Ecosystem service (ES)	1. Produced or received on site? Y/N	2a. Specify benefits	2b. Specify disservices	3a. List beneficiary groups	3b. Magnitude of benefit (for each group) H-M-L	4a. Decision positive impact likely? Y/N	4b. Decision negative impact likely? Y/N	5. Substitute available? Y/N	6. Substitute contested or disputable? Y/N How much? H-M-L	7. Scarce vs. demand? a. Quality: Y/N b. Quantity: Y/N	8. Is associated ecosystem threshold known? Y/N	9. Risk to ecosystem threshold from decision H-M-L	10. Can impact be mitigated effectively and in a timely manner? Y/N/DK
Provisioning services													
Food (crops, livestock, capture fisheries, aquaculture, wild foods)													
Timber and wood products; fibres, resins, animal skins, and ornamental resources													
Biomass fuel													
Fresh water for human consumption and use													
Genetic material													
Biochemical and medicinal resources													
Regulating services													
Air-quality regulation													
Climate regulation and carbon sequestration													

Continued on next page…

Ecosystem service (ES)	1. Produced or received on site? Y/N	2a. Specify benefits	2b. Specify disservices	3a. List beneficiary groups	3b. Magnitude of benefit (for each group) H-M-L	4a. Decision positive impact likely? Y/N	4b. Decision negative impact likely? Y/N	5. Substitute available? Y/N	6. Substitute contested or disputable? Y/N How much? H-M-L	7. Scarce vs. demand? a. Quality: Y/N b. Quantity: Y/N	8. Is associated ecosystem threshold known? Y/N	9. Risk to ecosystem threshold from decision H-M-L	10. Can impact be mitigated effectively and in a timely manner? Y/N/DK
Water-flow regulation													
Erosion regulation													
Water purification and waste treatment													
Disease regulation													
Pest regulation													
Pollination													
Natural hazard regulation													
Cultural services													
Cultural identity, social relations, community cohesion													
Spirituality/ religion													
Knowledge systems and education													
Cognitive development, physical and psychological health													
Aesthetic experience													

Continued on next page…

Ecosystem service (ES)	1. Produced or received on site? Y/N	2a. Specify benefits	2b. Specify disservices	3a. List beneficiary groups	3b. Magnitude of benefit (for each group) H-M-L	4a. Decision positive impact likely? Y/N	4b. Decision negative impact likely? Y/N	5. Substitute available? Y/N	6. Substitute contested or disputable? Y/N How much? H-M-L	7. Scarce vs. demand? a. Quality: Y/N b. Quantity: Y/N	8. Is associated ecosystem threshold known? Y/N	9. Risk to ecosystem threshold from decision H-M-L	10. Can impact be mitigated effectively and in a timely manner? Y/N/DK
Inspiration for human creative thought and work													
Recreation and ecotourism													
Sense of place and heritage													
Supporting or habitat services													
Soil formation													
Primary production													
Nutrient cycling													
Water cycling													
Habitat													

Click here to *Return to Chapter 2, Step 2*

Worksheet 3. Summarize Screening Results & Confirm Priority ES

Instructions

These instructions are a continuation of the steps followed for the *ES Priority Screening Tool* (*Worksheet 2*), and support the interpretation of results. The questions refer back to the answers in *Worksheet 2*, by column number.[204] Add pages as needed.

a) If any "supporting services" are likely to be negatively affected, which provisioning, regulating, and cultural services are likely to be affected through a "trickle-down" effect? Does this consideration affect the initial assessment of these other services? If yes, adjust responses accordingly.

b) Review the connections between projects anticipated to have a negative impact on ES (4b), the different beneficiary groups (3a), and the magnitude of their dependency (3b). This can signal likely inequitable outcomes and should result in reconsideration of the plan at best, and identification of fair and equitable mitigation measures at least.

c) Consider any cases where the response to 9 was "H" as critical, because the risk of breaching ecosystem thresholds for one ES is very likely to involve other ES simultaneously or through a cascade or cumulative effect over time. For such cases, identify the most likely ES to be co-impacted, and the degrees of human dependency associated with each. If the response to 8 is "N" and other responses for a particular ES suggest a high priority, a risk assessment may be advisable.

d) Substitutes (5 and 6) should only be considered when the response to 9 is "L" or, with due caution, "M," because it is never advisable to breach thresholds of ecosystem viability in the context of ES production. When considering whether substitution is a viable option, be certain to review responses to 7a and 7b. If substitution is a clearly viable option, then this may decrease the priority of an ES for assessment. Identifying the extent of dependency (how critical is it?) is an essential step in the decision-making process. Critical natural capital[205] is identified as critical because it generates ES that are essential and not realistically substitutable.

e) Are there any other factors that are likely to influence the availability of ES in the project or decision area (as defined in *Tools – Tab 2: Cross-cutting Issues and Key Considerations*)? What are these factors and what are the challenges or opportunities they are likely to introduce in this scenario? How will they relate to the high-priority ES? Do these factors elevate the risk to any ES beyond risks associated with the project or decision that is driving the ES assessment? Are there any synergistic effects possible and, if so, what are they and how could they affect the prioritization of ES for assessment?

f) Could potential impacts to ES be mitigated? When considering how impacts to ecosystems, and thus ES, might be realistically mitigated, be sure to consider whether mitigation can only protect or restore one ES, or multiple ES that are generated from the same source, or that pass through the source to support different beneficiary groups. Identify any limitations on mitigation and consider their severity to beneficiaries now and in the future.

g) Based on completion of the *Screening Tool* and conclusions to items a) through e) in this section, list the individual priority ES for assessment, ranking in three tiers (there can be more than one per tier). Is there any indication that some of the services are produced by the same ecosystem components or processes, or interact dynamically with each other? These interactions can be noted here.

[204] For more information on some of the technical concepts here, see *Tools – Tab 2: Cross-cutting Issues and Key Considerations* as well as other resources in this Toolkit.
[205] See *Critical Natural Capital* in *Tools – Tab 9: Glossary*.

Worksheet 3. Summarize Screening Results / Confirm Priority ES

Final Questions	Conclusions		
a) ES affected through "trickle-down" from impacted Supporting ES	Provisioning	Regulating	Cultural
b) Inequity risks	For whom	How	Implications
c) ES linked to risk of threshold breach, and degree of human dependence on it		Is risk assessment needed? Y/N	
d) Substitution	In which cases are substitutes viable options?	In which cases are they not viable options?	
e) Other factors affecting security of ES provision	Other risk factors	Degree of risk	Synergistic effects
f) Potential for realistic, timely mitigation	Which ES would benefit from mitigation measures available?	Which ES would not benefit from mitigation measures available?	Effects on different beneficiary groups
g) Ranked, prioritized ES for assessment	1st Tier (highest priority)	2nd Tier	3rd Tier (lowest priority)

Click here to *Return to Chapter 2, Step 2*

Worksheet 4. Characterize the Priority Ecosystem Services

Use this worksheet to identify and describe the characteristics of *each* ES being assessed in the context of the social-ecological system (including economic factors) for the area that is the subject of the ES assessment. Refer back to the completed *Worksheets 2* and *3* for some of this information, where relevant. Answer the questions to the best of the team's ability. Some questions may require some basic research (e.g., literature review), but answers do not need to be backed up with evidence at this stage. Some degree of expertise in ecology or ES will be helpful to answer all the questions, particularly in relation to identifying ecosystem components and functions that contribute to ES production. However, a good deal of uncertainty is expected, and reducing this uncertainty will be the basis of some of the assessment work to come. Some of the questions will have been explored when using the *ES Priority Screening Tool*, but are revisited now to characterize the ES in more detail and with more attention to links between the different elements of the system. Filling in the worksheet as a team provides an opportunity to ensure that terms and definitions related to ES assessment are understood in the same way by team members and for discussion about complexities within the system. Add pages as needed.

1. Define the ES more specifically (e.g., is the service of interest "food production" or "agricultural production" or more specifically "corn and soybean production" or "sustainable corn and soybean yields"?)

2. What components of the landscape, including both natural and built, contribute to the production of the ES? At what scale? (e.g., apple production may require field-scale irrigation infrastructure, surrounding vegetation for pollinator habitat)

3. What key ecological, social, and economic dynamics/processes contribute to the resilient production or functioning of the ES? What are the scales of those processes? (e.g., water filtration may require processes such as nutrient and pollutant filtration by vegetation and soil at the watershed scale. This should include the consideration of landscape extent, quality, and configuration necessary for ES production.)

4. Are there known or potential interactions between the ES and other ES? Sketch out the components of the study area and consider the interactions between them. What additional ES should be included in the priority list for assessment as a result of seeing these connections? (See FAQs for why this is important and tips for how to explore interactions among ES, for example, nutrient cycling and water quality on a landscape are often directly connected.)

5. What are the benefits that can be attributed to the ES? Are there multiple benefits? Who are the beneficiaries and how does their demand for the ES differ? At what scale are the beneficiaries present? Can different beneficiary groups be identified to take into account power imbalances or competing priorities? Are particular forms of human or built capital needed for people to access the benefits? Will some groups benefit (or lose) now versus in the future?

6. What are the recent trends in important drivers of change in the system? What is known about how these drivers may be affecting the ES? Do the impacts of different drivers need to be investigated further? Are the different drivers of change affecting each other or affecting system components in combination? (e.g., global-scale climate change and local-scale housing development impacting flood regulation in an area)

7. What is likely to change in the near future that will have an effect on the quality, quantity or access to the ES, separately from changes that may occur as a result of the specific problem or decision that is driving this assessment? Might there be important changes that will only materialize in the more distant future (e.g., demand for organic produce, changes in the use of pesticides and fertilizers, changing price of apples on local and foreign markets, rising real-estate prices, and so on, will combine to impact apple production in unforeseen ways)? Note all that may be relevant for longer-term planning as these will help with scenario development.

8. Identify and list the most relevant questions to ask about the ES that will allow the team to achieve the assessment goal (e.g., if the goal of the assessment is to determine the ES impacts of building a housing development in an area, a list of relevant questions for the flood control service might include (1) what are the landscape elements that are most important for flood control; (2) where on the landscape is the most important green infrastructure contributing to flood control; (3) where on the landscape would the housing development be subject to the highest or lowest risk from flooding; (4) is there a need for additional flood control infrastructure; and (5) could additional infrastructure be green infrastructure (i.e., a constructed wetland) or is built infrastructure necessary or more cost-effective?)[206]

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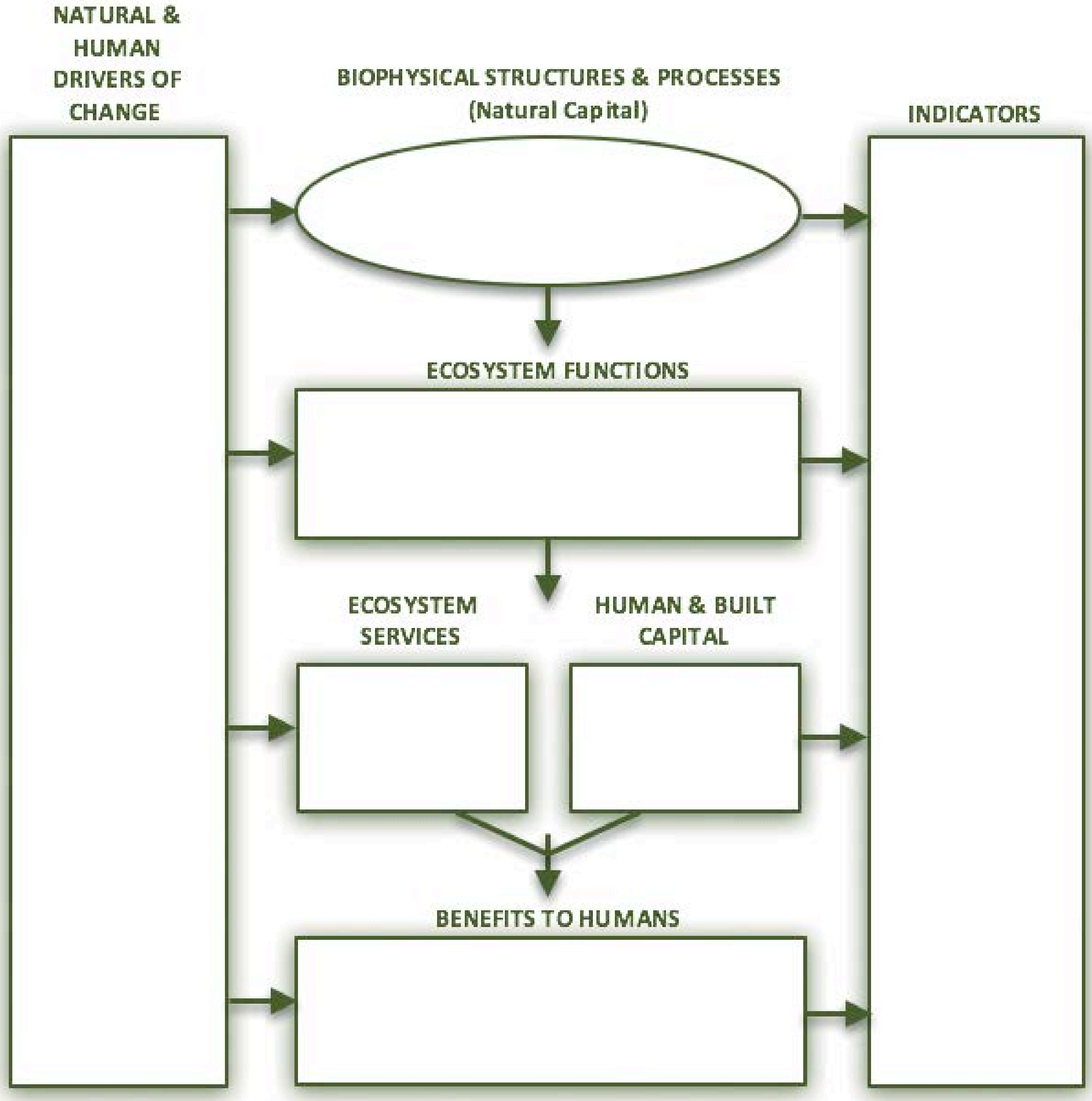
[206] Note that there are two levels of assessment questions: (1) the high-level questions being asked by the decision-makers (i.e., the problem context); and (2) these detailed questions that will each be answered using assessment methodology, and that will contribute to providing answers to the high-level questions of decision-makers.

Worksheet 5. Ecosystem Service Cascade Tool

Fill in the *ES Cascade Tool* for each ES that was prioritized in *Worksheets 2* and *3*. Insert information on all the components of the system that contribute to providing the ES. For example, flood control is dependent on certain types of land cover and ecological functions and processes, and provides several benefits to different groups of people in the area. In addition, built infrastructure (e.g., paved areas, drainage ditches) impacts on the functioning and delivery of the service. An example of a completed *Cascade Tool* is shown in *Step 3* in *Chapter 2*. In general, not all the variables that are added to the figure will be possible to assess, but the important ones that will help decision-makers have a full understanding of the ES can be assessed where data are available. Return to the *Cascade Tool* to insert chosen indicators (including, as needed, for the drivers of change) after completing *Step 4* in *Chapter 2*.



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Worksheet 6. Develop Detailed ES Assessment Plan

Building on results from *Worksheets 1* through *5*, use this worksheet to focus on what the remainder of the assessment will address: confirming the selection of ES, the types of analysis needed, the indicators to be used, and data sources, analysis methods, and tools. If the assessment includes multiple questions, fill out a separate Worksheet 6 for each question to the best of the team's ability. This plan will be refined as data, tools, and approaches are investigated further. Add pages as needed.

1. What is the specific assessment question to be answered—What do you need to know about the priority ES?

2. What group of team members will answer the assessment question?

3. What information will each team member contribute to help answer the assessment question (specify what aspect of the assessment of natural capital, ES, benefits or drivers of change they will take charge of and specify any details about approach to be taken. *Step 4* in *Chapter 2* provides more guidance on these issues and may need to be read first before answering these questions):

- What depth of information is required (e.g., accuracy, certainty)?
- Which indicators will be used?
- What spatial resolution (the grain-size of the analysis, e.g., the size of cells or hexagons on a map) and extent (the total area or time to be considered), and time scale will be included and what is the justification for this?
- Potential methods, tools, and approaches to be used[207]
- Potential data sources (be specific)

[207] See *Tools – Tab 7: Compendium of Data Sources, Analysis Methods, and Tools.*

4. How will the information developed by each team member be integrated to answer the question?

5. What potential interactions between ES and/or ecosystem or social components need to be considered? Review FAQ 22 to support your answers.

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Worksheet 7. Select Relevant Indicators to Assess ES

Introductory advice for this worksheet is provided in *Chapter 2*, as well as in the associated *FAQ*s listed at the end of *Step 4*. More specific instructions for this worksheet are included with each question below. Add pages as needed.

1. What form of information is needed?

A first step for determining which indicators to use is to discuss with decision-makers the type of information that would be most useful to generate for answering the assessment questions. Options include:

- qualitative descriptions (e.g., of the *importance* of certain types of services);
- biophysical quantification (e.g., of trends in ecosystem change under different scenarios);
- rankings, magnitude of change, degree of importance, and more;
- maps;
- monetary valuation (e.g., of selected services that have a clear link to well-being); and
- other types of indicators (e.g., number of people dependent on a resource, expected health benefits).

Note the forms of information likely needed in the box below.

2. What part of the system will be assessed?

For any ES, there are various system components that could be measured, from the *state of the underlying system* (the natural capital), through the *functions and processes* of the system, to the *service and benefits* it provides. These system components will have been identified and related to each other using *Worksheet 5 (Cascade Tool)*. Insert the list of system components for assessment in the box below.

3. What aspect of the system components should the indicators represent?

Indicators for biophysical system components will measure the supply, aspects of the demand for or use, or the sustainability of the ES.[208] The sustainability of the service is related to its scarcity or resilience. Two other terms, "stocks" and "flows," are also often used (although mostly relevant for provisioning services), and are related to the supply, use, and sustainability of the service and its benefits. Stocks of natural capital yield a dividend in terms of flows of ES and associated benefits. For example, a forest has a standing stock that can produce flows of timber and other non-timber forest products, and benefits such as profits from sale, nutrition, and cultural activities. Benefits are not always estimated using flow information, but may also be assessed using presence/absence data, rankings, qualitative descriptions or other values.

Stocks and flows. To understand availability and quality of ES, it is useful to investigate stocks and flows. Sustainability of *all* ES depends on both stocks and flows. The health of ecosystems determines the flow of regulating services and, to some extent, all other ES. The flow of regulating ES is normally used as a basis for estimating their condition or quality. In some cases, *stocks* refer specifically to the *quantity* of the service available and, in other cases, to the *condition* of the natural capital that contributes to a particular service. So in

[208] See the table of suggested ES indicators in *Tools – Tab 5: Indicators of Natural Capital, Ecosystem Services, and Benefits from Ecosystem Services*, FAQs in *Tools – Tab 8: Answers to FAQs (Frequently Asked Questions)*, and definitions in *Tools – Tab 9: Glossary* for more on indicators.

some cases (i.e., to answer some questions such as whether the natural capital that underlies regulating ES is in good enough condition to sustain those ES), it is appropriate to focus on natural capital or ecological functions, and going "further" down the *Cascade Tool* is not necessarily better. The emphasis should be on determining the exact system component that needs to be measured to answer the specific assessment questions.

Supply and demand. To understand a change related to an ES, it is useful to investigate supply versus demand. Understanding how and why ES are changing is an important part of identifying what people need to manage in a system. Models may be used to capture the dynamics of ES if there are sufficient resources to run the models and if the model outputs (indicators) are relevant to the assessment questions. Models can incorporate production functions and drivers of change to assess how changes in the system will impact ES and related human benefits. Aside from models, indicators may be chosen for which there are time-series data available to understand at least the important trends in those ES (i.e., are the ES increasing or decreasing, and at what rate?).

Indicators for socio-cultural and economic aspects of the social-ecological system can focus on measures of how people are benefiting from ES.

Write down the aspects of each system component that need to be considered to answer the assessment questions (i.e., stock/flow/supply/demand/other):

4. How many indicators are needed to answer the assessment questions?

When deciding what to measure, it is important to consider what each type of metric will provide and whether it may need to be complemented by other metrics to answer specific questions about ES.[209] In some cases, if only one indicator is used, it could provide incomplete or misleading information.

Be sure to ask all the relevant questions that will need to be answered to provide the assessment users with sufficient information to inform their decisions or their understanding of the issue. Together, sets of a few relevant indicators can tell a whole story about the dynamics of ES and inform management of the system effectively.

For each assessment question, mark down the indicators that will be needed to answer it effectively.

5. Choosing indicators that match available data, tools, approaches, and expertise

The part of the system that will be measured may depend on what data are available, which is why it is important to understand how the whole system fits together. For example, it may be ideal to measure how much water is being retained by forests in a watershed (i.e., the actual ES), but data limitations may instead only allow the measurement of the amount of forest cover (the underlying natural capital that contributes to water retention). Every time an indicator is chosen that is further from the system component of interest, it is important to understand what information is being lost and how this affects the results that can be obtained, as well as the degree of uncertainty related to the results. Identifying indicators that match both data and available tools/approaches is an iterative process, and the following steps can be run through several times.

1. In the right column of the *Cascade Tool*, enter the indicators next to the important system components the team has identified. Suggesting indicators for specific system components will help to narrow down what is measurable, and what should be measured. **Identifying a few options for indicators** of each system

[209] CBD 2011b.

component is a good idea, as only some will lend themselves to measurement using available tools and data. Double-check: will these indicators enable an answer to the questions defined in *Worksheet 4*? If not, review the questions and identify indicators that are a better match.

2. Determine if **data are available.** Make a first attempt to track down the data. If not, revisit indicator selection and identify alternate indicators that will still address the question adequately.

3. Begin an initial **exploration of what tools may be used to analyze the data** and ask whether the indicators are compatible with these tools. This is also an iterative process. If either the data are unavailable or incompatible with tools that will be used, try to identify alternative indicators that fit better.

6. Summary Checklist: Complete for each selected indicator

Is the chosen indicator:

- ☐ relevant to a problem or decision-making context?
- ☐ sensitive to changes in the system?

Does the indicator:

- ☐ match with existing data for the area?
- ☐ match with available tools and expertise for analysis?
- ☐ measure what it was intended to measure (e.g., the natural capital, the ecological function or the benefit)?

Additional criteria:

- ☐ is the indicator simple and defensible?
- ☐ are there time-series data available for the indicator?
- ☐ does the indicator need to be complemented by additional indicators and are they available?

Click here to *Return to Chapter 2, Step 4*

Worksheet 8: Determine Approach to Analysis Methods and Tools

This worksheet helps in the selection of a suitable approach and methods for the ES assessment by narrowing down the criteria by which they will be chosen. Thinking through information needs will help to select appropriate tools and approaches. Review the factsheets in *Tools – Tab 7: Compendium of Data Sources, Analysis Methods, and Tools* and supporting text on values in *Tools – Tab 6: Values and Valuation: Economic and Socio-cultural*. Insert answers in the boxes below and keep this worksheet on hand while reading through the sections on common ES analyses and methods for analysis. **Use this sheet with the answers filled in as a set of criteria to compare with available tools and approaches**. Add pages as needed.

1. Check the appropriate box below (check more than one). Is the team looking to develop:

- ☐ greater understanding of an issue in general?
- ☐ context-specific knowledge of conditions and trends in ES?
- ☐ precise information on how changes in management will impact ES and human well-being?
- ☐ better understanding of the trade-offs involved in a decision, relating to ES?
- ☐ other type of information (describe in the box below)?

2. What level of specificity is the team looking for in the assessment results?

- ○ High (e.g., results will be used to support decisions that require detailed information)
- ○ Medium (e.g., results will be used to support decisions that require accurate information about trends in ES)
- ○ Low (e.g., results will be used for communication purposes, general trends needed only)

3. Is the team looking for static or dynamic information about ES?

- ○ Static (need to know condition of individual or multiple ES at one point in time)
- ○ Trends (need to know how ES have been changing over time)—will require **time-series data**
- ○ Dynamic (need to be able to model changes in ES under different scenarios and into the future)—will require the use of **models that link drivers to ES production and benefit distribution** (things in landscape that will change under future scenarios need to be included in models)

4. What is the scale of analysis needed to answer questions?

- ○ Site/project scale
- ○ Landscape/watershed scale
- ○ Regional scale
- ○ Provincial/territorial scale
- ○ National scale

5. Does the team have a specific tool or approach in mind? (See *Tools – Tab 7: Compendium of Data Sources, Analysis Methods, and Tools* for guidance) If so, what is it? For this approach, is there access to the specific expertise needed?

6. When does the team need to have the assessment finished?

- ○ Several weeks
- ○ Several months
- ○ One year
- ○ More than a year

7. Are there any known risk factors or thresholds associated with the ES of interest? (See *ES Priority Screening Tool* results) What are they? Will these be analyzed?

8. Data availability in study area for each ES:

- ○ Local data available
- ○ Spatial data available
- ○ Time-series data available
- ○ Budget available for primary research
- ○ Expertise available for using remotely sensed data
- ○ Other

Click here to *Return to Chapter 2, Step 4*

Worksheet 9: Synthesize Analysis Results

Use this worksheet to integrate the results of the interdisciplinary ES assessment. Use the box after each question for notes, expanding the spaces as needed, and then insert the final answers in a chart. The chart may be set up similar to a cost-benefit analysis account statement or a structured decision-making or multi-criteria analysis consequence table, adapted for this content. Append additional materials such as graphs or maps, and reference supporting evidence. Indicate which methods were used to complete the analysis. Explicitly document all assumptions and limitations of results.

1. **From the assessment results, describe how the focal ES relate to the issue at hand, and their importance to beneficiaries. For each result, list any associated uncertainties or underlying assumptions to be aware of.**
   a) Describe *how* each ES is valued (social and cultural significance).
   b) Indicate results of importance ranking to beneficiaries, if obtained.
   c) If there are ES of major cultural importance, list them (e.g., a type of game animal central to a community's identity and cultural practices).
   d) Specify any economic values associated with any of the benefits from ES.
   e) Specify ecological or biophysical values identified: do any of the ES enhance the resilience of the system, contribute to the production of valued ES or protect the system from degradation or disaster?
   f) If any of the ES are assessed as being close to a resilience threshold, what are they?
   g) What ES, if any, need to be safeguarded at any cost? Why?

2. **What is the condition of each ES?** Are the results quantitative and/or qualitative?
   Summarize using text, tables or figures. Make notes of the major uncertainties around the condition of each ES.

3. **How is each ES changing over time?** Summarize using text, tables or figures showing increments of change for each ES. If there are statistical measures of change, include them.

4. **What factors are affecting each ES?** (i.e., drivers of change) How? What are the uncertainties about drivers of change and how they are interacting with ES? What is the potential for proposed activities to impact ES further in a substantial way?

5. **Will ES beneficiaries be affected by current and future change (from any drivers of change or proposed activities/policies)?** Describe how.

6. **Which ES are connected to each other? How are they connected?** Summarize using text, tables or figures, and consider developing a schematic diagram or overlay map of the assessment area.

7. **Is there enough information to answer the main assessment questions?** Try to answer them here. What information is missing?

Note: Because decision-support frameworks and tools vary widely in the activities that they focus on, it can be productive at this point to compare the information from the completed worksheets with the needs of the decision-support approach(es) or tool(s) chosen to help with the final phase of assessment (e.g., consideration of alternatives and consideration of trade-offs). Detailed advice on how to carry out both of these activities in ES assessment is provided in Ash et al., 2010, and Toolkit users are encouraged to use that free, downloadable resource: http://www.unep-wcmc.org/resources-and-data/ecosystems-and-human-wellbeing--a-manual-for-assessment-practitioners. In addition, many of the web-based ES analysis tools introduced in *Tools – Tab 7: Compendium of Data Sources, Analysis Methods, and Tools* include these steps.

Because this Toolkit takes a more broadly interdisciplinary approach than many guides and tools for ES assessment, it will be helpful for the assessment team to pay close attention to how they can adapt the decision-support framework or tool they are using to ensure that the full richness of data and analysis results are carried into the final analysis. Reviewing the guidance at http://www.structureddecisionmaking.org/ may be particularly helpful even if the team is using a different approach. Some of the structured decision-making tools may help to fully bridge the interdisciplinary results with the approach being used (that may not be designed to accommodate different kinds of information as readily).

Click here to *Return to Chapter 2, Step 5*

TOOLS – TAB 5 – INDICATORS OF NATURAL CAPITAL, ECOSYSTEM SERVICES, AND BENEFITS FROM ECOSYSTEM SERVICES

Contents of Tab 5

Table T5.1. Types of human benefits (from ES) indicators. *Indicators for reporting on human well-being benefits from ES can be considered as falling into 11 groups or types, shown here. The type of indicator influences the kind of information that the analysis will produce and how relevant that information will be for specific issues.*

Type of Indicator	Examples (not comprehensive)	Notes
Described benefit	Description of benefit as articulated by beneficiaries	Strength of this type of indicator is that it can describe the actual benefits to well-being, as reported by those who know the most about benefits. The data will usually need to be collected.
Use of ES	Harvest of plant species, number of deer killed by hunters, number of livelihoods supported by ES	Is similar to demand for ES, however, demand may include unmet demand. This indicator equates actual use of ES with benefits received, which may be appropriate for some ES and not others.
Economic value	Price increase of houses close to green spaces, willingness to pay for amenities, market value of crops	Can be quantified using a number of methods, see *Tools – Tab 6* and *7*. Often of interest to decision-makers, may be appropriate for some ES and not others.
Social value	Expressed cultural importance, number of people who participate in gathering a resource (e.g., berries)	Qualitative or quantitative indicators that show level of importance of ES to society or segments of society, appropriate to all ES.
Exposure to risk	Increased risk of landslide or flood	Important indicator of benefits from regulating ES (e.g., flood control, climate regulation). Increase or decrease in risk can be modelled or reported using time-series data.
Access to ES	Number of people who have access to ES, investment in infrastructure that allows access to ES	This indicator may complement demand or use indicators, as benefits may be limited by people's access to ES.

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Type of Indicator	Examples (not comprehensive)	Notes
Demand for ES	Expressed demand for ES, number of people with basic needs (e.g., for clean water, air)	This is a proxy indicator for the degree of importance people place on ES and related benefits. Similar to use of ES, but may include unmet demand.
Supply vs. demand	Comparison of supply vs. demand for water, map of areas where demand for ES is met vs. unmet	Comparison of supply and demand captures perceived importance of ES (or actual importance in cases of basic needs for fresh water, fuel, and food) and whether demand is being met (i.e., benefits are being delivered by system).
Cost of substituting ES	Cost of building and maintaining water filtration plant or flood pond	Proxy for hidden economic benefits from ES shown by calculating cost of their substitution, including need for maintaining built infrastructure into the future.
Cost of loss of ES	Cost to tourism from removal of a forest or loss of species	Proxy for hidden benefits from ES shown by estimating loss of benefits due to loss of ES, in economic or other terms (e.g., decreased number of tourists)
Improvements to well-being	Measured change in recuperation rates from patients exposed to green spaces	Suites of indicators for ES-specific aspects of human well-being in development (e.g., see Summers et al. 2012 and Smith et al. 2013)

Table T5.2. Examples of specific indicators for each type of ES, for both ecosystems and human beneficiaries. *While these are commonly used indicators, the list is not exhaustive and the suggested indicators may or may not be suitable for a particular scale or context. Natural capital, ecological functions, and ES are grouped together in this table because their indicators often overlap or depend on the context or scale of analysis. Human benefits indicators are oriented to how people benefit from the natural capital, ecological functions, and ES. It is very important to understand exactly which one is represented within the team's context when choosing any specific indicator.*

Ecosystem Service	Indicators for Natural Capital, Ecological Functions and ES	Human Benefits Indicators
Provisioning services – *the result of ecosystem processes and functions that provide goods or products that humans obtain and rely upon*		
• Food • Crops • Livestock • Capture fisheries • Aquaculture • Wild foods	• Total stock (kg/ha) • Net productivity (Kcal/ha/year) • Presence of edible plants/animals • Reproduction rate of fish in commercial use (estimated) • Size of catch • Number of species in commercial use • Market value of food • Number of jobs/income/businesses involved in food production • Amount of game meat caught • Animals killed • Realized crop production (ton/ha/year) • Total area cropland (ha) • Total area of grasslands suitable for grazers • Density of grazing livestock	• ** For *all* provisioning: number of people employed, including self-employment or subsistence activity in co-production, harvesting, processing, and distribution of these goods. • Number of wild foods harvested in an area • Extent that wild food contributes to diet • Access to wild food (rights of access) (Note that some provisioning ES are closely connected to cultural ES for different communities, especially when part of livelihoods)
• Timber and other wood products • Fibres, resins, animal skins, and ornamental resources	• Total biomass (kg/ha) • Net productivity (kg/ha/year) • Presence of species or biotic components with potential for use	• As above, adapted for these items • Extent of use of natural materials in region of harvest (or relative to imports of natural materials for use) • Extent of use of natural materials for outside distribution (contribution to livelihoods and trade)
Biomass fuel	• Total biomass (kg/ha) • Net productivity (kg/ha/year) • Presence of species or biotic components with potential for use	• As above, adapted for these items
Fresh water for human consumption and use	• Total amount of water (m^3/ha) • Maximum sustainable water extraction (m^3/ha/year) • Presence of water reservoirs • Untreated spring and groundwater (million m^3) and percentage share of water supply • Amount of water extracted per year per area • Total renewable freshwater supply by surface waters	• Number of people with access to clean water or who do not have access to clean water • Cost ($) to clean water where ecosystem is degraded (e.g., all infrastructure, labour, inputs that could have been avoided, plus maintenance costs) ***Continued on next page…***

Ecosystem Service	Indicators for Natural Capital, Ecological Functions and ES	Human Benefits Indicators
Genetic material	• Total number of species and sub-species • Maximum sustainable harvest • Presence of species with useful genetic material	• As per biochemical and medicinal resources below
Biochemical and medicinal resources	• Total biomass (kg/ha) • Maximum sustainable harvest (mass/area/time)	• Quantity of native species harvested for this purpose • Number of people that rely on native species for this purpose • Number/quantity of native species being developed and distributed to broader population in natural form • Number/quantity of native species contributing to pharmaceutical development • Sales or profit ($) from development of products
Regulating services – *the result of ecosystem processes and functions that regulate all aspects of the environment, providing security and habitable conditions that humans rely upon*		
Air-quality regulation	• Leaf-area index • NOx-fixation, among others • Amount of aerosols or chemicals "extracted" (effect on air quality) • Flux in atmospheric gases • Atmospheric cleansing (tropospheric oxidizing) • Deposition velocity of air pollutants on leaves (m/year) • Critical loads • Total amount of pollutants removed via dry deposition on leaves (ton/ha/year)	• Correlating air-quality/particulate data with incidence of respiratory illness (medical records) • Number of people who are exposed to "good air" (below emissions limits) and vice versa at their residence, at their place of work or where they engage in daily activity
• Climate regulation and carbon sequestration • Global climate regulation • Regional and local climate regulation	• Greenhouse gas balance (especially C-sequestration) • Land-cover characteristics • Quantity of greenhouse gases fixed and/or emitted • Effect on climate parameters (e.g., leaf-area index, total crown cover) • Carbon stocks above and below ground • Soil organic matter • Exchange of carbon between biosphere and atmosphere	• Extent of forced migration from areas no longer habitable or capable of supporting communities (e.g., Arctic or drought-prone areas) • Loss of livelihoods or cultural activities associated with changing climate • Risk of drought/flooding associated with agricultural production • Security of regional food sources if regional production declines due to climate change or other climate-related impacts *Continued on next page…*

Ecosystem Service	Indicators for Natural Capital, Ecological Functions and ES	Human Benefits Indicators
Water-flow regulation	• Water retention capacity in soils or at the surface • Quantity of water retention and influence of hydrological regime (e.g., irrigation) • Impact of vegetation on water flow, as a function of topography • Peak flows • Infiltration rates in soil • Changes in seasonability of flood events • Flood attenuation potential (residence time of water in rivers, reservoirs and soils) • Floodplain water storage capacity (mm/m) • Soil capacity to transfer groundwater • Trends in number of damaging natural disasters • Area coverage of natural/semi-natural wetlands in flood risk areas • Land-use change along waterways under flood risk • Number flood events per year	• Incidence, cost or risk of flooding
Erosion regulation	• Vegetation cover root-matrix • Amount of soil retained or sediment captured • Ground cover • Soil erodibility (e.g., slope characteristics, texture, organic matter content) • Rainfall erosivity • Soil erosion rate by land-use type • Area of forest in vulnerable zones • Total amount of soil retained (ton/ha/year) • Slope angle, slope length • Crop/vegetation/land cover • Support practice/conservation practices • Soil (e.g., organic matter, permeability, % sand, % clay)	• Incidence, cost or risk of harm and damage to persons or property from landslides due to de-vegetated terrain • Incidence, cost or risk of harm and damage to persons and property from flooding (e.g., due to wetland loss) • Change in regional food production • Cost of measures to decrease erosion

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Ecosystem Service	Indicators for Natural Capital, Ecological Functions and ES	Human Benefits Indicators
Water purification and waste treatment	• Denitrification (kg N/ha/year) • Immobilization in plants and soil • Maximum amount of chemicals that can be recycled or immobilized on a sustainable basis • Wetland presence and related processes (e.g., water filtration, nutrient recycling, absorption of inorganic pollutants) • Retention time of water in ecosystem • Comparison of pollutant concentrations between water flowing in and out of the system • Number of days that water is of insufficient quality for desired application • Biochemical degradation capacity of COD ($g/m^3/day$) • Amount of N and P stored (kg/ha/year)	• Incidence of water-borne disease • Volume of effluent released per geographic area (include industry, municipal, and septic) • Cost of having to build wastewater treatment plant
Disease regulation	• Number and impact of disease-control species • Reduction of human diseases	• Incidence, risk, and degree of vector-borne disease • Cost of disease eradication programs • Associated healthcare costs • Expressed sense of security in areas where diseases are controlled
Pest regulation	• Number and impact of pest-control species • Reduction of livestock pests, among others • Reduction of crop pests	• Incidence, risk, and degree of vector-borne disease • Associated costs ($) to mitigate pests (e.g., spraying infrastructure, application) • Associated costs to human health from spraying, and costs to healthcare system and productivity loss due to illness from exposure to chemicals, including through bioaccumulation in water, soil, and agricultural products, as well as direct exposure
Pollination	• Number and impact of pollinating species • Dependence of crops on natural pollination (%) • Distance between crops and natural ecosystems (m/km) • Increased yield attributable to pollination (crop dependency, annual production, ton/year)	• Number/quantity of regionally harvested pollinated food crops • Cost of hiring non-native pollinators to pollinate crops • Economic losses from decline in pollinators • Resilience of food system related to loss of diversity/quantity of pollinators *Continued on next page…*

Ecosystem Service	Indicators for Natural Capital, Ecological Functions and ES	Human Benefits Indicators
Natural hazard regulation	• Storm protective capacity dependent on vegetation structure • Topography • Length and width of vegetation belt • Presence of windbreaks (tree rows) • Impact of past storms • Protected values through protective forests (prevented damage potentials in $) • Probability of incident occurring • Total area coastal wetlands (ha) • Wetland area/depth • Water storage capacity • Reduction in flow/runoff • Delay of flood peaks	• Incidence of harm and damage to property from natural hazards (landslides and floods) • Associated costs ($) to property, healthcare system, worker productivity • Sense of security (expressed) related to risk of natural hazards
Cultural services – ***the result of ecosystem processes and functions that inform human physiological, psychological and spiritual well-being, knowledge and creativity***		
Cultural identity and heritage	• Number/area of culturally important landscape features or species • Number of people using forests (or other ecosystems) for cultural heritage and identity	• Extent of access to places of traditional/cultural significance • Level of satisfaction (expressed) with access to these places or condition of these places • Continuance of nature-based activities linked to cultural identity at local/societal scale (in this case frequency and extent may not be as important as just doing it—even once a year, e.g., Y/N and how many activities, % relevant population involved)
Spirituality and religion	• Presence of landscape features or species with spiritual value • Number of people who attach spiritual or religious significance to ecosystems	• Access to and use of natural areas (e.g., number of people) • Access to, use of, or expressed appreciation for known sacred places in nature • Expressed sense of peace from being in nature • Expressed spiritual significance of natural places

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Ecosystem Service	Indicators for Natural Capital, Ecological Functions and ES	Human Benefits Indicators
Knowledge systems and education	• Presence of features with special educational and scientific value/interest • Number of school classes visiting • Number of scientific studies	• Number or % of population employed in nature-related professions • Number of participants and extent in voluntary conservation and citizen science actions • Apprenticeships and transmission of traditional ecological knowledge or Indigenous traditional knowledge (e.g., number of people involved) • Consumption of nature-based media (expenditures, number of people)
Cognitive development, psychological and physical health and well-being	• Improvement in health or well-being related to being in nature or using green spaces (reported and scientifically measured)	• Incorporation of direct contact with nature in school curricula and programming (e.g., field trips, greening playgrounds) • Use of nature for rehabilitation of troubled youth (e.g., participation rates, investment) • Participation rates in local/regional nature groups • Access to and use of green spaces, public and private • Number of people who have chosen to live near access to nature • Number of people who cultivate green spaces around their homes (or number of hours spent in cultivation) • Expressed benefits of this type
Aesthetic experience	• Number/area of landscape features with stated appreciation • Expressed aesthetic value (e.g., number of houses bordering natural areas) • Number of users of scenic routes or scenic destinations • Square footage of beach	• Participation in gardening with plants and other natural materials • Participation in nature appreciation (e.g., birding, wildlife viewing, experiencing beauty in nature, in parks and gardens, private and public, wilderness, rural, or urban) • Amount ($) invested in greening spaces for aesthetic purposes (e.g., planting trees, flowers, removing pavement) • Willingness to travel for aesthetic nature appreciation
Inspiration for human creative thought and work	• Number/area of landscape features or species with inspirational value • Number of books, paintings, among others, using nature as inspiration	• Extent of literature/arts focused on nature in a region (e.g., number of writers, artists, photographers focusing on nature, or number of products, such as publications, websites) • Number of courses, workshops, events in nature-related arts, garden design, literature, dance, as well as participation rates

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Ecosystem Service	Indicators for Natural Capital, Ecological Functions and ES	Human Benefits Indicators
Recreation and ecotourism	• Number/area of landscape features with stated recreational value • Maximum sustainable number of people and facilities • Actual use (visits/day) • Size and accessibility of green areas in residential areas • Number of protected areas • Days spent in nature • Visitors to parks (number or hours) • Money/time invested in carrying out activities • Overnight accommodations in area • Access to natural areas or green spaces within specified distance from residence (e.g., "nearby nature" at <20 km)	• Participation rates (number of people or days) in nature festivals, nature tourism, nature-based recreation • Number of events, or places to recreate or participate in ecotourism • Visitors at parks and natural areas • Expenditures to participate (e.g., travel cost) • Expressed appreciation for recreation opportunities
Sense of place	• Number of households that consider an area or aspects of an area as important to their sense of place	• At local/regional scale can be done by observing local place-based marketing by municipalities and businesses, (e.g., in real estate, wineries marketing) • Extent local activism protects local nature from change • Number/extent of participation in community events featuring or celebrating local nature and its contribution to community identity
Supporting and habitat services – ***the underlying ecosystem processes and functions that are necessary for the production of all other ecosystem services, creating the biological environment***		
Soil formation	• Soil quality indicator • Soil organic carbon • % occurrence of problems limiting crop and livestock productivity	• Cost of labour and materials for rebuilding soil that is degraded • Security of farming livelihoods associated with good quality soil
Primary production	• Amount of food available to herbivores • Algal primary productivity (t/ha/year) • Total NPP • % occurrence of problems limiting crop and livestock productivity	• Costs associated with restoration of green areas
Nutrient cycling	• Nutrient export • Organic matter production • Phosphorus retention in soil (saturation) • % occurrence of problems limiting crop and livestock productivity • Days of harmful algal blooms • Clarity of water	• Cost of replenishing systems with nutrients (e.g., fertilization of agricultural fields) • Resilience of agricultural production associated with nutrient balance • Costs associated with eutrophication from over-fertilization

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Ecosystem Service	Indicators for Natural Capital, Ecological Functions and ES	Human Benefits Indicators
Water cycling	• Water balance in millions of m^3/year • Water use ratio • Water yield in kms^3	• Costs in urban areas associated with impermeable surfaces leading to flooding • Risk of flooding and erosion associated with impermeable surfaces • Resilience of system associated with engineering water systems (e.g., for irrigation, human consumption)
Habitat	• Number of transient species and individuals • Dependence of other ecosystems or services on habitat service • Vegetation structure • Topography (related to reproductive requirements of species)	• Costs associated with restoration of habitat • Resilience of animal populations used for hunting • Resilience of communities that rely on hunting and gathering for sustenance or cultural continuity

ES typology sources: *UN Millennium Ecosystem Assessment 2005. Ecosystems and Human Well-being: Synthesis. Washington DC: Island Press* http://www.millenniumassessment.org/en/Synthesis.html*; Landsberg et al. 2013 Weaving Ecosystem Services Into Impact Assessment. Washington, DC: WRI* http://www.wri.org/publication/weaving-ecosystem-services-into-impact-assessment*; TEEB n.d. Ecosystem Services.* www.teebweb.org/resources/ecosystem-services/#

Indicator example sources: de Groot, Fisher, et al. 2010; Hein et al. 2006; UNEP 2010; Layke 2009; Russi et al. 2013; Böhnke-Henrichs et al. 2013; CBD 2011b; Maes et al. 2011.

TOOLS – TAB 6 – VALUES AND VALUATION: ECONOMIC AND SOCIO-CULTURAL

Contents of Tab 6

T6.0. Introduction

A key factor in continued biodiversity loss is limited recognition of the specific ways that humans depend on healthy ecosystems.[210] Public policy plays a vital role, providing rules and tools to regulate and influence social and market behaviours, while attempting to avoid negative societal outcomes. To make informed decisions about new projects or policies, decision-makers need advice about how ecosystems and the ecosystem services (ES) they provide may be affected. They need to know the importance of those ES and how changes to the ES are likely to affect people. Two primary sets of approaches for providing information about this importance are economic valuation and socio-cultural valuation.

Government analysts, managers, and the public are increasingly aware that monetary values are sometimes helpful to demonstrate the importance of ES, and to inform decision analysis. There are also a number of other approaches used in both socio-cultural and economic valuation that can be helpful for informing many decisions.

This *Tool Tab* shows how valuation fits into the larger picture of ES assessment. It is a resource for completing valuation work and evaluating existing valuation studies. It can be used as supporting information for completing the step-by-step guidance in *Chapter 2* (especially *Step 4*), and in *Tools – Tab 4: Worksheets for Completing ES Assessment*, along with the factsheets that explain individual data collection

[210] MA 2005.

and analysis methods for valuation in *Tools – Tab 7: Compendium of Data Sources, Analysis Methods, and Tools*. Many of these tools are relevant in the context of ES assessment involving Indigenous communities, but there are important differences, so Toolkit users are also encouraged to read *Tools – Tab 3: ES Assessment Involving Indigenous Communities*.[211]

> ***Key Message:***
> Identification of values—in economic and/or socio-cultural terms—can be an important component of an ES assessment. Other economic analysis and socio-cultural analysis also have key roles to play in other aspects of ES assessment. They do this by providing evidence about human activity as it affects ecosystems, and about how people are using and benefiting from ecosystems and ES. These analyses are central to completion of worksheets (in *Tools – Tab 4*) that support each step in *Chapter 2*.

T6.1. Key Issues Common to Economic and Socio-cultural Valuation

"Valuation" in this section focuses on two types of analysis: economic and socio-cultural.[212] The methods, assumptions, and underlying bodies of theory for these two types of analysis are different but both provide important knowledge about how people benefit from ES and the relative significance of the benefits (the values). There are numerous direct and indirect ways to measure benefits and their significance, even in cases where people may not realize the ways that they benefit from biophysical processes that result in ES (e.g., in mitigating storm damage, controlling the spread of disease).

T6.1-1. The Need for Valuation and the Nature of Values

Valuation can be an essential element in making decisions in social settings. People continually face choices in their individual and collective lives. But while decisions can be made at random, people often make choices aimed at achieving a particular objective perceived as having worth.[213]

Valuation can be particularly useful when decisions involve trade-offs, when decision-makers need to justify costs associated with the management of ES, when there is a need to inform diverse stakeholders of the broad value of ES, or when weighing the costs and benefits of a particular decision. The public sector has long used cost-benefit analysis to assess decision options. It has, however, been a challenge.[214] For many environmental management issues, decision-makers are interested in having both socio-cultural and economic information to understand the significance of ES to people.[215] Both socio-cultural and economic valuation can include quantitative and qualitative measures such as descriptions and priority rankings. Economic valuation most often expresses values in monetary terms, whereas socio-cultural valuation does not.

Based on the accumulated experience acquired from 20 projects using ES analysis tools such as InVEST, the Natural Capital Project team and others reported that "to be useful for most decisions, tools must have the ability to estimate how *changes* in decisions lead to *changes* in [biodiversity and ecosystem services] and their values in terms of human well-being and nature." They found that decision-makers are interested in the consequences of actions for both "market commodities in monetary terms *along with* a host of non-market benefits, typically in biophysical units, and including cultural values and biodiversity."[216] If a study delivers results on ES in diverse output metrics, these can support various arguments relating to different stakeholder groups. It may also substantially enhance the meaning and transparency of results (compared to total monetary value estimates) and acknowledge the co-existence of multiple perspectives and value systems.

211 Additional interdisciplinary guidance on values and valuation for ES assessments was developed in 2015 by an international expert panel for the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) and can be accessed online, see IPBES 2015. See also Bennett et al. 2016.

212 See *Tools – Tab 9: Glossary*. This section addresses only economic and socio-cultural values. Ecological or biophysical values are defined here as measures of extent, condition, integrity, and resilience.

213 Epstein 2003.

214 The fields of environmental and ecological economics concern themselves with novel approaches to improving policy decisions by improving evidence and analysis. For more detail, see Field and Olewiler 2015 or Ranganathan et al. 2008.

215 For example, Kettunen and ten Brink 2013 discuss this in the context of protected areas.

216 Ruckelshaus et al. 2015: 18. The authors report on their observations of what decision-makers want in environmental decision-making and provide summaries of key lessons learned. Among these lessons is that being able to "follow biophysical estimates through to economic values has proven to be an important conceptual advance that has opened many decision-makers to discussions they did not previously consider. However, actually using the valuation models and providing estimates of monetary benefits has been less important than we anticipated." The authors further advise that in communicating to decision-makers, the link should be clearly made between changes in ecosystems and changes in multiple human well-being metrics, including income, health, and access to culturally important places and benefits. On InVEST, see factsheet in *Tools – Tab 7: Compendium of Data Sources, Analysis Methods, and Tools*.

T6.1-2. Context Dependency, Subjectivity, and Reliability in Valuation

As shown in *Figure T6.1*, human values—no matter how they are expressed or measured—are context dependent, inherently subjective, and influenced by numerous factors. The importance that individuals, groups, and society may place on a particular subject is widely recognized as a vital factor in management and decision-making processes.

There are many rigorous techniques to analyze values in socio-cultural and economic terms. Every established method is supported by a body of theory. Understanding the theory and its underlying assumptions is a critical aspect of determining the appropriateness of a given method for a particular situation.

The reliability of valuation data is an outcome of how it is collected and analyzed, because reliability is generated through:

- responsible application of logic in the design of an investigation;
- choice of methods and data that are relevant to the question(s) being asked;
- sound knowledge of the subject of investigation to allow correct understanding of data; and
- correct use of data collection and analysis methods, including correct identification of sources.

All statements of value are…

…INFLUENCED BY

- Experience, and personal well-being—generally and in relation to the subject of valuing
- The valuers' ethics and beliefs (e.g., worldview, culture)
- The valuers' sense of safety related to the communication of their values (e.g., perception of risk from the researcher, community, or others)
- Peer groups/families according to perceptions of what "should" be
- Media, advertisers, and other "distant" sources in terms of what is expected and what is possible
- Whether the valuer is speaking for themselves or for society
- New information, including:
  - Relative sense of urgency
  - Changes in socio-political effects on the subject of valuing (e.g., perceived increased/decreased threat)
  - Changes in personal well-being (e.g., safety, security, self-actualization)

…AND LIMITED TO

- The extent of knowledge held by the valuer
- Constraints set by the method used to elicit such statements, such as:
  - Pre-set choices never include all options, and can omit options relevant to the valuer
  - Questions are unavoidably influenced by the methodologist's worldview/culture, experience, expectations, knowledge, and assumptions about fundamental and seemingly minor issues
  - Analysis of results is compounded by limitations in bullet immediately above

***Figure T6.1.** Influences and limitations on all statements of value, regardless of the method used.*

T6.1-3. Distinguishing Between "Cultural Ecosystem Services" and "Cultural Values"

Practitioners of both socio-cultural valuation and economic valuation seek to assess cultural ecosystem services (CES), each using their discipline's distinct approaches. Of the four broad categories of ES, CES are the least well represented in ES research and practical applications of ES analysis.[217] There are several reasons, including (1) the tendency to confuse CES with cultural *values*;[218] (2) there is often a mistaken assumption that "cultural" refers to Indigenous communities only; and (3) CES are subjects better known to the social sciences—a field that has been underrepresented in ES research and application.[219] This segment explains CES and the difference between CES and cultural values to help Toolkit users more easily address CES alongside the provisioning, regulating, and supporting/habitat ES.

CES are characterized by direct personal interaction with nature and often involve an emotional, cognitive or physical experience for the beneficiaries. This quality of CES is sometimes confused or combined with the *values* that are attributed to them. In simplest terms, **CES are *things*** (services, like all other ES) and **values are the *importance*** of things (in this context, the importance of ES including CES).

The experience of CES is relevant to all people, in all places on Earth. It is important to keep in mind that CES and cultural values (or socio-cultural values) both apply not only to Indigenous cultures, but to all, because all humans are part of one or more cultures. Further, all peoples' values are informed by their culture(s). When considering whether to complete an ES assessment or when beginning an assessment, it is, therefore, important to consider the benefits of CES for *all* potentially affected beneficiaries. It is also important to consider that cultural values, or socio-cultural values as they are referred to in this Toolkit, are relevant for all types of ES.

The expert disciplines of philosophy, psychology,[220] and cultural anthropology provide the basis for understanding how and why CES—and all other ES—matter to people on *an experiential level*. A key task in working with all ES is to distinguish the *service* from its *benefit* to people, and then to ascertain the *relative significance* (how much the service and benefit matter, i.e., the value).[221] This will vary from one person to the next.

TIP: **People often mistake the terms "cultural ecosystem services" and "cultural values" as meaning the same thing. This is because the character of CES and their significance to people are often informally spoken of using the same terms. To illustrate, "aesthetic experience" is a CES but it is also how some people state *how or why* a natural place is important to them (what the benefit is), that is, "I value it because of the aesthetic experience" or more naturally, "I value it because it is beautiful." But the aesthetic experience is the *ES* and *beautiful* is a synonym for it rather than explaining why or how it matters. To complete the example of distinguishing "aesthetic ES" from "aesthetic value," note the description in *Table T6.1*, below.**

Table T6.1 helps to identify some key features of the benefits associated with each CES type, including:

- The initial benefits from one CES often become *catalysts* for the experience of other CES.
- Multiple CES can be experienced *simultaneously.* The assessment of only one of these CES cannot be assumed to encompass the others; they should all be addressed for their clearly different roles in human well-being.
- CES benefits are primarily *cognitive and emotional*; can be very focused on identity and practice, providing a sense of well-being, sense of orientation to the rest of the world, and fulfilment of essential human needs for connection and self-actualization.
- While the benefits are each experienced *internally* in individual people, they are often *shared* among groups of people through shared experience or shared learning about the experience (as in through family and community history).
- The benefits are mostly *intangible* with the exception of scientifically measurable improvements to physical health, or by considering the things that

[217] Chan, Guerry, et al. 2012; Satz et al. 2013.
[218] Scholte et al. 2015.
[219] Haines-Young and Potschin 2009.
[220] Maslow's 1943 "hierarchy of core human needs" remains widely accepted and used in social analysis: immediate physiological needs, safety, love (affection, belonging), esteem (respect), and self-actualization (including meaningfulness and self-transcendence), see, for example, discussion in Torminia and Gao 2013. Knowing that these needs are essential to human physical and psychological health reinforces the importance of CES and socio-cultural values in policy and decision-making.
[221] See the centre bar in the *Conceptual and Analytical Framework* in *Chapter 1* for the distinctions between these components.

people do as a result of their experience of the benefits (which could be considered indicators, e.g., creating a painting as a result of inspiration and aesthetic experiences).

- Some benefits from CES flow through an intermediary ES, for example, the provisioning service of wild food, from an Indigenous hunter's perspective, fulfils the benefit of sustenance (keeping his/her body alive) and at the same time the activities of hunting, handling the animal after it is killed, and using it for food, fibre, and possibly medicines, are grounded in cultural beliefs and reinforce identity and spirituality, inspire creativity, and inform knowledge systems.[222] A similar scenario of connections could be drawn for a farmer or a fisher.

Table T6.1. *CES: descriptions and how they inform human experience.*[223]

Type of CES	Abbreviated Description (see *Tools – Tab 1* for full version)	How/why it matters to people individually and collectively
Cultural identity and heritage	Identity and heritage are grounded in experience everywhere, in every type of ecosystem, and informed by relationships with nature that are distinctive to each place.	Feeling of personal and group security, groundedness, of being embedded in the collective home, connection and purpose, being part of something grounded in the knowledge and practices associated with place. Orienting the self socially and in time and space.
Spirituality and religion	Many religions, cultures, and individuals around the world attach spiritual and religious values to the earth and to ecosystems or their components, or find deep spiritual inspiration in their experience of nature.	Connection to a mystical "higher power," or "divine" or "life force" that most humans believe in as a creative force in the universe, provides a deep sense of meaningfulness in life. Feelings of love, affection, awe, and gratitude that can inform moral attitudes and beliefs about human place in nature, including feelings of genuine kinship and compassion for other living things.[224]
Knowledge systems and education	Perception of the Earth's ecosystems and their processes and functions are the foundation for all human knowledge systems.	Intellectual stimulation and the cognitive pleasure and growth that result; increasing capacity to understand the world and thus to aspire and achieve; the joy of discovery.
Cognitive development, psychological and physical health and well-being	Direct contact with nature is essential to support human cognitive development, and psychological and physical health.	Growth and capacity to process the world, to learn in all ways, to understand how to interact in the world. Capacity to be productive and to experience life. Healing, soothing psychologically and emotionally.
Aesthetic experience	The cognitive and associated emotional response to perceived beauty in the sounds, sights, scents, and sensations of nature.	Sensory and cognitive pleasure can be intensely life affirming, intoxicating, inspiring; can stimulate connections in the memory and emotions.

Continued on next page...

[222] These connections are well established and documented in the ethnographic, anthropological literature.
[223] Explanation of CES benefits in this table is informed by environmental values research summarized in S. Preston 1999, 2004, and 2011.
[224] Approximately 85 percent of people around the world believe in such a power (Pew Research 2012). Other research in both Indigenous *and* non-Native cultural contexts in Canada reveals deep kinship and compassion ties, for example, with some animal species as well as trees. In some cultures, the sense of kinship is formalized as ancestry, but in other cases it is based on a way of understanding one's place in the world as one of many sentient species. Ethnographic research demonstrates that depending on another species (even killing it for food) is not necessarily inconsistent with feelings of kinship and compassion for it (R. Preston 2002).

Type of CES	Abbreviated Description (see *Tools – Tab 1* for full version)	How/why it matters to people individually and collectively
Inspiration for human creative thought and work	Nature has always been and continues to be an important source of inspiration for much human art, literature, folklore, music, architecture, industrial design, symbols, and science.	Stir and fulfil the innate desire to express one's sense of self and sense of how to experience the world, in turn creating experiences related to the other ES; sense of active engagement in the world, enthusiasm, exuberance, passion for life.
Recreation and ecotourism	Nature-based recreation, leisure and ecotourism are all dependent on the direct experience of nature and engagement with it in some form.	Vitality and energy linked to physical activity given distinctive perceptual and experiential quality in nature; discovery and heightened awareness.
Sense of place	Perception of a distinctive identity of a place based on experience and informed by characteristics of that place which may be both natural and human-modified or built.	Connectedness, orienting oneself in the world, sense of forming mutual identity with self and place. (The experience of *place* is key to this benefit.)

Once the clear distinction is made between the "thing" (the type of ES) and the "benefit" (how or why it matters to people), the analyst can decide on how to (1) select data sources and what to look for in them; (2) select relevant analytic methods and tools; and (3) know what to focus on to reveal the relative significance.

Relative significance can be identified or measured in different ways, using methods from economics and other social sciences. The choice of methods to analyze that significance is discussed in this *Tool Tab*, in the sections below. The selection should be informed by considering both the underlying assumptions of the methods and whether they can logically be used to identify and measure the particular benefits and relative significance of a given ES or group of ES. The interconnectedness among CES (i.e., how people tend to experience multiple CES simultaneously) and their intangible character make it difficult to quantify their benefits, and the relative significance (values) of those benefits.[225]

Because the recreation and ecotourism CES are most easily measured and mapped (e.g., in terms of participation, location, expenditures), they tend to serve as a "catch-all" for CES in many assessments. But the methods used for assessing recreation and ecotourism typically do not capture the *importance* of those services to people and, while their inclusion in assessments is useful and informative, it does not reflect the importance of CES overall.

Anthropologists and other social scientists have researched human connections to nature since the early twentieth century and, in many cases, their research focuses on individual cultures and communities in specific locations. This literature can be useful for completing an initial scoping of priority ES (e.g., using *Worksheet 2*, the *ES Priority Screening Tool* in *Tools – Tab 4: Worksheets for Completing ES Assessment*) as well as contributing to desk-based and rapid approaches for an ES assessment. Recently, researchers have begun measuring the health benefits and associated values of ES.[226]

T6.1-4. Utility of Combined Valuation Approaches

Valuation that incorporates qualitative, quantitative, and monetary techniques and outcomes is recognized as an effective way to capture the importance of diverse ES to diverse beneficiary groups. Combining socio-cultural and economic valuation approaches can take different forms. For example, socio-cultural valuation methods can be used to identify, describe, and possibly

[225] For additional consideration of the distinctions between CES and cultural values, see also Scholte et al. 2015; Chan, Satterfield and Goldstein 2012; and Chan, Guerry, Balvanera, et al. 2012.
[226] See especially WHO and CBD 2015 for the state of knowledge on biodiversity and human health.

rank socio-cultural values of (some or all types of) ES, and economic valuation methods can be used to monetize utility-oriented values of some of the same ES or of different ES.[227]

Given the linkages between the economic and socio-cultural components of an integrated assessment, an interdisciplinary discussion on benefits can improve the overall usefulness and quality of work.

It is rarely necessary or feasible to complete a comprehensive valuation of all of the ES in a particular scenario or decision context. This emphasizes the importance of carefully identifying the priority ES (*Worksheets 2* and *3* in *Tools – Tab 4: Worksheets for Completing ES Assessment*). Although it may seem obvious, it is typically advisable to explicitly report that the results of valuation are a significant underestimate of the actual importance of ES, indicating which ES are assessed and which are not, as well as acknowledging any limitations created by the choice of indicators and data sources.[228]

Even when the main focus of an analysis is on any one type of value (e.g., social, economic, ecological[229]) there will be important complementary values to consider at the same time because of the relational character of ES.[230]

T6.1-5. Criteria for Choosing Valuation Methods (All Types)

There are a number of different economic and socio-cultural valuation methods. The valuation methods chosen to be used in a particular ES assessment should be guided by the reason for doing the analysis. The methods chosen should enable adequate assessment of the economic and socio-cultural values associated with the priority ES, and other relevant ES to the extent possible. It is important to keep in mind that different methods produce different kinds of results in different formats with different conclusions, because each method has its own underlying assumptions that inform its procedures and how its results can be interpreted.

Box T6.1 lists some considerations for choosing a non-monetary approach to valuation which are relevant to both economic and socio-cultural valuation.

Box T6.1. Considerations in choosing a non-monetary approach to valuation.
(Source: Kelemen et al. 2014:2)

"The choice among methods should depend on several factors:

1. the capabilities and the socio-cultural context of the communities involved,
2. the institutions and the value-systems held by stakeholders,
3. the needs and purposes of the decision-makers and of the concerned project,
4. the commitment and capacity of the researchers and practitioners who carry out the valuation process and
5. the main characteristics of the decision making process affected (i.e. number of relevant stakeholders, the level of conflicts, etc)."

"These contextual factors can remarkably influence the process and the results of valuation. For example, the use of monetary valuation to inform decisions may be more appropriate in a market economy than in a context of peasant, indigenous, or other community based societies where environmental values are deeply interwoven with community and spiritual values. Likewise, results may also be influenced by the (false) expectations of stakeholders and the mandate of the researchers and practitioners who carry out the valuation process. A key step towards the applicability of non-monetary valuation of ESs is, thus, to provide guidance on which valuation contexts enable the use of which methods (and which methods cannot be used reliably in certain contexts)."

227 This is suggested by research results reported in Asah et al. 2014: 180 who state that "Perceived ecosystem benefits, expressed in people's own words and from their own frames of reference, can facilitate better valuation of ecosystem services and setting of prices, compliance with ecosystem management and policy directives[...]"
228 Kettunen and ten Brink 2013.
229 While this Toolkit generally does not refer to biophysical metrics as "ecological values," there is an increasing use of the term in international ES literature to illustrate the need for pluralism and interdisciplinary approaches in assessing ES. See, for example, Gómez-Baggethun and Martín-López 2015; Gómez-Baggethun, Martín-López et al. 2014; and IPBES 2015.
230 See explanation of the requirement for interdisciplinarity in ES assessment in *Chapter 1*. Any ES assessment (including those with valuation analyses) will consider both ecosystem conditions and the human/social benefits from them because "ES" is inherently about this relationship.

A complementary set of criteria for choosing valuation methods from economics and other social sciences was developed by the Science Advisory Board for the US Environmental Protection Agency (EPA):[231]

- "Does the method capture the critical features of the relevant population's values, including how deeply they are held? Does it yield value estimates that reflect the intensity of people's preferences or the magnitude of the contribution to a given goal?"
- "Does the method impose demands on respondents that limit their ability to articulate values in a meaningful way? For example, does the method impose unrealistic cognitive demands on individuals expressing values? Does it allow those individuals to engage in the process that they would normally undertake to identify or formulate and then articulate their values?"
- "Does the method yield value estimates for individuals that those individuals would, if asked, consent to have used in the proposed way?"
- "Does the method ensure that measured or elicited values reflect relevant scientific information? A basic premise of the valuation approach proposed by the committee is that a method should elicit or measure values that individuals would hold when well-informed about the relevant science. This does not require that all individuals expressing values know as much as scientific experts in the field, but rather that they understand as much of the science as necessary to make informed judgments about the service(s) they are being asked to value. For example, they should be aware of the magnitude of the changes in ecosystem services or characteristics that would result from the ecological changes being valued, as well as the implications of those changes for themselves and for others."
- "Does the method yield value estimates that are responsive to changes in variables that the relevant theory suggests should be predictors of value, and invariant to changes in variables that are irrelevant to the determination of value?"
- "Are the expressions of value resulting from the method stable (i.e., reliable) in the sense that they do not change upon further reflection (Fischhoff, 1997) and are not unduly influenced by irrelevant characteristics of the researcher, process facilitator, or group?"
- "To what extent does the information elicited from participants in the application of the method (e.g., survey respondents or focus group participants) provide information that can be used to reliably infer something about the values of the targeted group within the relevant population?"

Even when using existing sources of valuation data (i.e., publications from previous primary research), it is important to assess the data's validity in terms of these criteria. In addition, TEEB authors advise that "since there are multiple theories of value, each valuation exercise should ideally: (i) acknowledge the existence of alternative, often conflicting, valuation paradigms; and (ii) be explicit about the valuation paradigm that is being used and its assumptions."[232]

T6.1-6. Participatory and Deliberative Valuation

Participatory and deliberative techniques (PDTs) are a set of tools available to decision-makers and analysts to account for ES by directly engaging with stakeholders to identify their values and preferences.[233] PDTs provide decision-makers and analysts with a set of tools to inform and enhance valuation when considering policies, plans, and projects that impact on ES and their management. This may be through *survey* methods, such as the use of interviews and stated preference questionnaires, but also more elaborate techniques based on the principle of group debate and shared learning, such as *deliberative monetary valuation* and *deliberative multi-criteria analysis*. PDTs can be used to complement and extend analytical information for appraisal through desk-based research, for example, where gaps in evidence and understanding are thought to exist. Stakeholders can help inform, for instance, a better understanding of winners and losers, basic qualitative descriptions of costs and benefits, and quantification of impacts as well as monetary valuation. PDTs provide a "toolbox" for helping to achieve this. PDTs can supplement insight derived from desk-based approaches, for example, where there are perceived gaps in available evidence or insight or where relying on desktop analysis appears insufficient.

Participatory processes should be understood as of general importance to decision-makers and analysts where the impacts associated with the future provision of ES are expected to be significant or where understanding of impacts is uncertain. More generally, a participatory approach is practically important where the management of impacts is potentially complex, for

[231] SAB/EPA 2009: 41-43. The SAB guide to ES valuation categorizes methods in seven broad groups (pages 42–43): (1) measures of attitudes, preferences, and intentions; (2) economic methods; (3) civic valuation; (4) decision science approaches; (5) ecosystem benefit indicators; (6) biophysical ranking methods; and (7) cost as a proxy for value. Within these categories they identify and explain 17 different methods. Their report and supporting papers may be considered by users of this Toolkit as a supplementary resource to *Tools – Tab 7: Compendium of Data Sources, Analysis Methods, and Tools.*

[232] Pascual et al. 2010: 191. See also UNEP 2010: 24. Factsheets in *Tools – Tab 7: Compendium of Data Sources, Analysis Methods, and Tools* provide information about assumptions as well as strengths and limitations for many different methods.

[233] Selected Text on participatory and deliberative techniques excerpted and reproduced from Fish et al. 2011b with permission.

instance, where interventions cut across a range of ES. An understanding of these areas may itself depend on consultation with stakeholders at an early stage in the policy cycle. The choice and mix of PDTs will be dictated by issues of proportionality, the quality of available evidence, the temporal and spatial scale of decision-making, as well as resource constraints. Where impacts on the future provision of ES are high, the case for incorporating these techniques is particularly strong. PDTs and desk-based analysis provide for different levels of engagement with decision-making, though all can be used to elicit monetary and non-monetary values for ES. An overall schematic of the relationship between values expressed and level of engagement is depicted in *Table T6.3*, with some indicative examples.

Table T6.3. *Overview of key PDTs and their contexts of application in valuation (from Fish et al., 2011b, used with permission).*

Key Techniques	Time/Money Inputs	Expertise Inputs	Type of Data/Values	Contribution to Regulatory Analysis	Stage in Policy Cycle
Analytic-deliberative					
Deliberative multi-criteria analysis. A technique for evaluating the costs and benefits of options against a range of non-monetary and monetary criteria.	High	Technical, social	Monetary and non-monetary combined into a quantitative non-monetary scale of values	Monetary and non-monetary valuation of costs and benefits	Formulating options and technical appraisal of options
Deliberative monetary valuation. A technique for deriving monetary values in a group setting.	Medium to high	Technical, social, economic	Monetary expressed in terms of "self" and "other" regarding preferences	Monetization of costs and benefits	
Deliberative approaches					
In-depth discussion groups. Group-based assessments of an issue, open and exploratory in structure. Participants can shape the terms of the discussion, developing themes in ways relevant to their own needs and priorities.	Medium to high	Social	Qualitative and non-monetary	Identifying winners and losers; describing costs and benefits	All stages, though technique tends to open up issues rather than close down
Citizen juries. Group-based assessment of an issue based on exposing citizens to evidence by way of expert witnesses and different stakeholder perspectives.	Medium to high	Social	Qualitative and non-monetary	Identifying winners and losers; describing costs and benefits	Testing of options

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Key Techniques	Time/Money Inputs	Expertise Inputs	Type of Data/Values	Contribution to Regulatory Analysis	Stage in Policy Cycle
Survey techniques					
Structured questionnaires. Technique to elicit information from individuals using a consistent approach to the content and phrasing of questions.	Low to high	Social, technical, economic	Quantitative monetary or non-monetary	Identifying winners and losers; describing costs and benefits; quantifying impacts; monetization of costs and benefits	Option formulation technical appraisal of options
Semi-structured interviews. Technique putting open-ended questions to individuals on a similar topic. Phrasing of questions varies between interviews.	Low to high	Social	Qualitative and non-monetary	Identifying winners and losers; describing costs and benefits	Option formulation
Focus groups. A semi-structured interview in a group format.	Low to medium	Social	Qualitative and non-monetary	Identifying winners and losers; describing costs and benefits	Testing of options

Values defined through processes of group deliberation with a focus on what is best for society (e.g., in terms of willingness to pay (WTP)) are quite different from values that reflect individual personal preferences. This has clear implications for environmental management and decision-making in the public sphere.[234]

The UK National Ecosystem Assessment Technical Report[235] lists five key findings about shared values:

- ecosystem assessment requires a consideration of shared values;
- shared values concern the values people hold for ES as "citizens";
- the reliability and legitimacy of decision-making processes that flow from ecosystem assessment depends on the explicit recognition of shared values;
- consideration of shared values within ecosystem assessment and decision-making requires a more interpretative approach to valuation; and
- there is an overall need for theoretical and methodological plurality in assessing the value of ES for human well-being.[236]

Details about many techniques available to complete economic and socio-cultural valuations are provided in the sections on economic *(T6.2)* and socio-cultural approaches *(T6.3)* and in the factsheets in *Tools – Tab 7: Compendium of Data Sources, Analysis Methods, and Tools.* The extensive range of valuation techniques

234 See discussion in Wilson and Howarth 2002; and see Fish et al. 2011a; and Fish et al. 2011b; and SAB 2009:15.
235 Fish et al. 2011a. For comparison of PDTs and instrumental approaches in ES valuation, see Raymond et al. 2014.
236 Some studies show that preferences and priorities elicited from groups tend to be oriented to the well-being of society rather than to individual self-interest and may, therefore, be better suited to public decision-making than elicitation of individual preferences. See Fish et al. 2011a and 2011b on justification and use of participatory and deliberative methods in both monetary and non-monetary ES valuation. Analysis by Ambrus et al. 2009 does not support this finding.

is illustrated in *Table T6.4.*[237] Techniques listed as "monetary" are specific to economic valuation; techniques listed as "non-monetary" all apply to socio-cultural valuation, but many of them can also be used in economic valuation that results in non-monetary descriptions that may be interpreted through the lens of economic theory.

Table T6.4. *Major valuation methods.* Adapted from TEEB 2010: 44; Christie et al. 2012: 71; and Keleman et al. 2014: 2. Other approaches can also be used, such as health-based and insurance.

Group	Method
Monetary techniques	
Direct	Market (actual prices) and simulated market (auctions)
Market alternatives	Replacement or mitigation costs (inferred from actual prices)
	Damage cost avoided/averting behaviour (inferred from actual prices)
	Production function ("invisible" inputs to commodity prices)
	Dose-response (damage) function
Surrogate markets (proxy values)	Hedonic (property and wage values)
	Travel costs (based on travel expenditures) and random utility models
Stated preference (includes consumer surplus)	Contingent valuation (WTP/willingness to accept (WTA))
	Choice experiments/modelling (WTP/WTA)
Participatory and deliberative	Deliberative valuation (group WTP/WTA)
Economic benefit transfer (value transfer)	Benefit transfer (mean value, adjusted mean value, benefit function)
Non-monetary techniques	
Consultative (individual respondents)	Survey questionnaires (closed format, e.g., choice, open-ended)
	Interviews (in-depth, semi-structured, ethnographic)

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[237] A comparison of many of the merits of economic and non-economic valuation approaches can be found in Christie et al. 2012, Table 3. Additional comparisons between economic methods are cited below.

Group	Method
Participatory and deliberative (individual and group respondents)	Focus groups (facilitated discussion)
	Citizens juries (facilitated negotiation)
	Delphi surveys (expert consensus building)
	Future scenarios
	Constructed scales (ranking and scoring)
	Participatory rural appraisal (social mapping, transect walks, other)
	Participatory mapping (spatial identification of values)
	Photo elicitation (preference ranking of options)
	Rapid appraisal (site observation and discussion)
Non-consultative techniques	Secondary sources, document analysis (statistics, research documents)
	Embodied energy, ecological footprint, court awards, insurance costs

T6.2. Considerations for Economic Valuation

T6.2-1. Basis of Economic Valuation

Economic valuation is used to identify and estimate the values held by an individual or society. These values are estimated based on individual preferences and choices, with the understanding of particular constraints such as income, demographics, time, values, education, and awareness, among others.

Conservation and sustainable-use ecosystems are necessary to ensure the flow of ES. The majority of ES are not recognized by economic markets and as such are viewed as externalities. One argument is that this non-recognition then leads to market failure because the actual costs of ES loss are not factored into economic decisions. The result is further decline of ecosystems and reduced human well-being.

Since not all ES are associated with economic markets and prices, there are a number of methods that economists use as proxy to estimate their economic value. These values are used in a variety of decision-making frameworks to inform public policy or management decisions. Valuation allows for a monetary analysis of trade-offs between the costs and benefits of a project or policy, both for the economy, society, and for impacted ecosystems.

Economic valuation of ES has become more widespread in recent years. These values are playing a greater role in public policy decisions, based on cost-benefit analysis that offers a relatively convenient approach to measuring societal value. Economic valuation is an inherently anthropocentric approach rather than a bio-centric approach.[238]

The theory of welfare economics sees individuals as able to assess their own well-being, and that changes to well-being can be monetized by determining individual preferences in terms of their WTP or alternatively, WTA. Further, welfare economics assumes that societal welfare overall is determined by aggregating the values of individuals. "Economic value" from this perspective is an estimation of either WTP or WTA.[239] Economic methods are also sometimes used to estimate a comprehensive monetary value for an ecosystem or its services to communicate importance.[240] The core assumptions of economic valuation are explained in *Box T6.2*.

[238] For elaboration on interpreting and estimating economic values of ES, see Goulder and Kennedy 2011.
[239] Philcox 2007; and see *Millennium Ecosystem Assessment* 2003, chapter 6, on valuation.
[240] See, for example, the series of reports published by the David Suzuki Foundation listed in *Tools – Tab 10: Canadian ES Assessments and Analyses Reference List.*

Box T6.2. "***Economic values*** assume that individuals are rational and have well-defined and stable preferences over alternative outcomes, which are revealed through actual or stated choices (see, for example, Freeman, 2003). Economic values are based on utilitarianism and assume substitutability, i.e., that different combinations of goods and services can lead to equivalent levels of utility for an individual (broadly defined to allow both self-interest and altruism). They are defined in terms of the tradeoffs that individuals are willing to make, given the constraints they face. The economic value of a change in one good (or service) can be defined as the amount of another good that an individual with a given income is willing to give up in order to get the change in the first good. Alternatively, it can be defined as the change in the amount of the second good that would compensate the individual to forego the change in the first good. Economic values can include both use and nonuse values, and they can be applied to both market and non-market goods. The tradeoffs that define economic values need not be defined in monetary terms (willingness to pay or willingness to accept monetary compensation), although typically they are. Expressing economic values in monetary terms allows a direct comparison of the economic values of ecosystem services with the economic values of other services produced through environmental policy changes (e.g., effects on human health) and with the costs of those policies. However, monetary measures of economic values should not be confused with other monetized measures of economic output, such as the contribution of a given sector or resource to gross domestic product (GDP)." *Source: SAB/EPA 2009: 14*

Economic *analysis* typically relies on several different kinds of information, including statistics (e.g., numbers representing amounts of things, such as number of people, units of water flow, amounts of various commodities), demographic data, valuation (e.g., market and nonmarket values), and monetary units associated with costs (e.g., replacement cost, damage cost, capital costs, forgone opportunity costs). All of these are important economic variables to support decision-making, and all of them contribute to analyzing the importance of ES to society. Monetary units are considered useful because they enable quantified comparisons of different variables using the common metric of money.[241] In the context of ES, this can be a very important part of analysis when land-use and land-cover changes may cause the loss of ES.[242]

T6.2-2. Contexts for Using Economic Valuation

Economic valuation can be useful in many decision-making contexts, including:

- appraising or evaluating the costs and benefits of a policy or project;
- investment decisions;
- where trade-offs are involved between use(s) of ES that are impacted by a policy or project;
- pricing and allocation of resources;
- management of resources and ES;
- conservation decisions and protected areas;
- demonstrating the importance of an issue or ES;
- assessment of damages where evidence is required for assessing compensation for use or restoration costs; and
- assessment of non-market costs associated with a project's or policy's impacts on ES (e.g., health costs, loss of ES, habitat loss).

Table T6.5 lists some of the questions that can arise in decision-making situations for which economic valuation in the context of ES assessment may be useful.

241 Although the unit of measure is standardized (dollars for dollars) and thus appears to compare equivalents, the diverse modes for calculating the monetary units introduce variability in their actual meaning that is not evident when reporting the monetary units alone, see Philcox 2007:30 and EPA/SAB 2009: 23. Validity is strongly supported by transparency about this variability in analysis and reporting. This can be facilitated by reporting a range of units rather than a single unit. *See Tools – Tab 2: Cross-cutting Issues and Key Considerations* for advice on communicating uncertainty in both quantitative and qualitative terms.

242 See, for example, all reports of the TEEB initiative.

Table T6.5. *Typical decision-making context for ES valuation. (Adapted from CCME 2010)*

Decision Context	Typical Decision-making Questions
Policy and project analysis issues (including demonstrating the importance of an issue; setting priorities; appraisal of investment projects, policies, regulations and standards, and damages)	Is a project or policy warranted? Which project or policy should be chosen among a set of alternatives? How can comparable projects and policies be ranked in order of "worth"? On what scale should a policy be implemented? What is the appropriate standard or target for a policy measure? How much should be spent on best management practices? Is there a case for conservation actions?
Pricing and allocation issues	What is the appropriate level of an ES user tariff? What uses should an ES be allocated to?
Legal damage assessment (including polluter liability and compensation)	What is the cost of environmental damages and/or degradation of ES? What scale of compensation for damage is justified or required by law?

T6.2-3. Determining If Economic Valuation Is Required and Feasible

In assessing whether economic valuation evidence is required, a key question to answer is *how would economic valuation of ES improve the decision made in a given situation?* This will depend on various considerations, but generally:

- If the decision-making context is one of demonstrating importance of an issue, economic valuation evidence could improve the case made for the issue in question.
- Economic valuation is particularly useful in the context of the monetary values assigned to other resources, assets or damages involved in the decision, project, issue or policy. In this context, the values associated with changes in ES can be compared on a like-for-like basis with other environmental, social, and market goods and other options or alternatives.
- If the decision-making context is policy or project analysis, the requirement for economic valuation depends on the analysis method used. If the context is one of appraisal or evaluation (e.g., through cost-benefit analysis or multi-criteria analysis), then value evidence is more likely to be needed.
- If the decision-making context is one of ES pricing or allocation, valuation is not necessarily a prerequisite for policy formulation but is likely to be beneficial.
- If the decision-making context is one of damage assessment or cost assessment, valuation evidence will be advantageous and may be a legal requirement depending on the liability regime.[243]

Additional considerations may include: [244]

- Is the ES benefit commensurable, since estimating a monetary value implies that the subject can be traded off or substituted?Do technical experts, stakeholders, and decision-makers consider assigning a monetary value to the effect on the ES benefit acceptable? Or would socio-cultural valuation communicate the value to decision-makers more effectively?
- Is there sufficient data to support estimating a monetary value? Application of valuation methods requires some form of quantitative or physical data on the change in provision of ES (e.g., quantity of water, size of user population affected). Where there are gaps or uncertainty in physical data, it may be necessary to first undertake scientific or other impact studies.

[243] These five points adapted from CCME 2010: 22–23.
[244] See Chiesura and de Groot 2003, and *Tools – Tab 9: Glossary* on critical natural capital and substitutability.

- Is there sufficient time and resources? Ideally the objective of ES economic valuation will be accounted for at the outset of any decision-making situation. Different valuation methods require different financial resources and budget constraints will influence their feasibility.[245]

T6.2-4. The Total Economic Value Framework

An economic valuation approach for estimating the benefits flowing from ES is to estimate their "total economic value" (TEV). While different authors may use slightly different TEV frameworks, the foundations of TEV are based in welfare economics and focus on the changes in economic welfare.[246] The adoption of the TEV approach can reduce the incidence of ES benefits remaining unvalued and unappreciated, and enable more obvious comparisons of benefits and costs in environmental management and decision-making.

Within the TEV framework, economists group values in terms of the "use" or "non-use" of a resource or ES, shown in *Figure T6.2.* There is a selection of valuation methods available for both groups. Use values can be both direct and indirect, and relate to the current or future uses of a resource or ES. Direct use values may be "consumptive" (e.g., drinking water) or "non-consumptive" (e.g., nature-based recreational activities). Indirect use values capture the ways that people benefit from ES without necessarily seeking them out (e.g., flood protection). Non-use values are based on the preference for nature's existence without using it, and are of three types: existence value, altruistic value, and bequest value. The different types of values are analyzed using different methods from *Table T6.4* in the previous section.

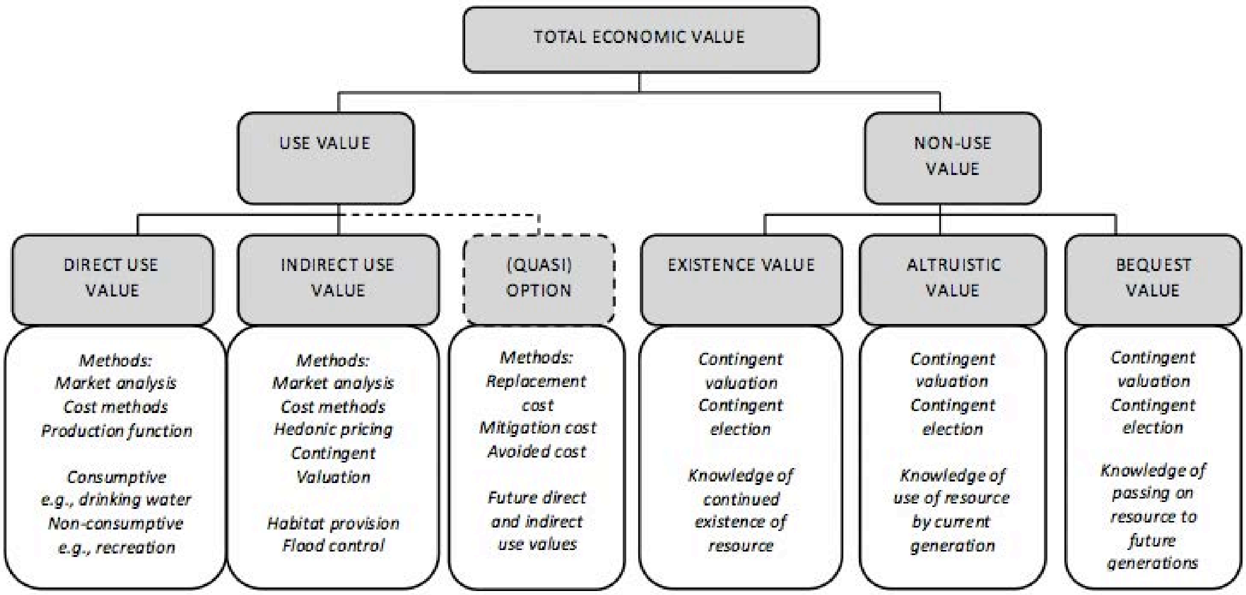

Figure T6.2. *The TEV framework.* (Adapted from CCME 2010)

While the TEV is a useful and holistic economic approach for identifying the array of values from ES, analysts should be mindful of the following: (1) TEV is anthropocentric in that the values are human-held. It does not attempt to account for the possibility that nature in general, and species in particular, have values unrelated to humans; (2) any attempt to calculate the TEV is likely to have problems with missing data; and (3) undertaking a full TEV is often unnecessary. In many cases, only a portion of values needs to be estimated to sufficiently inform a management decision.

In addition, the TEV framework typically does not capture biophysical approaches, physical costs, intrinsic values or several of the socio-cultural values such as spirituality and identity.

[245] See CCME 2010 for details on economic valuation methods.
[246] Nunes et al. 2001.

T6.2-5. Identifying the Appropriate Economic Valuation Method

When determining the valuation method to use, choose the one that is most appropriate to the decision-making question and the evidence needs, or as required by law. Economic valuation methods differ in the type of economic value they can estimate and in the type of data they use. A combination of methods may be required to answer the questions posed in an assessment. These may include existing studies or the collection of new data. A comparison of valuation methods based on type, aspect of TEV captured, approach, ES valued, data requirements, benefits, and limitations of approach is provided for each major economic valuation method in the *Guidance Manual for the Valuation of Regulating Services*, published by UNEP.[247]

The main economic valuation methods are grouped into two categories: revealed preference and stated preference.[248]

- **Revealed preference methods** can provide estimates for the value of ES through:
  - market prices for ES;
  - observed behaviour related to non-market (unpriced) goods and services, for example, valuing the environment through the cost (both money and time) incurred in undertaking nature-based recreation activities; and
  - production function (or input) which focuses on the indirect relationship between a particular resource or ES (unpriced) (e.g., water) and the production of a (priced) market good (e.g., agricultural crops). The use value is inferred by changes in production that result from changes in the input to production (e.g., quantity or quality).
- **Stated preference methods** can provide estimates of the monetary value for ES based on people's preferences. Stated preference methods are the only way to estimate non-use values in economic terms. These methods include contingent valuation, discrete choice experiments, and contingent ranking. They are all based on surveys in which the public is directly asked about its WTP (or WTA) for hypothetical changes in environmental quality, or about choices between different levels of environmental quality and the price of each level.

When time and financial resources needed for collection of new data are not available, existing data may be utilized through the benefit transfer method. This entails identifying appropriate value evidence from the results of existing studies and "transferring" these to the decision-making context of interest. Benefit transfer analysis can be quicker and less expensive, but care must be taken to use the correct transfer method.[249] There are three types of transfer methods:

- Value transfer – uses a single value from a study site or a mean from multiple study sites to provide a single policy site value estimate.
- Functional transfer – uses an estimated valuation function to compute a transfer estimate that is calibrated to policy site conditions using the variables in the equation.
- Model transfer (meta-analysis) – uses estimated valuation function results from multiple study sites.

Rather than use simple value transfer, it is more rigorous to use functional or model transfer and/or sensitivity analysis to minimize or properly characterize the differences in the policy and transfer sites.[250]

T6.2-6. Key Analytical Details in Undertaking Economic Valuation

When undertaking economic valuation of ES, two of the aspects of analysis that need to be addressed well for the results to be reliable are double-counting and discounting, discussed below.

Double-counting. Double-counting occurs when the value of something is counted twice. It often occurs in the valuation of ES, and can lead to inaccurate and unreliable estimates. Six fundamental causes of double-counting in ES valuation and measures to reduce or avoid it are:[251]

- **Ambiguity in the definition of ES.** It is important to distinguish between ecosystem *functions* and ecosystem *services*. Ecosystem functions are physical, chemical, and biological processes that contribute to maintaining an ecosystem and providing ES, whereas ES are the end products that provide direct benefits to people. Counting the value of both ecosystem functions and ES will often result in double-counting. When calculating the TEV of ES, the value of ecosystem functions should be excluded.

[247] UNEP 2010, Tables 9A, B, C, D, and E on pages 24–26. See also *Table T6.3* above and factsheets in *Tools – Tab 7: Compendium of Data Sources, Analysis Methods, and Tools*. Further pointers on advantages and disadvantages of each method of economic valuation are presented in TEEB 2012, Table 5.8.

[248] There are many guides on the use of different economic methods for identifying values, for example, CBD 2007; TEEB guides provide extensive descriptions of economic valuation considerations and methods and a comparison chart is provided in Brander et al. 2010 (TEEB Foundations). A description of each economic method is provided by the Treasury Board Secretariat of Canada in their guidance on completing cost-benefit analysis—see Government of Canada 2007.

[249] See factsheet on this method in *Tools – Tab 7: Compendium of Data Sources, Analysis Methods, and Tools*. Because benefit transfer is one of the most commonly used methods for estimating economic values of ES, it warrants additional attention here. TEEB 2012 Chapter 6: 231-237 outlines key issues.

[250] The *Environmental Valuation Reference Inventory* www.evri.ca is a searchable database containing over 4,000 summaries of health and environmental valuation studies, and may be a cost-effective instrument to assist in literature review, meta-analysis and benefit transfer.

[251] These six points are summarized from Fu et al. 2011. TEEB 2012 also discusses double-counting, identifying similar issues.

- **Complexity of ecosystems.** A key cause of double-counting is that ecosystem processes and their interactions are complex and are not yet fully understood. Ecosystems provide multiple complex services, and there are complicated causalities within and between ES. It is not possible to disaggregate total ES into independent services because most of them depend on or overlap with others. To avoid double-counting, it can be helpful to look at the change in the value of individual ES due to ecosystem changes rather than to estimate the absolute value of individual ES or of total ES.
- **Spatio-temporal dependence of ES.** The value that stakeholders place on ES depends on the time frame and geographic scale. The appropriate scale to use depends on the purpose of the research, the specific ES to be included, the need for the scale to reflect key relationships within and between ecosystems, and data availability. Some ES are generally best valued at specific scales (e.g., water regulation at a watershed scale; carbon sequestration at a national or global scale). Double-counting can arise if there is overlap of ES across different scales that is not properly identified. Information about the scale dependency of ES and the interrelations between scales and stakeholder values can be an important consideration for decision-makers, especially when trying to balance the interests of different stakeholders at different scales.
- **Exclusiveness and complementarity of ecosystem values.** ES have properties of exclusiveness, complementarity, or both. Exclusiveness means that the use of an ES by some people will make it unavailable for use by other people; complementarity means that an ES can be used by many people without affecting its availability for use by others. Most ES are complementary, but some ES (particularly in the provision services) are exclusive. Double-counting would arise when the values of all the exclusive and complementary ES are aggregated; and it could also arise when the values of some complementary ES are aggregated, depending on the interactions between them. To avoid double-counting, it is advisable to calculate the values of exclusive and complementary ES separately and check for potential interactions between them.
- **Inconsistency of ES classifications.** There are several different ES classification systems in the literature, with each system developed for a different purpose or context. Within these different classification systems, there is often overlap between some of the individual ES. To avoid double-counting, a classification system that minimizes the overlap of ES is useful.
- **Overlap and no cross-referencing of valuation methods.** Some ES can be valued by more than one valuation method, which makes it important to consider the context of the research when selecting the methods to use. There are individual valuation methods that are susceptible to double-counting within the method. Double-counting can also arise across the different valuation methods because they are not independent of each other, so when multiple valuation methods are used it is important to understand the complex connections between them.

When undertaking economic valuations of ES, it is difficult to completely avoid double-counting. However, the estimated value of ES can vary significantly depending on how the potential sources of double-counting mentioned above are addressed. Hence, it is very important to carefully identify and address the potential for double-counting to provide accurate and reliable information.

Discounting. When undertaking an ES assessment, the analysis often requires comparing costs and benefits that would arise at different points in time. In dealing with environmental policies and projects, there is often a substantial time lag between when the costs would be incurred and when the benefits would be experienced (i.e., the costs of implementing a program to improve the quality of some aspect of the environment are often incurred many years before the improvement in environmental quality is experienced). The challenge is to characterize the stream of future benefits and costs in a way that makes them comparable so that current decision-makers are informed about the trade-offs between policy options.

Discounting is the method commonly used for making costs and benefits that occur at different points in time comparable. Discounting involves multiplying future monetary values of costs and benefits by a discount factor that is intended to adjust the future values to present day value terms.

TEEB authors point out that discounting is a key issue in the economics of biodiversity and ecosystems. TEEB provides a summary of the major challenges to discounting biodiversity and ecosystem losses, including the following:[252]

> "…recent debates among economists over two of the most pressing issues of our time, biodiversity loss and climate change, have made it clear that no purely *economic* guidelines are available for valuing essential and irreplaceable features of the natural world. Responsibility to future generations is a matter of inter- and intra-generational ethics, best guesses about the well-being of those who will live in the future, and preserving life opportunities for

[252] Gowdy et al. 2012: 278-279.

humans and the rest of the living world. Economics can offer valuable insights, … but ultimately economic value represents only a small portion of the total value of biodiversity and ecosystems. The practice of discounting applies first and foremost to an individual deciding how to allocate scarce resources at a particular point in time. In general, an individual would prefer to have something "now" rather than in the future … This is the main argument for a positive discount rate. But, again in general, a higher discount rate will lead to the long-term degradation of biodiversity and ecosystems. For example, a 5 per cent discount rate implies that biodiversity loss 50 years from now will be valued at only 1/7 of the same amount of biodiversity loss today. This leads to the following observations [among others]:

- … a variety of discount rates, including zero and negative rates, should be used depending on the time period involved, the degree of uncertainty, ethical responsibilities to the world's poorest, and the scope of project or policy being evaluated.
- A low discount rate for the entire economy might favor more investment and growth and more environmental destruction. Macroeconomic consequences of a particular discount rate should be considered separately from microeconomic ones."

Users of this Toolkit are advised to clarify any obligations they may have regarding the discount rate to use, and to recognize that the best practice is to conduct sensitivity analysis using a range of discount rates. The choice of the discount rate is very important as it can have major implications for the results of the analysis and the decisions that are made.

T6.3. Considerations for Socio-cultural Valuation

T6.3-1. Basis of Socio-cultural Valuation[253]

People attribute or assign importance (values) to things (in this case, the benefits from ES) on the basis of their experiences, beliefs, and understandings which are influenced by their society and their culture.[254] These are the subjects of socio-cultural valuation approaches. The process of attributing or assigning values occurs both within the consciousness of an individual and collectively within groups of people through shared experience of the valued subject. It can also occur through group discussion or negotiation—even while values are being elicited for research. When values are shared by people in social groupings, those values can be considered "social" rather than only individual. When these values become part of the group of symbols and meanings informing the shared identity of a particular culture group, they are "cultural" values.[255] The term "socio-cultural values" is often used to refer to either or both of these, as it is in this Toolkit.[256]

Understanding the socio-cultural *benefits* of ES to people involves understanding the socio-cultural context of their knowledge and experience and how it informs values and behaviours. Once the context and benefits are clear, the relative significance (values) of ES benefits can be identified. Although attributed values for all ES benefits are informed by the beliefs and understandings held by valuers, the values are not always clear to the valuer(s) prior to being asked to communicate them. One reason is that people may not regularly think about their experiences in terms of ecosystem functions and ES benefits.[257]

Socio-cultural valuation methods can be qualitative or quantitative; there are many methods for each.[258] In addition, some field methods involved in rapid assessment (e.g., transect walks, participatory mapping) can be used to identify socio-cultural values of ES. Socio-cultural valuation methods can be designed to capture statistically representative results (as through probability sampling for open-ended surveys). Alternatively, they can focus on in-depth understanding among individuals and groups within a population.

253 For explanation of the difference between "cultural ecosystem services" and "cultural values" see section *T6.1-3*.

254 As shown in *Figure 6.1*. Published literature on socio-cultural values is varied in how the authors understand the concept, and by extension, the methods that they use. The techniques and assumptions of socio-cultural valuation do not result in monetary units.

255 Ariansen 1997 described experiential and affective values as "constitutive" because they are constitutive of the person's identity as well as the identity of the object of value. This can apply to culture groups as well, illustrating the profound importance of such values, and sheds light on why disputes can arise when those values are threatened.

256 Mackenzie 2012 provides a detailed explanation of how to understand socio-cultural values and a recommendation of how to include them in natural resources (water) planning.

257 This dynamic aspect is the basis for collaborative valuation approaches in section *T6.1.6*.

258 For a case study using multiple qualitative and quantitative methods to assess socio-cultural values of ES, see Oteros-Rozas et al. 2014. For four case studies comparing instrumental and deliberative approaches, see Raymond et al. 2014.

Because of their perceptual and cognitive origins, socio-cultural values tend to be expressed first in descriptive terms by the valuers. Typical methods for collecting this information include interviews, focus groups, open-ended surveys, and narrative analysis.[259] Quantification of these values through ranking (or through monetary units in economic valuation) is thus an abstracted interpretation of "how much the ES matters."

T6.3-2. Contexts for Using Socio-cultural Valuation

Socio-cultural valuation can be completed to inform trade-offs and, in some cases, with the intention of estimating economic values through a combined approach, but this need not always be the case. In many situations, decision-makers can benefit from the more in-depth information about the relative significance of ES that can be obtained from socio-cultural valuation, leading to an accommodation of all interests. In addition, there are some socio-cultural values that are incommensurate from the beneficiary's perspective—that is, the very idea of a trade-off is fundamentally unacceptable.[260]

ES beneficiaries and other stakeholders can help to identify a broader range of choices or options to support decision-making, such as:

- *Revealing trade-off options.* Socio-cultural valuation can help to identify what things (e.g., objects, experiences) people consider acceptable for trading-off in decision contexts, and what the acceptable extent of change might be. This is particularly helpful because analysts and decision-makers may identify trade-off options based on limited understanding, compared with stakeholder and ES beneficiary perspectives of the range of choices available. By including socio-cultural valuation, especially through participatory approaches, other options can be revealed that can lead to more acceptable and potentially sustainable outcomes overall.
- *Revealing how, why, and how much.* Socio-cultural valuation can be a useful component of ES assessment in nearly all cases because it provides insight into why and how parts of the ecosystem (e.g., natural capital), ES, and ES benefits matter to people as well as how much they matter. Descriptive and visual (e.g., participant mapping) approaches provide a richness of explanatory power that is rarely possible with quantitative measures. This richness can be critical in resolving complex and intense disputes, and can be constructive in land-use and conservation planning to avoid disputes in the first place.
- *Revealing intangible values and connections across ES.* Socio-cultural valuation is relevant for all ES, and especially for CES, because they are either experienced or held by beneficiaries. While monetary valuation is an obvious choice for "provisioning ecosystem services," especially those that have market values already associated with them, socio-cultural valuation can reveal additional aspects of importance that are not captured in markets. Most notably this occurs when a provisioning service is strongly linked to one or more of the CES or to other experiential and societal values that may be sufficiently important to make the subject ES a matter of serious dispute.

T6.3-3. Determining If Socio-cultural Valuation Is Required and Feasible

As with determining whether economic valuation is required and feasible, a starting question is *how would socio-cultural valuation of ES improve the decision made in a given situation?* The three broad points made in the previous section all contribute to answering this question (e.g., revealing trade-off options; revealing how, why, and how much ES matter; revealing intangible values and connections across ES benefits). Additional considerations for whether socio-cultural valuation is required include (but are not limited to):

- *Is public consultation a requirement of the policy or regulatory procedures involved?*
  Because ES assessment is a fairly new tool to Canadian decision-making, it is not widely incorporated as a "required" procedure. However, public participation and consultation *is* widely incorporated at different levels of governance through regulations and policies. This is an opportunity to complete socio-cultural valuation which can be fully compatible with the objectives of some approaches to stakeholder consultation—asking people what matters, why it matters, and how much it matters—and doing so using analytically robust methods.[261]
- *What is the scale of the potential effect of the decision on people or the ecosystem?*
  The potential impact of a decision or project for both the human population and the ecosystem is a key consideration for determining whether socio-cultural valuation is required. This potential can be identified by completing *Worksheets 1, 2,* and *3*. Doing so as

[259] Scholte et al. 2015 provide a detailed discussion of socio-cultural values of ES and describe some of the main methods for their valuation.
[260] On suggestions regarding incommensurability, see Chan, Satterfield, and Goldstein 2012. For a Canadian case study demonstrating how socio-cultural values of ES are experienced and communicated in a community context, and a critical analysis of methods for their valuation, see Klain et al. 2014.
[261] Examples include several participatory and deliberative methods.

early as possible in the process can help maximize available time for robust data collection and analysis. Although socio-cultural valuation can be a key part of all assessments, it becomes increasingly important as the seriousness of the potential effects of a decision or project increase.

- *Is the decision generating conflict or raising serious expressions of concern from the potentially affected people?*
  Resolving conflict and finding acceptable solutions is best achieved through participatory valuation approaches that allow ES beneficiaries and other stakeholders to openly and fully communicate their concerns, to know that they are being heard and that their concerns are being incorporated into deliberations that could reveal acceptable options.
- *Has the screening process identified CES as particularly important in the case?*
  A key benefit of using the *ES Priority Screening Tool (Worksheets 2* and *3)* is that, in addition to identifying the highest priority ES for assessment in a specific case, the process identifies the issues associated with each ES and the ways that ES are (or are most likely to be) benefiting people. All ES can be valued using socio-cultural methods to reflect their importance to people in experiential and philosophical terms. However, most CES are considered by many experts as most suitably analyzed using socio-cultural valuation approaches.[262]
- *Have stakeholders already expressed views that suggest socio-cultural values are a significant factor in their perception of the case? Alternately, have other expert sources (e.g., literature, scholars) indicated that socio-cultural values play a major role in the case or people's interaction with the ecosystem potentially affected by the case?*
  If the evidence suggests that ES are important to beneficiaries in terms of their identity or other deeply held feelings, and if there is apparent rejection by beneficiaries of more quantified ways of defining value, socio-cultural valuation approaches can be effectively used to identify issues, concerns, and relative significance; in some cases, leading to a willingness to participate in ranking and scoring approaches.[263]

Regarding feasibility, understanding how, why, and how much something matters to a community of people is never a simple task and one that is not reliably accomplished in a matter of hours. The spectrum of time commitment can range from a few years (in the case of fully developed ethnography for example) to a few weeks or, in exceptional situations, a few days (in the case of "rapid assessment" for example). Necessary methodological skills also vary in degree depending on the methods used (see the criteria considerations throughout this section, and factsheets for more on required resources for each method).

T6.3-4. Framework for Socio-cultural Valuation

Figure T6.3 organizes many common "non-monetary valuation" (NMV) techniques in a structure conceptually similar to TEV which can be helpful for comparison purposes, and can help to clarify for analysts the range of approaches in relation to the type of data and process involved in generating it. Method selection will be based on several factors, including those listed above, and as advised in the factsheets in *Tools – Tab 7: Compendium of Data Sources, Analysis Methods, and Tools*.

[262] Ecotourism and nature-based recreation are the exceptions; see for example, Scholte et al. 2015; and, Chan, Guerry et al. 2012.
[263] Satterfield et al. 2013.

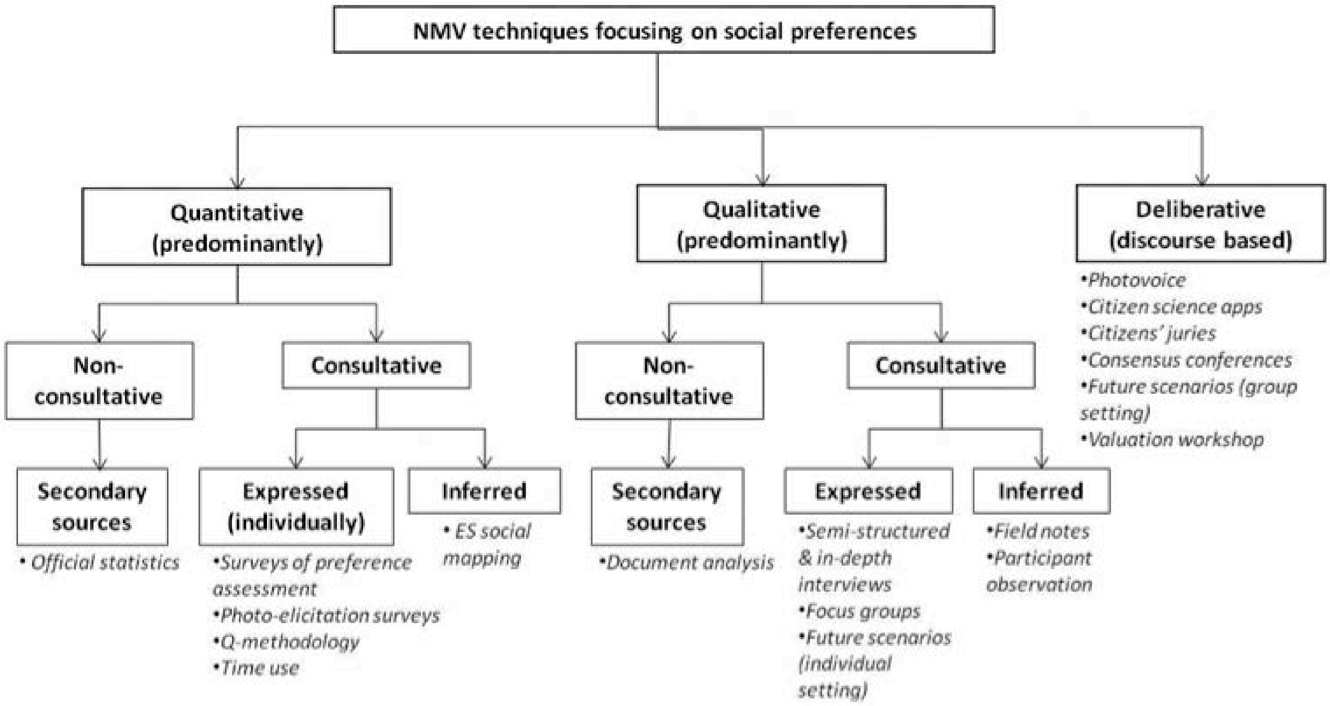

***Figure T6.3.** Socio-cultural (non-economic) valuation techniques according to methodological similarities in data collection. (Reproduced with permission by the editor from Kelemen et al. 2014)*

In addition to the recent literature about socio-cultural values in ES assessment, researchers and professional practitioners have been publishing case studies and methodological advice on identifying socio-cultural values qualitatively in environmental management since at least the 1970s.[264] Because many Toolkit users may be less familiar with many of these methods, they may benefit from reading a selection of those publications as examples of when and how each method can be used, and what kinds of results can be obtained.

T6.3-5. Identifying the Appropriate Socio-cultural Valuation Method(s)

Reliability of results in socio-cultural valuation is influenced by the relative roles of the beneficiary (or person for whom an ES is important) and the analyst, which are an outcome of the method or methods chosen:[265]

- *Valuer alone (elicited).* The valuer is the most direct source. Data collection must be designed to avoid the imposition of assumptions by the analyst, and ensure that the valuer has a full understanding of what is being asked.
- *Valuer with analyst (participatory).* Reliability can be optimized during participatory research because the valuer(s) and the analyst(s) can discuss the subject and the values to build stronger mutual understanding.
- *Analyst/professional expert.* It is possible for a qualified expert to identify, describe, and rank values without the valuers present. This is possible as long as the professional's expertise is specific to both the population and the population's relationship (i.e., the distinctive practices, beliefs, and values of different communities, cultures, and societies) to the subject matter.
- *Analyst with locally knowledgeable advisor(s).* If a professional expert is not available, engaging a locally recognized expert to guide and validate the analysis can be the next best thing.
- *Analyst alone.* If it is not possible to consult valuers through elicitation or participatory approaches, and if expert advisors cannot be consulted, the analyst can conduct a critically designed study that triangulates multiple methods and multiple sources of information to reduce the risk of error.[266] Reliability will also depend on how thorough the analyst is in learning about the socio-cultural context of the population (e.g., reading expert sources about the population, its history, recent/current issues).

264 Reviewed and summarized across disciplines in Preston 2004.
265 A similar list of criteria also applies to the role of analyst in economic valuation.
266 Error can be introduced in multiple ways, see Bernard 2013 on a comprehensive range of social research methods. Triangulation can help avoid errors of omission, unequal representation, flawed assumptions in analysis, and more.

TOOLS – TAB 7 – COMPENDIUM OF DATA SOURCES, ANALYSIS METHODS, AND TOOLS

The factsheets in this Compendium can be used to familiarize the reader with different data sources, analysis methods or tools and what needs to be taken into account when considering their use. The intent is to provide clear, concise, and easily accessible overviews to enable users to efficiently identify relevant approaches for their work. Each description includes an overview with resource requirements, strengths, limitations, most suitable contexts for application, and sources for more information.

Many factsheets were produced specifically for this Toolkit. Additionally, links are provided for factsheets produced by GIZ and its partners which they developed following a very similar model in the framework of the ValuES Project on behalf of the BMUB.[267] Links to the factsheets provide additional case studies and references that may be of interest for learning about a specific tool or approach. The authors gratefully acknowledge their permission to incorporate links to these factsheets as part of this Toolkit.

Contents of Tab 7

Table T7.1. Factsheets in this Compendium *(listed alphabetically). Click on a link in this table to access the corresponding factsheet, or locate by page number.*

Continued on next page…

[267] GIZ is Deutsche Gesellschaft für Internationale Zusammenarbeit, or German Corporation for International Cooperation, owned by the German government. BMUB is the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety.

Method or Tool Internal links	B (Biophysical) E (Economic) S (Socio-cultural)	Page # in Toolkit	ValuES Factsheet External links
Constructed Scales	S	p.172	–
Contingent Valuation	E	p.173	http://www.aboutvalues.net/data/method_navigator/values_method_profile_contingent_valuation.pdf
Cost-Based Valuation	E	p.173	http://www.aboutvalues.net/data/method_navigator/values_method_profile_cost_based_methods.pdf
Cost-Benefit Analysis	E	p.174	http://www.aboutvalues.net/data/method_navigator/values_method_profile_cost_benefit_analysis.pdf
Cost-effectiveness Analysis	E	p.174	http://www.aboutvalues.net/data/method_navigator/values_method_profile_cost_effectiveness_analysis.pdf
Direct Market Price Valuation	E	p.174	http://www.aboutvalues.net/data/method_navigator/values_method_profile_direct_market_prices.pdf
Ecological Production Function	B	p.175	–
ECOMetrix	B	p.177	–
Economic Production Function	E	p.177	http://www.aboutvalues.net/data/method_navigator/values_method_profile_effect_on_production.pdf
Envision	B	p.178	–
Focus Groups	S, E	p.180	http://www.aboutvalues.net/data/method_navigator/values_method_profile_focus_group_discussion.pdf
GIS Mapping	B, S	p.182	http://www.aboutvalues.net/data/method_navigator/values_method_profile_mapping_overview.pdf
Hedonic Pricing	E	p.184	http://www.aboutvalues.net/data/method_navigator/values_method_profile_hedonic_pricing.pdf
Interviews	S, E, B	p.185	http://www.aboutvalues.net/data/method_navigator/values_method_profile_interviews.pdf
InVEST	B, E	p.187	http://www.aboutvalues.net/data/method_navigator/values_method_profile_invest_general.pdf

Continued on next page...

Method or Tool Internal links	B (Biophysical) E (Economic) S (Socio-cultural)	Page # in Toolkit	ValuES Factsheet External links
Literature Review	B, E, S	p.189	–
LUCI	B	p.191	–
Marxan	B	p.193	http://www.aboutvalues.net/data/method_navigator/values_method_profile_marxan.pdf
MIMES	B	p.195	http://www.aboutvalues.net/data/method_navigator/values_method_profile_mimes.pdf
Multi-Criteria Analysis	B, E, S	p.197	http://www.aboutvalues.net/data/method_navigator/values_method_profile_multi_criteria_analysis.pdf
Participatory and Deliberative Economic Valuation	E	p.199	http://www.aboutvalues.net/data/method_navigator/values_method_profile_participatory_valuation.pdf
Participatory and Deliberative Socio-cultural Valuation	S	p.199	–
Participatory Mapping	S, B	p.200	http://www.aboutvalues.net/data/method_navigator/values_method_profile_participatory_mapping.pdf
Participatory Rural Appraisal; Rapid Rural Appraisal; Rapid Ethnographic Assessment Procedures	S, E, B	p.201	http://www.aboutvalues.net/data/method_navigator/values_method_profile_pra.pdf
Remotely Sensed Data	B	p.203	–
Scenario Analysis	B	p.205	http://www.aboutvalues.net/data/method_navigator/values_method_profile_scenario_development_planning.pdf
SolVES	B, E, S	p.206	http://www.aboutvalues.net/data/method_navigator/values_method_profile_solves.pdf
Stakeholder Analysis	S, E	p.207	http://www.aboutvalues.net/data/method_navigator/values_method_profile_identification_of_stakeholders.pdf
Statistical Analysis (correlation, causation, bundles)	B, S	p.208	–
Structured-Decision-Making	B, E, S	p.210	–

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Method or Tool Internal links	B (Biophysical) E (Economic) S (Socio-cultural)	Page # in Toolkit	ValuES Factsheet External links
Survey Questionnaire (multiple types)	S, E	p.212	http://www.aboutvalues.net/data/method_navigator/values_method_profile_questionnaires.pdf
TESSA	B, S, E	p.214	http://www.aboutvalues.net/data/method_navigator/values_method_profile_tessa_general.pdf
Travel Cost	E	p.215	http://www.aboutvalues.net/data/method_navigator/values_method_profile_travel_cost.pdf

Note: Many of the research and analysis methods introduced here are fully detailed in standard research methods texts. Many ES modelling and analysis tools are described and compared in Bagstad et al., 2013.

Note: Factsheets for economic valuation methods are provided through off-site links with the exception of benefit transfer, which is included in the current version of this Toolkit. There are many current publications providing guidance on these methods in the context of ES (see, e.g., www.teebweb.org).

ARIES (ARtificial Intelligence for Ecosystem Services) (Analysis tool)

Can be used to assess the following:

- Carbon sequestration and storage
- Flood regulation
- Coastal flood regulation
- Aesthetic views and open-space proximity
- Freshwater supply
- Sediment regulation
- Subsistence fisheries
- Recreation

Best used when asking

What is the supply, demand, delivery, and value of ecosystem services (ES) in the landscape (watershed scale)?

Allows users to model, map, and quantify ES delivery between source and use locations.

Focuses on service delivery: Who are the beneficiaries? Where are they located?

Distinguishes between possible and actual ES delivery, highlighting efficiency of use and solutions for mediating supply and demand imbalances.

Well suited for baseline studies and scenario assessment for different future climate, land use, and land-cover conditions.

ARIES is a modelling platform that is fully customizable to address a broad range of physical, social, and economic contexts. It is an open-source, web-accessible technology capable of selecting, assembling, and running models to quantify and map flows of ES. ARIES considers ES from the viewpoint of beneficiaries, while distinguishing among accrued, potential, and theoretical ES.

ARIES accounts for data-related uncertainties through probabilistic modelling of ES supply and demand. Uncertainty is computed throughout the process to enable accuracy assessment of final results.

The models explicitly account for the spatial and temporal dynamics of ES transport and support dynamic trade-off analysis. Model output includes a set of maps describing ES supply, demand, and delivery. Aggregate indicators extend beyond the state of the art to address value, efficiency, and equity, in both ES provision and distribution.

How it is done

A version of ARIES is planned to be available as a public prototype accessible through a web browser, but currently requires download of special software and training to use properly. Data and model storage, data transformations, model runs, and reporting of results take place behind the scenes without the need to purchase and gain proficiency using commercial GIS or modelling software. User data are not required, but may be necessary to achieve desired accuracy standards beyond publically available global coarse-resolution datasets in the online version. Users define the ES beneficiaries/benefits of interest, draw or provide GIS maps of their system boundaries, and can supplement or replace the ARIES datasets with more locally relevant data for model runs. Additional training or collaboration with developers may be required for customized applications (e.g., when designing context specific models, adding user data, developing new ES models).

The program uses probabilistic models (spatial Bayesian networks) to map the ecological and socio-economic factors contributing to the provision and use of ES. After each ES is modelled independently, it is linked to other services. Unlike InVEST (factsheet below), the basis for ES valuation is the quantification of the actual flow of benefits and not of the processes that bring them into existence. For example, it creates Bayesian network models of provision, source, and sink (depletion of a benefit along its path to the beneficiary) and the flow analysis is then used to determine what areas are critical to the delivery of the service.

How to optimize

- The graphic user interface available through the Internet works best with Mozilla Firefox, Google Chrome, or Safari, but not Microsoft Internet Explorer.
- Familiarity with geographic information systems (GIS—factsheet below) will allow users to extend data analysis and produce custom-designed maps based on model results.
- Depending on how the results will be used, some validation may be necessary to have confidence in the model results. Validation is especially important in systems that are very different from those in which the models were developed.

Strengths/advantages

- Will be open-source GIS application.
- Can accommodate a scale-explicit approach to mapping ES since the provision and usage of services occurs at different spatial and temporal scales.
- Intended to assist with rapid assessment and valuation.

Limitations/disadvantages

- The strengths of the approach taken by ARIES developers will become clearer as the model is further tested and refined, and becomes more widely accessed and reported in the scientific literature.
- An independent review of ES models in the context of decision-making found that ARIES required substantially more time, data, and expertise to parameterize the models than other ES models.

Resource requirements

- Expertise: Specialized modelling software skills (Thinklab and/or GeNie).
- Cost: Software is free; data, training, and so on, are extra considerations.
- Time: Parameterization of models is time intensive.

Examples

ARIES has been used in at least one Canadian project. A fully detailed comparison between conventional benefit transfer and ARIES in Ontario's provincial parks is available in Voigt et al. 2013. Case studies can be seen in the "on the ground" section of their website at http://aries.integratedmodelling.org/.

Further information

Villa, F., et al. 2014; ARIES (n.d.) http://aries.integratedmodelling.org/

See also http://www.aboutvalues.net/data/method_navigator/values_method_profile_aries.pdf

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BENEFIT TRANSFER (Economic Valuation Method)

Best used when needing to produce monetary estimates of values and are not able to collect new data.

How it is done

Values that have been estimated using primary research (original data collection) in one or more "host" locations are transferred to the study, or "policy," location. Criteria that should be met include the following:

- effort should be made to ensure comparability between the host and policy location in terms of their biophysical environments and their socio-economic and cultural composition;
- the data to be transferred must be evaluated for their quality (including critical assessment of the methods that were used, the researchers' assumptions, and their interpretation and reporting of results); and
- the host data should be calibrated to more correctly meet the conditions of the policy location, including adjustments, for example, for demographic variables, population density, and ecosystem characteristics.

Three main ways of transferring values are:

1. *Unit value transfer* in which values are transferred from the original study site expressed as a monetary value per unit (usually per unit area or per beneficiary), combined with information on the quantity of units at the policy site but without calibration to account for differences between the study and policy sites.
2. *Value function transfer* uses a value function[268] estimated for the study site, combined with information on the policy site characteristics, to calculate the unit value of an ES at the policy site.
3. *Meta-analytic function transfer* uses a value function estimated from the results of many different primary studies representing multiple study sites, combined with information on the policy site characteristics to calculate the unit value of an ES at the policy site. Since the value function draws from results of multiple studies, it reflects a much greater degree of variation in biophysical and socio-economic characteristics.

How to optimize

The benefit transfer method is most reliable when:

- the original site and the study site are very similar in terms of factors, such as quality, location, and population characteristics;
- when the environmental change is very similar for the two sites; and
- when the original valuation study was carefully conducted and used sound valuation techniques.

Primary estimates must therefore be assessed for suitability and appropriately adjusted to account for differences between the primary valuation(s) and the secondary subject site.

Adjustments to the existing values to better reflect the value for the secondary site under evaluation can be undertaken using local and regional information, for example, statistics on demographic differences, income level changes, inflation rates, costs and prices, ES demand, biophysical extent of an ecosystem, and/or biophysical characteristics.

Experts have cautioned that values transfer should be a "last resort" when it is not possible to collect new data that are specific to the decision context or location.

Strengths/advantages[269]

- Benefit transfer is generally a less expensive method than an original valuation study.
- Valuation of economic benefits can be estimated more quickly than an original study.
- It can be used as a preliminary tool to determine whether an original valuation study is needed.
- It is quick and easy to conduct a benefit transfer for gross values associated with recreational values, as long as the sites and recreational experiences are similar.
- A wide range of relevant literature is sometimes available.

[268] A value function is an equation that relates the value of an ecosystem.
[269] Bulleted points on advantages and disadvantages quoted from Philcox 2007: 22.

Limitations/disadvantages

- Benefit transfer may have limited validity, unless the sites share all (or the vast majority) of the site, location, and demographic characteristics.
- The number of ideally suited studies may be limited, unavailable or difficult to find if unpublished.
- Relevant studies may not disclose sufficient information to make important adjustments to the point estimate or function.
- Existing studies may not be accurate or valid, and benefit transfers can only be as accurate as the initial value estimate.
- Point estimates can quickly become dated.

The most prominent limitations cited in the peer-reviewed expert literature are that data available from previous studies may be inconsistent or poor quality and it can be difficult/impossible to empirically validate their results; errors may be introduced during value transfer; and calibration to account for a wide range of ecological, cultural, and socio-economic differences between the host site and the policy site is very complex and often omitted.

Resource requirements

- Expertise: Knowledge of economic valuation methods and statistical calibration.
- Time: Variable, depending on congruity between original and study site.
- Cost: Minimal.
- Access to information: Access to databases of relevant reliable primary studies, for example, EVRI (there are several others); thorough data on policy site (e.g., biophysical, economic, socio-cultural).

Examples

Molnar 2015:

> Study of Howe Sound coastal ecosystem approximately 200,000 hectares in southern British Columbia used the TEEB ES classes, and assessed primary valuation sources on three criteria: robust (primarily peer reviewed or government), North American sites, and consistent with methodological recommendations of Farber et al., 2006. The "policy site" was quantified spatially using GIS data for each land cover type (e.g., forest, beach, river). Multiple primary studies were used to estimate values for each ES. Economic valuation ranges were produced for each ES and for each land-cover type. All primary ranges and data sources are reported. Purpose of study: communication to public and policymakers.

See also: Creed 2011; McCandless et al. 2008; Molnar et al. 2012; Lee et al. 2013

Further information

EVRI database: https://www.evri.ca/Other/AboutEVRI.aspx; Rosenberger 2005; Van der Ploeg and de Groot 2010. TEEB Valuation Database and Support: http://es-partnership.org/services/data-knowledge-sharing/ecosystem-service-valuation-database/; TEEB presentation on BT: http://www.teebweb.org/resources/training-resource-material/module-4/

See also: http://www.aboutvalues.net/data/method_navigator/values_method_profile_benefits_transfer.pdf

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CANADIAN HYDROLOGICAL MODELS (Analysis Tools)

Can be used to assess the following ES:

Hydrological ES (e.g., flood control, water storage, infiltration)

Best used when asking

In projects supported and/or funded by Environment and Climate Change Canada, various hydrological models are under development for predicting streamflow events, especially floods. A key aspect of these models is that they consider the effect of terrain and vegetation characteristics (*sinks*).

1. **The Canadian Land Surface Scheme (CLASS):** A land-surface parameterization scheme for use in large-scale climate models. It is a state-of-the-art model, using physically based equations to simulate the energy and water balances of vegetation, snow, and soil.
   - **Developers:** Research project led by D. Verseghy at the Canadian Atmospheric Environment Service.
   - **Description:** An Environment and Climate Change Canada land-surface model.
2. **The Cold Regions Hydrological Model (CRHM):** A flexible, object-oriented software system, originally developed to provide a framework within which to integrate physically based parameterizations of hydrological processes to simulate the hydrological cycle in small- to medium-sized basins in high latitudes or altitudes.
   - **Developers:** University of Saskatchewan, Environment and Climate Change Canada.
   - **Scale:** Intermediary scales.
   - **Grid size:** CRHM works on a hydrological response unit based on contiguous areas that behave similarly.
   - **Description:** A University of Saskatchewan hydrologic model.
     - http://www.usask.ca/hydrology/CRHM.php
3. **MEC-Surface and Hydrology (MESH):** A community environmental-modelling system, a framework within which to facilitate coupling between models representing different components of the earth system. The ultimate objective of MEC is to use the coupled models to produce operational forecasts.
   - **Developers:** University of Saskatchewan, Environment and Climate Change Canada.
   - **Scale:** MESH is appropriate for larger river basins, up to the size of the Mackenzie River, for example.
   - **Grid size:** MESH works on grouped response units (i.e., it assumes that all grasslands within a grid (with the grid up to a few kilometres on each side), no matter where they are within the grid, behave the same way hydrologically).
   - **Description:** An Environment and Climate Change Canada hydrologic model that includes CLASS and a routing scheme.
     - http://www.usask.ca/ip3/models1/mesh.htm
     - http://www.usask.ca/hydrology/MESH.php
4. **GEOtop:**
   - **Developers:** Riccardo Rigon; main developer of the model, Prof. Stephan Gruber—now at Carleton University.
   - **Scale:** GEOtop is appropriate for areas of a few hundred square kilometres.
   - **Grid size:** GEOtop works on square grids of size from a few metres to hundreds of metres.
   - **Use:** Model that Environment and Climate Change Canada is using in northern Canada to consider changes in land surface on hydrology (but has not been used in inundated areas).
   - Complete information about GEOtop at: http://abouthydrology.blogspot.it/search/label/GEOtop
     - http://www.geotop.org/wordpress/
5. **JGrass-NewAGE:** Offers an expandable framework integrated with GIS (standard) features.
   - **Developers:** Same developers as GEOtop.
   - **Scale:** Large scale.
     - http://abouthydrology.blogspot.it/search/label/JGrass-NewAGE

Allows users to model hydrological processes and associated ES at various scales.

Important assumptions in hydrological models

HEC, HSPF, LISFLOOD, MIKE, PRMS, SWAT, xprafts, CLASS, and MESH assume contributing areas to the stream are static and sub-grid heterogeneity is irrelevant to the lateral transfer of water. Because they do not explicitly represent the connections between sub-grid landscape units (e.g., wetlands) and the stream, they should not be used to evaluate landscape change (e.g., wetland drainage).

At Environment and Climate Change Canada, CLASS AND MESH are currently being improved in this regard.

CRHM can model wetland contributions to flood control, but requires a lot of fine-scale information about the watershed (especially elevation and land cover). For this type of application, it is not necessarily meant for watersheds larger than 100 km^2.

Like CRHM, GEOtop can explicitly represent lateral sub-grid flow connections. For the same reason, it needs really good elevation and land-cover data and operates best in smaller watersheds.

Example

See Pomeroy, et al. 2014.

http://www.usask.ca/hydrology/Reports.php

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Can be used to assess the following ES:

- Provisioning services (e.g., crops, animal husbandry, other farmed goods)
- Drivers of change (e.g., land use, demographics, employment, education)
- Population values (e.g., employment, movement of populations, other activities)

Best used when asking

What is the current status and recent broad trends in provisioning services and certain drivers of change?

The strength of census data is that they are very reliable and are available for every five-year period in recent history.

***Allows users to*:**

- access reliable data about agricultural production and the population; and
- access reliable trend data in these areas, going back for several generations.

How it is done

The Canadian Census of Population and Census of Agriculture are two sources of data from which to study trends in both drivers of change (e.g., population, migration, employment, education) and some types of ES (e.g., agricultural production, livestock, orchards, Christmas trees) across time. For spatial data, there are several different levels of census geography, each of which nests inside another (i.e., division, subdivision, metropolitan areas, tracts, federal electoral districts, and dissemination areas). Census reference maps can be used to understand census geography. Larger geographies include the country of Canada, as well as its provinces, territories, federal electoral districts, and census divisions. Census data can be accessed and analyzed using the software, Beyond 20/20 (available at URL: http://www.beyond2020.com/).

The latest census data can be found at:

> The Canadian Census Program website: http://www12.statcan.gc.ca/census-recensement/index-eng.cfm
>
> The Canadian Census of Agriculture website: http://www.statcan.gc.ca/ca-ra2011/index-eng.htm.

Historical census data can be found at:

> The Canadian Census Analyser (requires access through a subscribing university or government library)
>
> Statistics Canada http://www.statcan.gc.ca/start-debut-eng.html

Strengths/advantages

- Credible data source.
- Time series.
- Free and requires no expertise.

Limitations/disadvantages

- Limited number of variables that are relevant to ES assessment.

Resource requirements

- Expertise: Basic statistics.
- Time: Rapid.
- Costs: Free.
- Access to information: Available online.

Example

Raudsepp-Hearne et al. 2010a:

> Researchers assessed the quantity or quality of multiple ES to better understand how ES are "bundled" across landscapes. To quantify some of the provisioning ES, they used agricultural census data in conjunction with land-cover maps to estimate crop cover, pork production, and maple syrup production. The data were freely available, organized spatially in a manner that made it simple to map using relevant spatial units (municipalities), and credible. See article for details about methods. The data were downloaded using Beyond 20/20 software, with an identifying code matching data to map units.

See also: Berka et al. 2001.

Further information

Statistics Canada 2015. http://www12.statcan.gc.ca/census-recensement/index-eng.cfm

AAFC 2013. http://data.gc.ca/data/en/dataset/1dee8513-5c73-43b6-9446-25f7b985cd00

Statistics Canada 2014. http://www.statcan.gc.ca/pub/16-201-x/16-201-x2014000-eng.htm

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CHOICE EXPERIMENTS (Economic Valuation Method)

For a factsheet on this item see: http://www.aboutvalues.net/data/method_navigator/values_method_profile_choice_experiments.pdf

For example, see Gardner Pinfold 2011.

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COMMON DATA SOURCES

The following data sources are commonly used to develop ES information. Any source that is not listed below may be the subject of its own factsheet within this Compendium (e.g., remotely sensed data, most used social science approaches to gathering data).

Databases

When there is a need to measure ES within a particular system, data may be found in databases at relevant scales. Databases owned by governments, non-government organizations, universities, and private companies may contain data representing indicators or proxies for ES. Some datasets are public while others are private and their use must be negotiated. A relevant list of databases used in the federal interdepartmental "Measuring Ecosystem Goods and Services" (MEGS) initiative is provided in: http://www.statcan.gc.ca/pub/16-201-x/16-201-x2013000-eng.htm.

Selected Canadian databases include:

- National Forest Information System (CCFM 2013): https://ca.nfis.org/index_eng.html
- National Atlas of Canada (NRCan 2015): http://atlas.nrcan.gc.ca/site/english/
- Environmental Valuation Reference Inventory (EVRI n.d.): https://www.evri.ca/Global/HomeAnonymous.aspx
- Agriculture Canada maps (AAFC 2014b): http://sis.agr.gc.ca/cansis/publications/webmaps.html
- Statistics Canada (see Census below): http://www.statcan.gc.ca/start-debut-eng.html
- Trendwatching (reports on trends and drivers): www.trendwatching.com
- Soil Landscape of Canada (AAFC 2014b): http://sis.agr.gc.ca/cansis/nsdb/slc/index.html

Ecological fieldwork

The nature of the ecological fieldwork required for an assessment of ES depends on which services are included in the assessment. An assessment of soil services may involve designing a sampling methodology to sample soils in a field or across a region. An assessment of pollination may require complex sampling procedures and exclusion experiments. Generally, most ecological fieldwork requires a lot of resources, including people, funding, and time. It is beyond the scope of this Toolkit to provide methods for estimating the ecological properties of multiple ES in the field. When the priority ES have been identified using the *Screening Tool* (*Worksheet 2* in *Tools – Tab 4: Worksheets for Completing ES Assessment*), scientists that specialize in each of the services (e.g., hydrologists, biologists, soil scientists) should be consulted to determine whether data exist for each service or, if fieldwork is necessary, how it should be designed. See Mitchell et al. 2014.

Field survey (ecological or socio-cultural focus)

On-site observations of the social-ecological system are methodically structured, often using site-scale maps, and can involve different spatial scales, the most precise being transect walks but, more commonly, targeting locations that have been identified as significant (by local or external expert sources) and a more general scan of the land-cover and land-use conditions.[270]

Expert opinion

"Experts" include scientists and other professionals as well as recognized holders of local and traditional knowledge. Expert opinion is often an important source of ecological and social information, and it is important that the expertise of the source be clearly recognized as relevant to the questions that they are asked to address.

[270] Transect walks are one of several techniques used in rapid appraisal methods.

For example, the area of expert opinion sought from a hydrologist should be hydrology, and practitioner knowledge should be associated with the specific activity of the practitioner. Within many traditional communities, the holders of traditional knowledge are recognized by their community as reliable sources—these are the individuals to seek out. For detailed advice regarding Indigenous communities, see *Tools – Tab 3: ES Assessment Involving Indigenous Communities*, and for advice regarding conflicting expert opinion, see *Chapter 2* and *Tools – Tab 6: Values and Valuation: Economic and Socio-cultural*.

Maps (all types)

Maps are spatial representations of data and knowledge. Maps and remotely sensed images are valuable sources of information and potentially powerful communication tools. The usefulness of the information contained in maps depends on both the content it represents and the level of processing it has undergone (especially for remotely sensed images). GIS-compatible maps can be overlaid and compared with each other, and subjected to spatial analyses. Data in maps may originate from remote sensors, land surveys, and participatory approaches, among other sources. Any data that are georeferenced may be viewed in map form.[271] Concise advice on steps for mapping ES is provided in a 2015 guide on ES and Biodiversity from the European Commission.[272] In addition, a summary of approaches to mapping ES is provided by Grêt-Regamey et al. 2014:

> Martinez-Harms and Balvanera (2012) distinguish five different methodological approaches to map ES: The first covers a very simple method that establishes binary links between land cover and a constant ES value for supply or demand obtained from previous studies at other places and other spatial scales. If experts are asked to rank an environmental variable category based on the knowledge that they have about the potential of these categories to supply an ES, the methodology corresponds to an expert knowledge approach (e.g. Burkhard et al., 2009, Kienast et al., 2009 and Grêt-Regamey et al., 2012). Another widely used methodology relies on well-known relationships between indicators and ES including information from literature (e.g. Chan et al., 2006, Egoh et al., 2008 and Naidoo et al., 2008). Methodologies of the fourth category extrapolate ES estimates of primary data such as field surveys (e.g. Anderson et al., 2009 and Raudsepp-Hearne et al., 2010). The last category covers quantitative regression model approaches (e.g. Lavorel et al., 2011).

Andrew et al. 2015 provide a substantial, descriptive table of data sources for ES, including mapping and other spatial sources.

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[271] Statistics Canada developed a major geodatabase as one product of the MEGS initiative and they continue to expand its content. See the appendix of http://www.statcan.gc.ca/pub/16-201-x/16-201-x2013000-eng.htm.

[272] Science for Environment Policy 2015.

Can be used to explain how a system is connected, interactions among multiple ES, the production of ES, impact of drivers, and relationship between ES and benefits, among other things.

Allows users to:

- explore, discuss, and communicate how systems are perceived to function;
- develop a hypothesis for how elements of a system interact;
- organize and synthesize related factors into a coherent, simplified representation;
- make alternative routes to an endpoint explicit;
- summarize an existing body of literature and/or propose new research directions;
- plan data collection and data analyses;
- integrate theories from multiple disciplines; and
- visually represent elements of a theory.

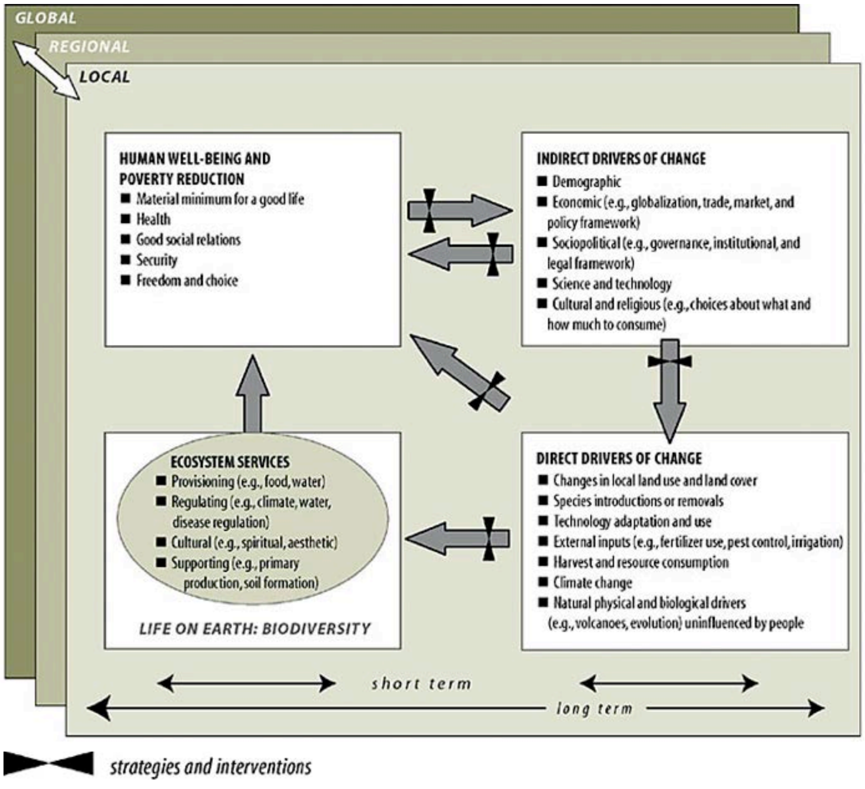
Best used when asking

How does a system work?

A **conceptual model** is a model composed of concepts, which are used to help people understand or simulate a subject that the model represents. Some models are physical objects, for example, a toy model that may be assembled, and may be made to work like the object it represents. Others can be diagrams or drawings, or connected words. Conceptualization from observation of the world and conceptual modelling are a means for thinking and solving problems.

How it is done

Relationships depicted in a conceptual model are driven by a combination of theory and evidence. The first step is to review existing information and knowledge about what is to be understood. Start by developing a basic, simple model structure and add additional sets of variables as needed. Models are individualized; there is no one "right" representation. Determine the desired level of variable specificity, based on the purpose of the model, clarity regarding relationships among variables, and measurement that may be employed. Share the model with colleagues both knowledgeable and unknowledgeable about the content area for feedback.



One of the most well-known conceptual frameworks for understanding ES is the UN *Millennium Ecosystem Assessment* conceptual framework (MA 2003). To initiate the work of this global assessment, the many hundreds of scientists and stakeholders involved in the work needed to develop a common understanding of the ES concept and develop this understanding to a degree of detail that would allow them to move forward with the assessment. The details associated with this diagram are presented in the MA's Conceptual Framework book (2003).

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Can be used to assess many types of social and cultural significance, and is especially useful for attempting to identify *relative* importance between different and sometimes interconnected subjects of value that are not naturally understood using a common metric.

Allows users to structure and prioritize values that have no pre-existing relative ordering system.

Best used when asking

What is the level of importance attributed to a subject that has no existing associated metric for evaluation?

How it is done

Constructed scales, ranking, and scoring can be completed in interviews, focus groups, and other participatory approach contexts. In some cases, it is possible to develop an expert interpretation based on extensive knowledge of the community whose values are being structured in this manner. These tools are commonly part of decision support or analysis frameworks such as structured decision-making and multi-criteria analysis.

Identifying the relative significance of a subject in this approach involves first establishing the attribute or performance measure that is being valued.[273] Three types of such attributes are:

- "Natural" attributes are direct quantitative measures of a subject, for example, cost has the attribute of money.
- "Constructed" attributes are created to enable structured analysis when the subject has no natural attributes or metrics. Well-designed constructed attributes can be very analytically robust and measurable.
- "Proxy" attributes do not measure the subject directly but can be inferred to reflect a major characteristic of the subject, and often have associated metrics, for example, increased ppm (parts per million) of a chemical in streams could be a proxy attribute for contamination. Proxies are used when there are no "natural" attributes for the subject and it is not possible to construct new, specifically relevant attributes.

Constructed scales enable the relative ranking of measures for an attribute, and comparison of importance across attributes. A constructed scale consists of, at minimum, a "simple rating" within a numeric range, for example, from zero to five, with each increasing level from zero representing incremental change in consequences, significance, or other evaluative characteristic within a realistically possible range. "Defined levels" are more robust, combining the numerical rating with a description of the specific conditions of each level.

In this approach, when comparing different attributes or performance measures, the first step is to adjust the data to the same numerical scale so that they are comparable. For example, the maximum values for each could be 10, and the scores would then be adjusted to this scale. The second step is to assign a weight to each criterion. There is no one correct way to assign a weight; decision-makers or stakeholders must decide how important each criterion is. It is important to review the weightings after completing the initial calculations to see if they make sense. Sensitivity analysis, which involves analyzing how the results would differ with minor changes to the weighting, can help refine the weighting scheme.

Strengths/advantages

Enables structured analysis of otherwise complex and often subjective issues and values using a neutral metric and enables consideration of the relative significance of multiple subjects together along comparable scales.

Limitations/disadvantages

Risk of over-generalization at the stage of comparing across subjects in which comparable scales can lead to the illusion that they represent issues of equal significance. Attention to sensitivity analysis and precise definitions is thus a very important part of this approach.

Resource requirements

- Expertise: Methods, knowledge of the subject of evaluation, facilitation of stakeholder and expert engagement, ability to assess relevance and interpret metrics and descriptive data.
- Time: Minimal if completed by expert analysts; can be moderate if engaging stakeholders and external experts (typically results in more reliable results).

[273] On selecting attributes see Keeney and Gregory 2005 and Gregory et al. 2012 (especially Chapter 5); they note that good attributes should be unambiguous, comprehensive, direct, operational, and understandable (2005: 3). The two publications also explain constructing scales, weighted scales, and ranking and scoring with numerous examples.

- Costs: May be incurred to host data-gathering sessions; may involve hiring expert consultants.
- Access to information: Methodology freely available; access to stakeholders as data sources.

Example

Chan, Satterfield, and Goldstein 2012*: 15-16:*

> "Several particularly good examples can be found in the work of Gregory and colleagues, whose work is theoretically grounded in multi-attribute utility theory but who have advanced subjective scaling, whereby the language of local constituents is often the basis for 'constructing' scales that render otherwise excluded (often intangible) variables visible and commensurate (Gregory et al., 2011). Constructed scales or metrics of this kind are used when no suitable measures exist. An example might be a scale to measure the ES benefit that maintaining a species used only for local (e.g., Indigenous or First Nation-to-First Nation) trading, such as dried edible seaweeds, a coveted food and widely used for ceremonial purposes across the BC coast (Turner and Loewen, 1998). Impact in the face of harm may affect provisioning or market value, but also the cultural value placed on 'enduring trading relationships' or 'ceremonial or cultural' use. That is, a scale would then be developed for the value of relationships across communities that might be harmed if trading is not maintained. In a situation such as this, an index might be created spanning 1–5, with 1="complete loss of local trading partner/relations", ranging through 5="no loss of trading partner/ relations", or similar for effect on ceremonial practices. Such a constructed index can focus a decision-maker's attention on trade-offs with other attributes and questions such as "is it worth protecting against potential impact on seaweed for x years in order to increase protection (e.g., of trading relations or networks) from level 2 to level 4 or 5?"."

Ranking as a means of identifying socio-cultural benefits of ES can be found in Hughes et al., 2011, Section 4.0, pp. 58–64, and 90–91. This was part of the Alberta Ecosystem Services Approach Pilot on Wetlands (full citation in *Tools – Tab 10: Canadian ES Assessments and Analyses Reference List*). That study solicited the views of stakeholders in a workshop setting.

Further information

Gregory and Trousdale 2009; Satterfield et al. 2013; Keeney and Gregory 2005; Gregory, Failing et al. 2012

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CONTINGENT VALUATION (Economic Valuation Method)

For a factsheet on this item see:

http://www.aboutvalues.net/data/method_navigator/values_method_profile_contingent_valuation.pdf

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COST-BASED VALUATION (Economic Valuation Method)

For a factsheet on this item see:

http://www.aboutvalues.net/data/method_navigator/values_method_profile_cost_based_methods.pdf

Example: see Wang et al. 2011 for the use of three cost-based methods.

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COST-BENEFIT ANALYSIS (Decision-Support Framework/Approach)

For a factsheet on this item see:

http://www.aboutvalues.net/data/method_navigator/values_method_profile_cost_benefit_analysis.pdf

Example: see how CBA was used in the 2014 federal Regulatory Impact Analysis Statement for a Species at Risk listing: http://gazette.gc.ca/rp-pr/p2/2014/2014-12-17/html/sor-dors274-eng.php

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COST-EFFECTIVENESS ANALYSIS (Decision Analysis Approach – Economic)

For a factsheet on this item see:

http://www.aboutvalues.net/data/method_navigator/values_method_profile_cost_effectiveness_analysis.pdf

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DIRECT MARKET PRICE VALUATION (Economic Valuation Method)

For a factsheet on this item see:

http://www.aboutvalues.net/data/method_navigator/values_method_profile_direct_market_prices.pdf

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ECOLOGICAL PRODUCTION FUNCTION[274] (Ecosystem Analysis Method)

Can be used to explain how ES are produced, which variables contribute to their production, and how their production is likely to change given changes in those variables.

> *Allows users to:*
>
> - determine with a degree of probability how things are changing or related to each other; and
> - communicate trends and relationships in ES with a degree of power and credibility.

Best used when asking

How are ES produced? What contributes or is necessary to their production? How can we develop a model that can be used to test various scenarios of management to explore their repercussions on ES?

Ecological production functions characterize relationships between ecosystem condition, management practices, and the delivery of economically valuable ES. Production functions have long been used in agriculture and manufacturing, where the delivery of a commodity (e.g., crop yield) is related to quantity and quality of various inputs (e.g., pesticides). This approach can be adapted to the delivery of ES through ecological production functions describing the links between land use, ecosystems, and communities, and delivery of ES.

For the moment, the understanding of the relationship between land use, biodiversity, and service provision is still limited and, therefore, ecological production functions tend to be simplistic. They do not, for instance, usually take into account the contribution of different components of biodiversity to ES delivery. Importantly, the predictive ability of ecological production functions is often uncertain because validation has been limited. Furthermore, key services remain to be modelled and integrated into multi-service frameworks. While developing or using ecological production functions is a recommended approach to assessing changes to management of ES and understanding ES provision in a more dynamic way, recognition of the limitations and assumptions related to each production function is necessary.

How it is done

The ecological production function takes as input ecosystem conditions and predicts outputs. The output of an ecological production function is measured in physical units, for example, tons of carbon sequestered or amount of phosphorus exported to surface water.

There is growing understanding of the production of ES and details that can help in the development of production functions can be found in the scientific literature on ES or on more specific topics such as soil science and hydrology. This research has been integrated into freely available tools, such as the Natural Capital Project's InVEST (Integrated Valuation of Environmental Services and Trade-offs) software package. Because many ES have been studied extensively outside of the ES field, even if formal production functions have not yet been constructed for a given ES, relevant research is likely to be available, although much ecological research does not directly address the ecological characteristics of concern for ES: the benefits to humans. However, in the case of Chan et al. 2011:

> The carbon budget model of Kurz et al. (1997[275]) was directly applicable for estimating changes in carbon storage. According to the model, forest types in the central interior ecoregions in British Columbia, Canada, store on average 10% more carbon under natural disturbance cycles than under managed (forestry) cycles. The same carbon budget model is currently used by Canadian Forest Service and has been central to prominent scientific publications.[276]

Developing ecological production functions requires expertise in the specific field in question (e.g., soil science, wetland hydrology, agriculture) and the necessary time to develop and validate the model. To start, look at models that have been developed previously in the academic literature and in the documentation for models such as those included in InVEST.

[274] There are many types of mathematical models used in ES assessment, ranging from simple equations for explaining the distribution of multiple ES, to more complex models of risk associated with ecological change. Aside from the already developed ES models that are presented in this tool compendium, developing specialized models for specific contexts requires some experience in modelling, available input data, and the opportunity to test the model and validate the results.

[275] Kurz et al. 1997.

[276] Chan, Hoshizaki, and Klinkenberg 2011.

Strengths/advantages

- Can be used to assess ES dynamically and to explore the impacts of alternative management strategies for ES.
- Some production functions have already been developed and can be adapted for specific contexts.

Limitations/disadvantages

- Models may be simplistic.
- Ready-made models may not be relevant to certain contexts.
- Models should be validated, which may be challenging.
- Developing new production functions requires high level of expertise.

Resource requirements

- Expertise: High level.
- Time: May be lengthy, depending on need.
- Costs: Cost of labour to develop and validate production function model.

Further information

Brief discussion of modelling ecological production function dynamically with GIS is available in Nemec and Raudsepp-Hearne 2013. Tallis et al. 2015 explain how a production function approach is best for ES impact assessment to identify the irreplaceability and vulnerability of biodiversity in an ecosystem "serviceshed" so as to reduce impacts from development or land-use change.

A general discussion of ecological production function models is available in SAB/EPA 2009.

See also Andrew et al. 2015.

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ECOMetrix (Analysis Tool)

Can be used to assess ES associated with:

- Food and fibre
- Fisheries
- Agriculture
- Fresh water
- Climate regulation
- Natural hazard mitigation
- Pollination
- Water purification
- Water regulation
- Aesthetic
- Sense of place
- Spiritual and religious
- Recreation and ecotourism
- Soil formation
- Erosion control
- Cultural heritage

Best used when needing to determine the gains and losses in ES benefits across a landscape under different scenarios of land use and land management. Communicate analytical results using visual data, for example, bar charts, heat maps, and score cards.

ECOMetrix can help answer questions like:

- What are the gains and losses of ES benefits across a landscape under different land-use or management scenarios?
- What is the percent performance of an ecosystem function and/or ES in a given landscape?

How it works

A conceptual model is developed for individual ecosystem functions on the landscape and used to identify the types of data to collect and how to use the data to understand how well the ecosystem function performs. The specific landscape attributes in each conceptual model are then identified and a unit of measurement is decided upon. The units of measurement are most often quantitative but can also be given qualitative ranges. The next step involves developing scoring curves for each of the landscape attributes that describe how a particular attribute's abundance on the landscape affects the performance of the relevant ecosystem function. The individual attributes are aggregated to create functional performance scoring algorithms that can be adjusted using weighting factors that are determined by the policy/project context. The final step involves calculating the gains and losses in ES benefits on the landscape, and ES scores are generated for use in maps or charts to communicate the findings.

Strengths/advantages

External peer-review process for function development and weighting factors allow adjustments to project context. The output, expressed as the ability of a given area on the landscape to perform a specific ecosystem function, is easy to understand and communicate to a broad range of stakeholders.

Limitations/disadvantages

ECOMetrix is a proprietary software system that is used by the ECOMetrix Support Group (ESG). The list of ES that can be included in an analysis is limited to those listed above, but development of this tool is ongoing and additional ES and modules can be expected.

Resource requirements

ECOMetrix is part of a decision-support service provided by ESG.

Developers: Parametrix and EcoMetrix Solutions Group
Website: http://www.ecometrixsolutions.com

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ECONOMIC PRODUCTION FUNCTION (Economic Valuation Method)

For a factsheet on this item see:

http://aboutvalues.net/data/method_navigator/valuesmethod_profile_effect_on_production.pdf

Further information

For a methodological examination of economic production function to assess the value of ES inputs to market-priced agricultural commodities in Canada, see DSS 2010.

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ENVISION (Analysis Tool)

Can be used to assess the following ES:

- Soil ES
- Hydrological ES
- Provisioning ES (e.g., timber, food)
- Carbon storage and sequestration

Allows users to:

- evaluate how different scenarios will impact ecological functions at landscape scale;
- explore how human behaviour and policies/governance may impact ecosystems; and
- explore how climate change and other important drivers will impact resource scarcity and human behaviour.

Best used when asking how decisions about land use and management, guided and constrained by policies, will affect the landscape and its functions.

Envision is an agent-based modelling platform where agents weigh the relative utility of potentially relevant policies to determine what policies, if any, they will select to apply at any point in time/space. Once applied, a policy outcome is triggered that modifies one or more site attributes, resulting in landscape change. Policies may also be constrained to operating only with selected agent classes (e.g., all home owners, farmers with streams flowing through their property, forest owners with fish in adjacent streams).

How it is done

The process is quite long, but is presented in detail on the Envision website (see http://envision.bioe.orst.edu/Tutorials/Tutorial1-EnvisionBasics.pdf).

The steps include:

1. Site selection and characterization, where landscape datasets are inputted into platform.
2. Alternative scenario selection, based on goals, policies, stressors, and drivers (each needs definition).
3. Evaluation of individual production (per agent), where individual models are integrated into platform (e.g., water quality, carbon, other models, indicators).
4. Aggregate evaluation of management alternatives, involving visualizations (maps).

Strengths/advantages

- Envision is a platform that can integrate a variety of spatially explicit models of landscape-change processes.
- Flexible and modifiable.
- Incorporates social and ecological components of systems, including decision-making and governance.
- Open source and freely available.
- Training is available (costly).
- Agriculture Canada uses this program, so there is already some expertise within Canada, as well as an Envision-specific database.

Limitations/disadvantages

- Requires a high level of expertise.
- Does not incorporate ES specifically, but can be used to assess ES.

Resource requirements

- Expertise: Requires programming/coding expertise, experts on many specific subject matters.
- Time: High.
- Costs: Free, but training costly.
- Data: Intensive.
- Requires high-speed computer.

Example

Multiple case studies can be found on the Envision website, here:

http://envision.bioe.orst.edu/caseStudies.aspx

A case study from Ontario http://envision.bioe.orst.edu/StudyAreas/EasternOntario/Outputs/:

> ES included: risk indicators (a set of 20+/- climate indicators, nitrogen, phosphorus, wildlife habitat, biodiversity, flooding) and productivity measures (biodiversity, wildlife habitat, crop yields) along with a number of regional statistics on land use, population demography, etc). The indicators are federal reporting indices derived from peer reviewed, published, and adopted sets of indicators.
>
> The Envision model for Ontario was developed in order to input available information for a region into a dynamic simulation tool to allow people to run 'what if' scenarios of change. Scenarios were initially focused on climate change, but now include how climate change may interact with other important

drivers, which in the case of eastern Ontario, include global markets, demographic change, policies and programs. These drivers fall into two categories, fixed or externally influenced trajectories (such as climate and markets) that cannot be controlled locally, and drivers that can be locally controlled. Envision is used as a platform that allows planners to see how different management or operational and policy shifts would change impacts from drivers. The impacts included in the model are biodiversity standards, wildlife and environmental indicators, agricultural reporting indicators, and others. The Envision system can be expanded and modified using datasets that can also be expanded and updated at any time to run new simulations. The platform is being used as a learning and research tool. University partners are developing and validating elements of the models, while local agricultural and environmental organizations are giving input.

Partners working to test and refine the model include: Carleton Univ. Geography; Dalhousie Univ. Engineering/hydrology; Univ PEI, Climate Lab; Univ. Ottawa, Health, Conservation Authorities (Mississippi, Toronto Region); OMAFRA, City of Ottawa, AAFC, ECCC.

Further information

Bolte et al. n.d. (http://envision.bioe.orst.edu/)

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FOCUS GROUPS (Socio-cultural Valuation and Issues Identification Method)

Best used when needing to find out what stakeholders think about a potentially complex topic.

How it is done

Researchers identify between eight and 12 individuals representing a stakeholder group or multiple stakeholder groups and invite them to meet and discuss their views (e.g., values, attitudes, perceptions) about a well-defined topic. A moderator guides the discussion with questions designed to probe attitudes and perceptions about the topic, typically for about two hours. Participants express their individual views and may debate the issues, but are not normally expected to negotiate a unified position. This is a key distinction between standard focus groups and some participatory deliberation methods that seek negotiated outcomes.

Participant mapping can be part of a focus group, for example, to indicate places of community activity, concern, and importance, or to map local knowledge of ecosystem conditions and pressures. Additional activities can be included, such as ranking and scoring.

Traditionally, focus groups have been conducted in person, but recently web-based formats have been adopted to enable participants from distant and even remote locations to interact with each other while still being able to see each other's facial expressions. In either approach, the session is recorded by a note-taker and electronically, so that a detailed analysis of both the discussion and the group dynamics can be made afterwards.

How to optimize the use of this technique

Focus groups can be used to scope out key issues, concerns, and perspectives. They can be useful as standalone methods, but can also be used (1) as a preliminary method to clarify issues that could be designed into a survey questionnaire targeting a larger respondent population; or (2) as a forum to inquire more deeply into issues identified through responses to a survey questionnaire or other information source to ensure that the analysts understand values and issues before moving into advanced decision-support analysis methods.

Because of the small number of participants in a normal session, it is generally recognized that scheduling multiple sessions (commonly more than two and less than 10 groups) with different participants, for example, in different parts of the study area, will significantly improve the likelihood of producing meaningful results that can better represent the scope of issues and values relevant to the case.

Well suited to identifying values, awareness, perception, issues—normally discursively and qualitatively, although can incorporate participant mapping as a tool to stimulate recall and engage participants especially when focused on place-based issues like ES. Can incorporate development of constructed scales and ranking as a form of prioritization. Can contribute to socio-cultural or economic valuation.

Setting criteria for selection of participants is important—considerations include the relative role of demographic variables as well as the considerations related to the activities and knowledge of potential recruits.

Strengths/advantages

- Can produce valuable information that is not likely to come from individual interviews or survey.
- Responses can be clarified through follow-up questions at the same time.
- Non-verbal responses can be recorded/interpreted.
- Group dynamics produce information, including new ideas, that individuals might not think of when alone.

Limitations/disadvantages

- Not statistically representative of a population, not statistically generalizable.
- Analysis of open-ended responses requires more skill and time than ranking or choice-based data.
- Possible for one or more individuals to dominate/overwhelm group, depending on skill of moderator.

Resource requirements

- Expertise: Clear scoping of issue in advance, experienced skilled moderator, qualitative analysis, potentially geographic knowledge, potentially cultural knowledge of study population.
- Time: Can be brief (as little as a few weeks depending on location, number of sessions, and depth of reporting), including organizing, conducting, and analyzing.
- Cost: Moderate depending on the number of groups and whether travel costs are paid to bring participants from distances, and whether a formal facility with a one-way window is needed. Payment of an "incentive" to compensate participants for their time is common. Typically contracted to market research firms.

- Access to information: Sufficient knowledge of the stakeholder groups and issues to be able to guide the session, access to stakeholder contacts.

Example

McIntyre et al. 2008.

> This study used survey, focus group, and valued place mapping.

Further information

Most university-level social and qualitative research methods textbooks contain a chapter on focus groups, and there are several books dedicated to focus groups, such as Krueger and Casey 2015; and Einsiedel et al. 1996.

See also: http://www.aboutvalues.net/data/method_navigator/values_method_profile_focus_group_discussion.pdf

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GIS MAPPING (Analysis Tool)

Can be used to map/assess any ES.

Best used for

Determining the spatial distribution of ES and underlying components of social-ecological systems that contribute to the provision of ES, benefits, and beneficiaries. GIS can be used to visualize how ES are distributed across a landscape, compare the distributions of multiple ES with each other, with drivers of change and other social-ecological parameters, and model how changes in land use or land cover, land management, ecosystem and climatic conditions, and human populations affect ES provision and the value and use of services. GIS can be used to identify ES bundles and "hotspots" where high provision of individual or multiple services occurs, and analyze trade-offs and synergies among services. GIS has long been used for planning purposes, and this also applies to planning that involves the management of ES.

Allows users to:

- model, map, and quantify ES at multiple scales, using existing data, expert advice and participatory approaches;
- create context-specific ES maps and models;
- communicate the distributions of ES with stakeholders quickly and effectively; and
- visualize and analyze how services are provided within a heterogeneous landscape.

How it is done

Using GIS requires GIS software, the most common of which is ArcGIS. There are also a number of open-source GIS software packages (a full list of GIS software can be found online). Suitable expertise is required to run GIS software, map ES, and create or run models. Spatial data are collected and inputted into the GIS interface.

Approaches to estimating ES values using GIS include (1) the development of "static" estimates, or data-driven values that present a snapshot of current or past ES across a landscape; (2) the development of ES models that can be used to analyze how changes in landscapes impact the provision of ES and benefits; and (3) the development of models and approaches that emphasize social preferences and priority-setting for ES. Mapped service estimates are derived from land cover or other ecosystem proxies (e.g., forest cover), indicators of ES use (e.g., number of moose killed in a year by hunters), data related to the condition or supply of a service (e.g., water-quality data), and ES equations that link production values to their potential use or benefit to human populations, among others. Interviews, workshops, and expert consultation can also be used to develop and map information about ES (e.g., condition and trends), benefits from ES, and the values held by different populations related to ES. Each service indicator is mapped at a chosen spatial resolution using boundaries that are arbitrary (e.g., raster grid), ecological (e.g., watershed) or social (e.g., census units).

Assigning values to the benefits from ES has focused mainly on producing estimates of "total economic value" (TEV) for the provision of ES, often estimated by assigning monetary values to specific land covers using GIS. More recently, studies have attempted to use GIS in conjunction with social science methodologies to assign non-monetary values to ES benefits. This has been accomplished through participatory mapping exercises, where ES beneficiaries rate areas that are important or valuable to them in terms of ES provision and benefits.

Decision-makers often want to know the estimated rate of change in value of an ES compared with changes from current levels of the service, because policy and economic decisions are made in terms of the marginal values of an ES. For example, decision-makers want to know how the supply of ES will change given alternative development plans or policies. To provide this type of information, modelling of the ES is usually needed, which requires a high level of GIS and modelling expertise. In some contexts, space-for-time substitutions have been used to infer how land-use choices and management may impact ES.

ES models have recently been developed for off-the-shelf use, but may or may not be suitable for providing the information that is needed in a specific case. For decision-making purposes, a principal benefit of GIS mapping of current and past distributions of ES is the ability to use context-specific data and indicators, which may be more accurate and relevant than values obtained from generic models. In many cases, a combination of approaches may be needed to answer policy-relevant questions about ES using GIS.

How to optimize the use of this tool/method

GIS methodologies encompass a broad range of functionalities and tools. The goal of spatial analyses should be clear before deciding on their use (e.g., communication, trade-off analysis, supply-demand comparison). The proper experts should be lined up before starting the work to have someone on the assessment team who can advise on which GIS approaches could be used and what data are available. The use of modelling for many services is in its infancy and there should be a clear understanding of what can be done prior to using any of the GIS models that are available or before developing new models. Results should be validated and reviewed whenever possible.

Strengths/advantages

The proliferation of freely available satellite imagery and associated databases allows for a GIS-analysis of ES in areas of the world where few other forms of data are available.

New GIS models are attempting to incorporate both the provision and associated benefits and values to humans of ES into their design, and hold much promise for supporting complex decisions around landscape management and conservation.

Limitations/disadvantages

Spatial data and metrics used to quantify the supply or production of ES are not always relevant to human well-being (e.g., remote sensing data can be used to quantify net primary production in grasslands, but may not be able to account for how much is actually consumed or used by humans). Choosing ES indicators from a list of available spatial data does not always yield relevant results.

Secondary data consisting of spatial units such as land-cover classes and watersheds are more often used as proxies for ecosystems. Although maps based on proxy data are helpful for depicting broad-scale patterns in ES, because the maps do not fit actual data well they are less useful for identifying priority areas that provide multiple ES. Scientists are encouraged to report the shortcomings of their approaches to ES mapping so that decision-makers are more aware of the benefits and drawbacks to using a given approach for depicting the provision of ES.

GIS-based models are designed to produce specific types of results and are not always suitable for use in all contexts. Care must be taken to design an assessment approach that will yield relevant results.

Resource requirements

- Expertise: Intermediate to advanced skills in ArcGIS or other software packages required, as well as knowledge of available data and relevant models.
- Time: GIS analysis and use of models may require anywhere from two to 16 weeks. More time is required if new models must be learned.
- Cost: GIS packages that are most commonly used require expensive licenses, running models may require several weeks of person hours.
- Access to information: Software can be used with almost any data source, from satellite imagery to census data. Data on ES use and benefits to human well-being are harder to access (may not exist).

Examples

O2 Planning + Design Inc. 2011; Cimon-Morin et al. 2014.

Further information

Petter et al. 2012; Nemec and Raudsepp-Hearne 2013. *"This paper reviews GIS approaches and software developed for the assessment of ecosystem services and highlights their strengths and weaknesses in the context of different end uses."*

See also http://www.aboutvalues.net/data/method_navigator/values_method_profile_mapping_overview.pdf

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HEDONIC PRICING (Economic Valuation Method)

For a factsheet on this item see:

http://www.aboutvalues.net/data/method_navigator/values_method_profile_hedonic_pricing.pdf

Further information

A limitation of hedonic values is that multiple variables are likely to inform willingness to pay for the non-market (unpriced) item and the correlation between the non-market good and the chosen proxy often cannot be tested. For example, hedonic pricing of the ES of "water purification" in a suburban subdivision situated adjacent to a prominent natural area may be based on real-estate values and may assume that, all else being equal, the difference in sales price between properties in that location and similar properties that are not adjacent to similar natural areas must reflect the purchasers' attribution of value to the natural area. However, purchasers may have prioritized other amenities that are not immediately apparent to the analyst, or may have prioritized specific aspects of the natural area other than water purification (omitted variable bias and wrong choice of functional form).

Example

DSS Management Inc. 2009.

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INTERVIEWS (Socio-cultural Valuation and Issues Analysis Method)

Best used when needing to collect explanations, opinions, experiences, and facts about ecosystems and human values and activities, including detailed understanding of how people perceive, access, and benefit from ES. They are valuable for gathering information from stakeholders and representatives of various groups in a population, as well as from experts in different fields.

Well suited to collecting information specific to a place or group of people that is not otherwise available; useful in the scoping/ screening of priority ES and in different analyses of ES, most notably socio-cultural valuation, but also a key means of obtaining expert local and traditional knowledge about species and ecosystems.

How it is done

Because an interview is, in its most basic form, an interaction where a researcher solicits information from a "respondent," the term "interview" is used when discussing many different processes and data collection methods.[277] This factsheet focuses on four types of interview: structured, semi-structured, unstructured, and ethnographic. The distinction between these is the degree to which the respondent has latitude to answer questions in their own words, and the degree to which the interviewer directs or controls the scope of discussion. In all cases, the interviewer designs questions that are expected to elicit information about specific issues.

Structured interviews are the verbal version of completing a survey questionnaire where respondents are given a limited range of answer options that are either affirmative/negative or a selection from a set of possibilities.

Semi-structured interviews allow for both structured responses and open-ended or unstructured opportunities for respondents to describe information in their own words. These open-ended options can range in extent from a short statement to lengthy explanations and discussions. Interviewers develop and ask probing questions during the interview based on what respondents say, to ensure that they collect as much relevant information about the subject of inquiry as possible, including exploring unanticipated issues that are introduced by the respondent.

Unstructured interviews may begin with the interviewer framing a subject of interest and then inviting the respondent to discuss it from their own perspective, with little direction from the interviewer.

Ethnographic interviews focus on gathering information that can be illustrative of a respondent's culture and can be semi-structured or unstructured.

Interviews are normally conducted with one respondent, but small groups can work (i.e., two or three people at most). Criteria for selecting participants will depend on the objectives of the data collection. Research ethics practices should be followed in all research involving human subjects.[278] With consent, the interview may be recorded electronically or the interviewer may make written notes of the answers.

How to optimize

Prepare for the interview by reviewing existing documentation relevant to the place, people, and issue that is the subject of the inquiry (ranging from local media and websites of stakeholder groups to scientific and government literature). Interviews aimed at collecting information about ES can be enhanced by combining participant mapping (where the participant indicates on a map the places discussed for various reasons). Transcription of written notes and audio recordings (if made) should be completed by the interviewer when possible to avoid potential errors that can significantly impact the analysis of results. Ethnographic research has found that respondents remember details about places more effectively when they are in the landscape rather than in a conventional indoor setting. When possible, incorporating site visits, photos or maps can increase the detail and quality of information obtained.

Strengths/advantages

Enables collection of a wide range of information, much of which is undocumented elsewhere, such as how people in a place interact with their environment in complex and sometimes important ways. Interviewers can (and sometimes should) use initial responses as a cue to ask more questions to reveal potentially important information, unconstrained by pre-established question structure.

[277] For example, some forms of group deliberation can be referred to as "interviews," and survey questionnaires are also referred to as a type of interview, but these are all treated separately in this Toolkit.

[278] See TCPS 2010. In face-to-face interviews, the respondent should be provided with a document explaining the purpose and process of the interview, confirming their permission to have their contributions used in a specified way.

Limitations/disadvantages

Gathering information from one individual at a time is time consuming if there is a need to communicate with people representing many different perspectives. Analyzing non-standardized data requires time and strong observational skills. Content analysis software can be used, but is not designed to capture the meanings communicated by body language, tone, and conceptual linkages that an interviewer should be able to observe and understand by being present.

Required resources

- Expertise: Knowledge of how to design effective interview questions, and how to analyze responses (especially open-ended).
- Time: On average, a semi-structured or open-ended interview should not exceed two hours (to respect the respondent); multiply by the number of interviews. Comprehensive manual transcription is slow. Voice recognition software is not yet reliable for this use.
- Cost: Very low (with the exception of possible travel to access respondents).
- Access to information: Depends on availability and willingness of respondents, otherwise unlimited.

Example:

Klain et al., 2014:

> In 2010, Klain conducted semi-structured, map-based interviews with residents of coastal communities in the Regional District of Mount Waddington, British Columbia. The interviews highlighted the complex ways in which their marine environment is important to residents, and provided a testing ground for an interview protocol designed to draw out information on cultural ecosystem services, which tend to be overlooked in ecosystem services research. Interviewees were asked to identify important places on a map and to assign a weight to the importance of the place. They were asked to discuss how and why these places are important. Interviewees were also given verbal prompts to encourage them to articulate values, benefits and services. By systematizing the interview protocol, coding and comparing responses, researchers were able to compare the effectiveness of different prompts and assess whether and how the protocol aided in eliciting information that might have otherwise been missed. In addition to capturing views of nature as a service provider, the researchers found their interview protocol assisted in capturing clearly and meaningfully articulated social and cultural values associated with ecosystems. The research also highlighted and provided a method to account for bundling of values, benefits and services that link biophysical, economic and social attributes, which is often difficult for researchers to record.

See also Klain 2010; Klain and Chan 2012; O2 Planning + Design Inc. 2011; Cimon-Morin et al. 2014.

Further information

See also http://www.aboutvalues.net/data/method_navigator/values_method_profile_interviews.pdf

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InVEST (Suite of ES Analysis Models)

Can be used to assess the following ES:

- Wave energy
- Coastal protection
- Crop pollination
- Marine overlap analysis model: fisheries and recreation
- Marine habitat risk assessment
- Carbon storage and sequestration
- Manage timber production
- Sediment retention model: avoided dredging and water quality regulation
- Coastal vulnerability
- Marine fish aquaculture
- Marine aesthetic quality
- Terrestrial biodiversity: habitat quality and rarity
- Reservoir hydropower production
- Water purification: nutrient retention

Best used when needing to

Compare baseline services (quantity and economic value) to what could exist under different scenarios or compare past service provision to present or near-future provision. Current models can identify areas on a landscape where investment may enhance human well-being and nature. The tool is built to evaluate trade-offs. For example, government agencies could use InVEST to help determine how to manage lands, coasts, and marine areas to provide an optimal mix of benefits to people or to help design permitting and mitigation programs that sustain nature's benefits to society. Corporations, such as timber companies, renewable energy companies, and water utilities, could also use InVEST to decide how and where to invest in natural capital to ensure that their supply chains are preserved. Models do not provide credible or specific enough information at all scales and for all systems to answer some policy-relevant questions.

How it is done

Download the ArcGIS compatible software from the InVEST website (http://www.naturalcapitalproject.org/invest/). Following the directions in the accompanying manual, data must be collected and formatted to fit the needs of the particular models of interest. While not very data-intensive, it may take several weeks to obtain and format the relevant data. Some of the parameters may need to be checked with local experts to ensure that relevant values are being used. A course on InVEST may be invaluable if no one with previous experience is available to parameterize and run the models. However, instructions for how to run each model are provided by the InVEST manual, and are relatively easy to follow.

InVEST can help answer questions like:

- Where do environmental services originate and where are they consumed?
- How does a proposed forestry management plan affect timber yields, biodiversity, water quality, and recreation?
- What kinds of coastal management and fishery policies will yield the best returns for sustainable fisheries, shoreline protection, and recreation?
- Which parts of a watershed provide the greatest carbon sequestration, biodiversity, and tourism values?
- Where would reforestation achieve the greatest downstream water-quality benefits while maintaining or minimizing losses in water flows?
- How will climate change and population growth impact environmental services and biodiversity?

InVEST has a tiered design. **Tier 0 models** map relative levels of environmental services and/or highlight regions where particular services are in high demand. For example, the coastal vulnerability model in InVEST maps regions of the coastline that are particularly susceptible to erosion and flooding. It does not use a production function to yield outputs of metres of shoreline eroded or to value coastal protection services provided by nearshore marine habitats. There is no valuation done in Tier 0 models. **Tier 1 models** are theoretically grounded but simple. They are suitable when more data are available than are required for Tier 0, but they still have relatively simple data requirements. Tier 1 models can identify areas of high or low environmental service production and biodiversity across the landscape, and the trade-offs and synergies among services under current or future conditions. Tier 1 models give outputs in absolute terms and provide the option for economic valuation (except for biodiversity). For example, the Finfish Aquaculture model can provide outputs in pounds of fish or in dollars. More complex **Tier 2 models** provide increasingly precise estimates of ES and values. Scenarios that represent a change in the monthly or seasonal timing of fertilizer application or water extraction in agricultural systems cannot be assessed by Tier 1 models, but will be treated well by Tier 2 models.

Strengths/advantages

Off-the-shelf availability and functionality, relatively easy to learn even for non-GIS experts, continues to be improved and updated, already a community of users available online to help troubleshoot, case studies available to guide work, and can be used in conjunction with other methods (particularly sharing of expert and traditional knowledge, participatory approaches, scenario development). Models for a large number of ES are available.

Limitations/disadvantages

No methods built in for validating results, ES are defined in a set manner, may or may not be relevant in a particular context, are more suitable for some ecosystems than others (low functionality in drylands, for example), better for comparison among values than for developing precise values associated with individual ES provision, depending on how the results will be used, some validation may be necessary to have confidence in the model results.

Resource requirements

- Expertise: Running InVEST does not require Python programming, but it does require basic to intermediate skills in ArcGIS.
- Time: Several weeks to several months depending on access to data, GIS experience, stakeholder involvement and number of services being assessed.
- Cost: A small budget is required if GIS software is already available, InVEST software is free. If InVEST is run with stakeholder participation, a larger budget is required.
- Access to information: Much of the data needed are available from literature or global datasets, however, the more local and fine-scaled the data used, the better the results will be.
- Software and hardware: InVEST tools run as script tools in the ArcGIS ARCTOOLBOX environment. To run InVEST, the team must have ArcGIS 9.3 (service pack 1 or 2) or ArcGIS 10 (service pack 1), ArcINFO level license to run some of the models, and the Spatial Analyst extension installed and activated. The pollination model and all marine models require additional Python libraries available for download at www.naturalcapitalproject.org.

Example

Marine InVEST was first applied to a 460 km stretch of shoreline on the west coast of Vancouver Island in 2010 as a partnership with West Coast Aquatic, a co-management body for the region. The goal was to inform an integrated management approach using several of the InVEST models. Details are provided in Guerry et al. 2012 and McKenzie et al. 2014.

Further information

Natural Capital Project (n.d.) http://www.naturalcapitalproject.org/invest/

Ruckelshaus et al. 2015

See also http://www.aboutvalues.net/data/method_navigator/values_method_profile_invest_general.pdf

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LITERATURE REVIEW (Data Source – All Types)

Can be used to assess the following ES

All ES. Focus on studies that are as similar in context as possible.

Best used when asking

What is the current state of information available in documents on any particular topic? For example, what are potential trends in particular ES, and how might certain drivers (e.g., projects or policies) affect those services and, in turn, human well-being? How does a particular community or culture group interact with the environment (particularly in the case of Indigenous and other traditional communities)?

A literature review will show what has already been written and understood about a topic, and to determine gaps in understanding of the topic that may require further study. In some cases, data from relevant cases studies may be used for parameterizing[279] models, comparing against data from the study area, or providing a rationale for investigating certain components of the study system (e.g., to help answer questions in the *ES Screening Tool* in *Worksheet 2*). Literature review is useful in (1) initial scoping; (2) core analysis; and (3) scoping the use of ES with different policy instruments. Reviewing the literature to see whether there are insights to be gained about impacts on certain ES within specific systems should be an early step in any assessment. In some cases, decision-makers are interested in whether certain action may result in negative consequences for ES and human well-being, and it may be sufficient to report back results from the literature if they are credible and relevant. A literature review alone will not suffice if decision-makers require information about the impacts of specific drivers on ES within a given area.

Allows users to:

- understand whether there are common trends in particular ES within certain systems, or associated with certain drivers;
- determine whether it is likely that proposed projects or policies will have an impact on a range of ES;
- explore whether further analysis is needed on particular services or drivers of change; and
- use the *Screening Tool* (*Worksheet* 2) with more confidence in answering questions credibly.

How it is done

A literature review is a survey of everything that has been written about a particular topic, theory or research question. Selective use of a small number of publications is not sufficient. Instead, a literature review surveys all relevant literature to determine what is known and not known about a particular topic. It may provide the background for larger work or it may stand on its own. Much more than a simple list of sources, an effective literature review analyzes and synthesizes information about key themes or issues. Searching for relevant literature usually involves the use of keywords related to the topic. To access articles or documents that are relevant but were written prior to the popularization of the ES concept, consider using specific keywords related to individual ES (e.g., soil organic matter, erosion control). The most relevant articles will describe studies conducted in similar social-ecological systems to the one of the interest. For each publication, consider whether the author is a known expert in the field or has relevant credentials and whether the publisher is well regarded.[280] Consider also whether the evidence presented supports the conclusion, and whether the argument or evidence is complete. When comparing sources, consider whether all research arrives at the same conclusion or there are differing opinions. What evidence or reasoning are the differences based on? Are there any errors or omissions, that is, what questions are raised by the literature?

This applies to social, cultural, ecological, and economic information gathering. It is likely to have a uniquely important role in considering Indigenous cultural relationships and values with the environment wherein the literature will be published ethnographic accounts of a culture group, rather than about an ecosystem component. In most cases, for Indigenous cultures, it would be the anthropological literature. This evidence will be in journals and scholarly books, but especially in dissertations, conference proceedings, and reports prepared for Indigenous councils. It may entail contacting an ethnographer or anthropologist who is recognized for work with a particular Indigenous community to identify relevant literature to review.

279 Parameterization is the process of deciding and defining the parameters necessary for a complete or relevant specification of a model. For example, a pollination model might require the following parameters to be inputted: crop of interest, size of area, type of pollinator, and so on.

280 Although these are considerations, they are not strict guidelines as new experts regularly arise.

How to optimize

A literature review aims to cover all of the research on a given topic. If the topic is too large, there will be too much material to cover it adequately. It is a good idea to start with a narrow focus and expand it as needed. It can be useful to begin with a few "review articles" (that provide a review of existing research) in the subject area as a way of identifying key issues and key sources for further exploration. It is also important to search through databases for multiple disciplines across the social and environmental sciences. Ensuring that the sources used are fully relevant rather than peripheral is essential.

Strengths/advantages

Low cost, does not require special expertise, can be completed reasonably quickly, and useful for communicating important issues to stakeholders and decision-makers early in the process.

Limitations/disadvantages

May be difficult to find relevant information on specific ES in similar systems. Cannot be used to draw conclusive statements about links between drivers of change, ES, and human well-being in unstudied systems.

Resource requirements

- Expertise: Low to moderate—should be aware of the scope of subject areas that should be scanned, should understand how to correctly search and report from technical and academic literature.
- Time: Relatively quick.
- Cost: Low.
- Access to information: Readily accessible through online searches, as well as through university and government libraries. May require contacting agencies, organizations, and so on, for "grey" literature (reports).

Examples

Mitchell et al. 2013; Karst 2010; Liss et al. 2013; Troy and Bagstad 2009.

Further information

In general, it is advisable to use documents and publications that are the original report on results of research and analysis. Existing literature reviews can help identify issues and sources to be investigated during the scoping and data collection phases of an assessment (see, e.g., Centre for Indigenous Environmental Resources 2013).

University-level research methods texts typically include directions for completing a robust literature review.

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LUCI (LAND UTILISATION & CAPABILITY INDICATOR) (Analysis Tool)

Can be used to assess the following ES

Crop production, carbon sequestration, flood control, erosion control, sediment delivery, water quality, and habitat, as well as trade-offs/synergies identification.

Allows users to:

- run models using nationally available data;
- embed other models, and aspects can be embedded in other models (LUCI is a *framework*); and
- compare impact of current land use with different land-use scenarios.

Best used when asking

What is the capability of a landscape to provide a variety of ES, such as agricultural production, erosion control, carbon sequestration, flood mitigation, and habitat provision? LUCI is an open-source GIS toolbox that compares the services provided by the current utilization of the landscape to estimates of its potential capability, and uses this information to identify areas where change might be beneficial, and where maintenance of the status quo might be desirable. It can be used from the site to the watershed/landscape scale.

LUCI is an evolving tool; details on how to obtain it are available at http://lucitools.org/.

How it is done

LUCI requires ESRI's ArcGIS 10.1 or above to run. Documentation and help are embedded within the LUCI software. Minimum data requirements for successful application are:

- a gridded digital elevation model, ideally of approximately 5x5 – 10x10m resolution;
- land-cover information; and
- soil information.

A number of national datasets are supported for UK and New Zealand applications; for other countries it is currently necessary to match land-cover and soil information into the supported classification systems. Support for a broader range of datasets will be added in the future. Estimation of each ES is based on the following approaches:

Service	Method
Production	Based on slope, fertility, drainage, and aspect
Carbon	IPCC Tier 1 – based on soil and vegetation
Flooding	Detailed topographical routing of water accounting for storage and infiltration capacity as function of soil and land use.
Erosion	Slope, curvature, contributing area, land use, and soil type
Sediment delivery	Erosion combined with detailed topographical routing
Water quality	Export coefficients combined with water flow and sediment delivery models
Habitat (approach A)	BEETLE – Forest Research's cost-distance approach to dispersal, examines connectivity
Habitat (approach B)	Identification of priority habitat by biophysical requirements (e.g., wet grassland)
Trade-offs/synergy identification	Various layering options with categorised service maps (e.g., Boolean, conservative, weighted arithmetic)

Strengths/advantages

- Open source.
- Flexible toolbox, can be used with other models.
- Used with stakeholder engagement.
- Simple and transparent (models are intuitive and simple, so that users can understand and trust in them).

Limitations/disadvantages

- Still under development.
- Does not report uncertainty levels.

Resource requirements

- Expertise: Basic GIS knowledge, some programming knowledge, ability to develop ES values using another approach/tool.
- Time: Not extensive to run, but ideally is accompanied by extensive stakeholder consultation.
- Costs: Free.

Further information

Jackson et al. 2013.

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MARXAN (Modelling Analysis Tool)

Can be used to assess biodiversity and ES (need to be developed separately and then input to Marxan).

Best used when asking how to optimize the spatial provision of biodiversity and ES and plan protected areas to maximize both biodiversity and ES provision.

Marxan is used by Environment and Climate Change Canada to assist in the delineation of boundaries for protected areas.

Marxan incorporates biodiversity features as well as costs to identify trade-offs between conservation and socio-economic objectives. Typically, a Marxan analysis compares the benefits from the presence of fauna or flora in a planning unit with the costs of conservation in monetary terms. The program attempts to maximize the benefits at a minimum cost and delimitate the most efficient boundary to meet that objective. While Marxan was not designed to consider ES, these types of benefits have been successfully incorporated in a Marxan analysis by Chan et al. 2006.

How it is done

Marxan is a standalone program. However, since output is provided in text or comma-delimited files, a GIS mapper such as ArcGIS is needed to display the results so they can be better visualized.

Users create input files using the Inedit tool. The input file "instructs" the program on how it should perform the optimization, for example, number of iterations, runs, heuristics, and where to find input data files. The user must also prepare input data files (text files) that list values for each planning unit (this is how ES values can be inputted). The program produces a result that finds the best (most valuable) reserve boundary at minimum cost subject to user-specified constraints. The program identifies the planning units that should be included within the reserve boundary.

Strengths/advantages

One of the major strengths of Marxan is that it is the most widely used conservation planning software in the world. As such, there is a lot of available reference material, training, and an active user support forum.

While Marxan is an independent program that uses text files for input and output, it is also possible to translate ArcGIS data as input for Marxan and vice versa.

Marxan is free to download.

Allows users to:

- optimize the provision of multiple ES and biodiversity;
- design new reserve systems based on location of biodiversity and ES;
- report on the performance of existing reserve systems; and
- develop multiple-use zoning plans for natural resource management.

Limitations/disadvantages

The major weakness of Marxan is that the program is not designed to be an ES assessment tool. Therefore, users must first determine ES values and then assign them to planning units to create input to be used in Marxan. Once the user has done this, Marxan can be used to determine an optimal reserve boundary that includes various ES values. However, Marxan will not aid the user in the first part of the task (i.e., determining ES values and their location).

Resource requirements

- Expertise: Basic GIS knowledge, some programming knowledge, and ability to develop ES values using another approach/tool.
- Costs: Free.

Example

British Columbia Marine Conservation Analysis 2012:

> Between 2006 and 2013 the British Columbia Marine Conservation Analysis (BCMCA) developed resources and tools to support conservation in the BC Pacific coastal region. The BCMCA gathered data through broad engagement with ocean users and experts in, or familiar with the study area, via workshops, participatory mapping, secondary research and expert review to create an atlas of ecological resources and human uses. This data was used to conduct Marxan analyses to identify potential areas of high conservation value (using ecological data only) and to identify areas important to human use (using human use data only). The process was carefully documented to demonstrate how Marxan can be used to integrate different types of data from multiple sources to produce scenarios to support area-based planning decisions. The various scenarios, based on different user-defined

input, were displayed on maps allowing users to easily compare the results of different combinations of criteria, and enabling users to visualize the trade-offs resulting from different options.

Further information

Chan et al. 2006.

See also http://www.aboutvalues.net/data/method_navigator/values_method_profile_marxan.pdf

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MIMES – Multi-scale Integrated Models of Ecosystem Services (Analysis Tool)

Can be used to assess the following:

- Carbon sequestration
- Existence of nature
- Waste treatment
- Water supply
- Nutrient regulation
- Rangeland for livestock
- Soil formation
- Non-timber forest products
- Carbon storage
- Storm protection
- Pollination
- Water regulation/flood protection
- Sediment regulation
- Nitrogen mineralization for agricultural production
- Raw materials
- Aesthetic/recreation potential

Best used when needing to

Assess the economic value of ES under a variety of different land-use and management scenarios. MIMES is a modelling tool that helps to map and quantify the economic value of ES. The suite of integrated models included in MIMES can be applied at multiple scales. The systems approach emphasizes interactions among system components, including positive and negative feedbacks. MIMES is most useful for scenario planning and sensitivity analysis.

MIMES can help answer questions like:

- What is the value of ES under different land-use and management scenarios?
- How are the selected ES distributed across a landscape in each of the scenarios?
- What, if any, economic argument can be made regarding ES for a given development scenario?
- How do system dynamics affect ES values?
- How are ES linked to human welfare?

How to optimize

The models used in MIMES can be developed with information and data elicited through the participation of stakeholders in a workshop setting or using a design charette approach. The quality of input data and use of time-series data are optimal for this systems-modelling approach. MIMES is ideal to use in conjunction with other tools such as SERVES. Target users include land-use managers and researchers.

Strengths/advantages

The software is freely available to download from the Affordable Futures website as a ZIP file. Output from the analysis, including maps and charts, can be effective visual aids that help with communicating findings. Quantitative measures of ES can facilitate economic arguments for conservation as an option for economic development.

Limitations/disadvantages

Use of MIMES requires commercial visual modelling software called Simile (available at http://www.simulistics.com). The analytical methods used in the models are limited to economic valuation, that is, they do not include biophysical values or qualitative measures of values. Use of MIMES requires technical expertise with GIS software. The time requirements are high for developing and applying the tool to new case studies and model construction requires contracting with the development group.

Resource requirements

- Expertise: Technical experience with ArcGIS software.
- Time: Depends on availability of data, GIS proficiency, size of study area, and number of variables included in the analysis.
- Cost: Undetermined.
- Access to information: Internet access to publicly available databases.
- Computer and Internet access.
- Software: ArcGIS.

Example and further information

Boumans, R. et al. 2015:

> *Abstract:* "In coupled human and natural systems ecosystem services form the link between ecosystem function and what humans want and need from their surroundings. Interactions between natural and human components are bidirectional and define the dynamics of the total system. Here we describe the MIMES, an analytical framework designed to assess the dynamics associated with ecosystem service function and human activities. MIMES integrate diverse types of knowledge and elucidate how benefits from ecosystem services are gained and lost. In MIMES, users formalize how materials are transformed between natural, human, built, and social capitals. This information is synthesized within a systems model to forecast ecosystem services and human-use dynamics under alternative scenarios. The MIMES requires that multiple ecological and human dynamics be

specified, and that outputs may be understood through different temporal and spatial lenses to assess the effects of different actions in the short and long term and at different spatial scales. Here we describe how MIMES methodologies were developed in association with three case studies: a global application, a watershed model, and a marine application. We discuss the advantages and disadvantage of the MIMES approach and compare it to other broadly used ecosystem service assessment tools."

Boumans and Costanza 2007.

Developers: Gund Institute, Accounting for Desirable Futures LLC

Contact: Dr. Roelof Boumans, rboumans@afordablefutures.com

Website: http://www.afordablefutures.com/home

See also http://aboutvalues.net/data/method_navigator/values_method_profile_mimes.pdf

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Best used when needing to integrate different kinds of values information, sometimes in different formats, to support a decision.

> ***Ideal to*** "identify a single most preferred option, to rank options, to short-list a limited number of options for subsequent detailed appraisal, or simply to distinguish acceptable from unacceptable possibilities." (Government of UK 2009: 19)

Multi-criteria analysis (MCA) allows different criteria to be considered when deciding which management options are most desirable, and it is also useful when trying to incorporate the views of diverse actors on different management options. It is most useful when a set number of management options are available and decision-makers need to decide among them. Because economic, ecological, and social criteria in some MCA approaches can be combined, it can be well suited to interdisciplinary ES work. MCA can aggregate different criteria into a single *index* to be used in making a complex decision. The technique integrates different elements of a decision, recognizing that these might not always be easily comparable. One way of doing this is to rank or rate the different potential outcomes according to desired criteria and then compare them using a formula, such as a checklist of several desired features (e.g., assign one point for each criterion met, and add up the points). MCA is also useful for aggregating the views of different actors on a particular issue. It is a good approach for team-based decision-making, where the preferences of different team members can all be integrated into the final decision without necessarily privileging the opinion of one person.

Stakeholder decision analysis is a type of MCA, and refers to a participatory approach to applying decision criteria to a problem. For example, stakeholder decision analysis can be MCA that is led by multiple stakeholders who give input into how criteria should be weighted and scored.[281] Some forms of MCA are also referred to as multi-criteria decision analysis (MCDA).

How it is done

MCA is a class of techniques, most often used for systematically evaluating the costs and benefits of options against a range of socio-cultural, environmental, and/or economic criteria. Criteria are used to judge the performance of options using a standardized scale of values. Criteria are weighted according to priorities specific to the decision context. *Deliberative multi-criteria analysis* encourages stakeholders and decision-makers to examine the full range of criteria that are important to varying degrees to a decision situation. The technique is a way of screening and ranking options in a systematic way and may be regarded as complementary to cost-benefit analysis.

A key tool in MCA is a "performance matrix" or "consequence table" for documenting the relationships between options and criteria using a standard notation to represent the relative weight in each intersection of the matrix. Notations within the same matrix may represent ranking, yes/no assessment or qualitative description of different variables that cannot be directly characterized using a common metric. The matrix may be used by decision-makers to compare the relative strength of each issue. Alternatively, analysts may convert the different metrics in the matrix to a common numeric value and a weighted average of scores is calculated. In either case (as with all decision-making), a degree of subjectivity and interpretation by both the analysts and the decision-makers is unavoidable. However, MCA makes all of the considerations visible and the process transparent.

The main steps in MCA are comparable across the different specific techniques, and comparable with some other decision-support approaches:[282]

1. Clarify the decision context (e.g., *Worksheet 1* in *Tools – Tab 4: Worksheets for Completing ES Assessment*).
2. Identify options.
3. Identify objectives and criteria.
4. Characterize anticipated performance of each option for each criterion, and score the value of consequences for each option.
5. Assign relative importance weights to each criterion.
6. Combine weights and scores for overall value.
7. Examine results.
8. Complete sensitivity analysis.

Strengths/advantages

The identification and use of explicit scores and weights for evaluating options is based on established techniques and can provide for consistency,

281 See factsheet in this compendium on Constructed Scales, Ranking and Scoring.
282 This list is based on Government of UK 2009, Figure 5.1, page 31.

transparency, and repeatability. MCA can be completed by professional technical "experts" or through participatory processes with such professionals and stakeholders. A community-led MCA may not require significant input from professional technical experts, and may be well developed by including experts in traditional and practitioner knowledge, as well as other stakeholders or community members.

Limitations/disadvantages

The techniques can be technically complex and, in some cases, can be applied without sufficient recognition of the differences in modes of significance (diverse kinds of values). It is important for practitioners and decision-makers to know that the practical benefits of concrete criteria and scores are ultimately based on the judgement of those who assign them.

Resource requirements

- Expertise: The most important expertise needed for MCA is sound knowledge of the decision context and its potential effects, so that these may be included as variables and assessed. There are numerous practical guides explaining the technical application of MCA steps.
- Time: Also depends on extent of stakeholder engagement and complexity of the case.
- Cost: Varies depending on degree of stakeholder engagement, need to contract experts, and the degree of complexity in the case at hand. If done in-house with voluntary community engagement, it can be in the low to moderate cost range.
- Access to information: Because MCA draws together a broad range of variables representing socio-cultural, ecological, and economic considerations, it requires information from many sources. Stakeholder, traditional, and practitioner knowledge can be particularly useful as well as existing economic analysis.

Further information

On MCA and MCDA, especially for integrating non-monetary evidence in valuation and appraisal, see Maxwell et al. 2011. For a detailed guide on MCA, see Government of UK 2009.

For other factsheets on MCA see: http://unfccc.int/adaptation/nairobi_work_programme/knowledge_resources_and_publications/items/5440.php

http://aboutvalues.net/data/method_navigator/values_method_profile_multi_criteria_analysis.pdf

For a review of different kinds of MCA in the context of ES in forest management, see Uhde et al. 2015. For brief comparison with structured decision-making, see Gregory et al. 2012.

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PARTICIPATORY AND DELIBERATIVE ECONOMIC VALUATION

For a factsheet on this item see:

http://aboutvalues.net/data/method_navigator/values method_profile_participatory_valuation.pdf

Further information

Fish et al. 2011b.

In addition to collecting new data from individuals through surveys and interviews, there are several methods that focus on collecting information from groups of people in planned settings such as focus groups, citizen juries, and workshops. In these venues, the group of participants discusses the issues among themselves with the benefit of an expert facilitator who can provide any needed technical or process information to support the discussion. The group may provide a range of responses, or a set of agreed responses to questions posed by the facilitator. Negotiation is therefore an important part of participatory deliberation. These techniques are used to generate monetary and non-monetary estimates of value and to collectively rank priorities, and can also involve mapping.

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PARTICIPATORY AND DELIBERATIVE SOCIO-CULTURAL VALUATION

For information on this see:

Fish et al. 2011b.

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PARTICIPATORY MAPPING (Social and Ecological Data Collection)

Best used when needing to identify geospatial information about places of activity and importance to stakeholders, communities, and expert respondents, including holders of local and traditional environmental knowledge.

How it is done

Through participatory mapping, experts, community members, and stakeholders can identify many important issues in their geospatial context. Participatory mapping can be incorporated into different data collection methods, including face-to-face interviews, focus groups, written or web-based survey questionnaires, and workshops. Respondents may be invited to make notations on printed maps (e.g., topographic or other), locations of activity, concern, places of importance, and ecological information that are often not obtainable through physical science methods. This may reflect specific sites, larger areas, and corridors or spaces of movement between sites. In addition to identification of these places, respondents typically are asked to explain the reasons for their importance, the issues of concern, and/or the nature of associated activity (by people or by other species). Results can be digitized on a plotter and incorporated as distinct layers for use in GIS analysis. Maps may be provided at any scale.

Well suited to identify in geospatial terms the places of interest, concern, activity, or ecological knowledge held by individuals.

How to optimize this method

Providing maps at two (or a maximum of three) scales can be important for capturing local details and regional connections. Maps showing place names and topographic features are useful. Questions to the respondents should be very clear and encourage as much spatial specificity as possible. Semi-structured and open/guided interview techniques of using probing questions to draw out explanations are important to ensure that the analyst's interpretation captures the respondent's intention.

Strengths/advantages

When attempting to document places of importance, concern or activity for people and about ecosystems, maps can be very effective visual reminders for respondents. For ES, this is valuable for identifying both the knowledge of ES flows (and barriers to flows) and the places and ways that ES beneficiaries experience ES. It can also help to identify places of conflicting demand or conflicting use that may be addressed in a decision process. Can be incorporated into surveys with large population samples.

Limitations/disadvantages

Completing and transcribing face-to-face interviews with a large number of respondents can be time consuming. Ecological knowledge is variable from one person to another, and it is easier to obtain reliable information about human aspects than ecological aspects from the general population. Identifying and including holders of local and traditional ecological knowledge is very important for ES analysis.

Required resources

- Expertise: Minimal.
- Time: Minimal.
- Cost: Minimal.
- Access to information: Minimal.

Example

Klain et al. 2014. (See factsheet on Interviews, above).

Further information

Klain and Chan 2012; On participatory GIS see Raymond et al. 2009, and Brown et al. 2012; McIntyre et al. 2008. This study used survey, focus group, and valued place mapping.

See also http://aboutvalues.net/data/method_navigator/values_method_profile_participatory_mapping.pdf

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PARTICIPATORY RURAL APPRAISAL
RAPID RURAL APPRAISAL
RAPID ETHNOGRAPHIC ASSESSMENT PROCEDURES
(Socio-cultural, Economic, and Biophysical Data Collection and Analysis)

This factsheet discusses three closely related approaches together.

Best used when needing to understand how people/communities interact with the environment in daily life, through work and leisure activities. These "rapid" approaches are designed to produce data and analysis when time is very limited. Participatory rural appraisal (PRA) and rapid rural appraisal (RRA) typically focus on how people/communities, for example, farmers, herders, and pastoralists, manage their activities in agrarian environments. Rapid ethnographic assessment procedures (REAP, or REA) are most often used in health sciences and medical anthropology, but are also used in agriculture, development, heritage, and land-use planning, for example, by the US National Park Service. While PRA and RRA focus on the environmental knowledge and management aspects of human behaviour, REA focuses more on understanding socio-cultural aspects of human behaviour, with the environment being one of many possible subjects of study.

Well suited to identify in socio-cultural terms the practices and places of interest, concern, activity, or ecological knowledge held by individuals. RRA and REA are particularly designed for use when time is very limited for collecting new data.

How it is done

PRA, RRA, and REA combine and triangulate multiple qualitative and quantitative data collection and analysis methods (several are explained in other factsheets in this Compendium). RRA was originally developed as an expert-driven approach but, in practice, has often been very participatory. PRA evolved from RRA to build local capacity through community-driven research, with the "outside" researcher acting as a facilitator and catalyst. All three approaches can include the use of cognitive, observational, phenomenological, historical, ethnographic, and discourse approaches. To use REA in support of ES assessment, methods that make the connection to places should be included, for example, participant mapping, behavioural mapping, and transect walks, as well as interviews with focus groups. Principles of RRA that apply to PRA and REA as well include (1) optimizing trade-offs; (2) offsetting biases; (3) triangulating; (4) learning from and with ES beneficiaries and stakeholders; and (5) learning rapidly and progressively.[283]

How to optimize

Three key optimizing principles for rapid assessment are (1) *observe* (be actively alert and watch for patterns relevant to ES access, land use, and related issues); (2) *converse* (researchers should interact with ES beneficiaries and stakeholders directly to learn views); and (3) *record* (researchers should document *everything* in the process).[284] Begin with a clear intention to address a specific, targeted question. Follow a team-based approach. Interact with ES beneficiaries and stakeholders in a fully participatory way. These methods rely heavily on the knowledge of key informants in the study community, requiring the ES assessment practitioner to identify appropriately expert local sources for participation.

Strengths/advantages

Can be used to gather key information in a short amount of time. "When carefully designed, REA procedures are replicable, and highly useful in practical situations."[285] It is cost efficient (for training and research). All three approaches are inherently interdisciplinary and participatory, which make them well suited to ES analyses and assessment. In optimal conditions, rapid assessment approaches could be used during a scoping stage to inform the design of more comprehensive data collection.

Limitations/disadvantages

Time constraints may make it difficult to identify informed participants and gain acceptance by the community. T|ime constraints may also challenge the research team in terms of planning and collaboration. Rapid assessment methods are not comprehensive. Results may not be representative of an overall population. Triangulation helps to compensate for the limitations of gathering data quickly with limited resources.

283 Adapted from Crawford 1997 (Chapter 8).
284 Adapted from Crawford 1997 (Chapter 8).
285 Medanth 2016.

Resource requirements

- Expertise: Skills in a range of qualitative and quantitative research methods, particularly those listed in the "How it is done" section above. Typically involves multiple researchers.
- Time: Comparatively fast, designed to enable data collection under tight timelines. Depending on the extent and thoroughness of data needed, could generally range from one to six weeks.
- Cost: Potentially low: No special equipment needed. Will involve travel costs to access the study location.
- Access to information: Information gathered from documents, field observation, personal and group interviews, expert interviews, focus groups, transect (site) walks, and so on.

Example

An example of rapid ethnography relevant to environmental management is provided by the US National Park Service at http://www.nps.gov/ethnography/training/elcamino/phase1.htm. The web pages outline the case and use of REA techniques.

Further information

RRA: Chambers 1992; Chambers 1994; Crawford 1997 (FAO) Chapter 8

PRA: Chambers 1994; For a separate factsheet on Participatory Rural Appraisal, see: http://aboutvalues.net/data/method_navigator/values_method_profile_pra.pdf

REA: Low et al. 2005; a summary of the broader uses for REA is available on the Medical Anthropology Wiki from University of South Florida: https://medanth.wikispaces.com/Rapid+Ethnographic+Assessment

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REMOTELY SENSED DATA

Can be used to assess the following ES:

- Soil ES
- Hydrological ES
- Provisioning ES (timber, food)
- Carbon storage and sequestration

Allows users to:

- obtain data remotely when local data are otherwise unavailable;
- assess time-series data for changes in ES or ecological functions over time and space;
- compare locally collected data with a different data source, and use comparison to scale up information; and
- input data into different models requiring this form of data.

Best used when asking

How particular ES are changing broadly across time and space. Remotely sensed data can be used as proxies for some ecological functions and natural capital.

Remote sensing is defined as acquiring information about an object without being in direct physical contact with the object. Remotely sensed information is usually a measurement of the properties of an object through its interference, that is, scattering, reflection, and absorption/emission with electromagnetic radiation as the primary carrier of the information signal. Remote sensing has advantages in that it enables large-scale mapping of some ES (usually through proxies) with relatively low cost. In addition, remote sensing is a useful source of data for areas inaccessible for ground surveying. It provides consistent time-series of data and real-time data for monitoring these ES.

How it is done

In general, the quantification of ES is a two-fold indirect procedure. The remotely sensed information is used as a proxy for some kind of variable (e.g., biomass), which in turn is used as a proxy for the actual ES (e.g., carbon storage). There are two commonly used approaches for deriving biophysical variables like biomass: (1) using the remotely sensed radiation signal with statistical regressions and/or radiative transfer models; and (2) using remote sensing data to generate land-use/land-cover classifications which are subsequently linked to ES and also serve as input layers within biophysical models of ES.

Strengths/advantages

- Data available for every area, often when no other data are available.
- Time-series data available at many different time steps (depending on sensor).
- Data can be inputted into different models, can be mapped.
- Relatively easy to do in a simple way, expertise required for complicated data mining and transformations.

Limitations/disadvantages

- Requires a high level of expertise to use the data well and understand all underlying assumptions.
- Can be used as a close proxy for some ES (e.g., aboveground carbon storage), but generally represents more distant proxies to most ES.
- Should be validated on the ground, which requires fieldwork and associated expertise.
- Relationships between data and ES not always well understood.

Resource requirements

- Expertise: Requires remote sensing expert, experts on specific ES to interpret data and develop equations.
- Time: Low-medium.
- Costs: Often free.
- Access to information: Often freely available, for long time periods.

Example

Pasher et al. 2014.

Further information

Ayanu et al. 2012.

Note: The Ayanu et al. article also includes two tables of commonly used sensors and their key attributes with respect to scale, costs, and availability by remote-sensing type and the application of remotely sourced data relative to different ES. Please note the following updated advice: Landsat MSS: revisit times = 16–18 days; SPOT 4,5/VGT: revisit times = 1 day; SPOT 4/5 VGT is superior to AVHRR for any purpose that relates to vegetation monitoring. AVHRR is a modified atmospheric sensor and does not function in the same way; AVHRR spatial resolution 1.1–4 km. It is not constantly 1.1-km resolution, but varies from the middle to the edge of its swath; SPOT 4,5/VGT is a true 1-km resolution sensor; Landsat is incomplete and should include the new Landsat 8 platform, or data continuity mission. This is probably the most important mesoscale environmental monitoring satellite there is. This sensor is excellent. ETM+ (on Landsat 7) is still up there and still working (in 2015), with a broken scan line corrector, so its mission is not ended as of 2003, just degraded. People still use it; MODIS is usually viewed as a hyperspectral sensor. Revisit times are daily. (*Thanks to Dr. Jeremy Kerr, University of Ottawa, for this information*)

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SCENARIO ANALYSIS

Can be used to assess any ES.

Best used when asking how the future will unfold.

There are many approaches to looking at future change in systems, including scenarios, trend analysis and extrapolation, forecasting, simulation, speculation, and so on. Scenario exercises are seen as being particularly useful for assessing the prospects of future developments within complex and uncertain systems, such as ecosystems and social-ecological systems. Scenarios are defined as plausible and often simplified descriptions of how the future may develop based on a coherent and internally consistent set of assumptions about key driver forces and relationships (MA 2005).

Allows users to:

- explore how a system's ability to provide ES will change and how this will affect people;
- explicitly identify the most important drivers of change;
- identify the most uncertain aspects of ES provisioning (which could then be the focus of further assessment or investigation);
- avoid being caught off guard by changes or future "surprises";
- raise awareness about thresholds and future risks;
- test management or policy strategies against alternative futures; and
- stimulate creative thinking and discussion, as well as engagement in an assessment.

How it is done

There are many different ways to develop scenarios. Chapter 5 of *Ash et al. 2010* provides further resources. Scenario guidance for communities, including entirely qualitative approaches, are available as well.[286]

Generally, there are several steps to follow:

1. Define the scope of the scenario exercise (including time horizons, expert and stakeholder involvement, key issues, spatial scale, qualitative versus quantitative, and how the scenarios will be integrated with other information).
2. Tailor a set of existing scenario steps to the team's particular needs and context:
   a) Identify the key issues or concerns.
   b) Discuss the important drivers and uncertainties.
   c) Select the underlying scenario logics (which involves choosing two critical uncertain drivers and constructing a matrix depicting the two opposing extremes of each uncertainty).
   d) Describe the scenario assumptions and storylines (i.e., how each scenario will play out with ES and beneficiaries. These relationships may be explored qualitatively or quantitatively).
   e) Analyze the scenario implications.

Strengths/advantages

- Flexible approach that can be used to explore any topic and can be either a simple or very complex exercise.
- Can be used to identify critical uncertainties in a system (i.e., the things not known about how ES will continue to be produced and should really be investigated for society's benefit).
- Can be a very productive platform for stakeholder engagement as discussing an uncertain future that no one can claim to understand creates a level playing field for participation.

Limitations/disadvantages

- Requires the ability to convey meaning of process and results in a way that resonates with stakeholders.
- Even though the approach can be very simple, requires confidence to initiate scenario exercises, as often people are unfamiliar with approach and assume that it is more difficult than it is.

Resource requirements

- Expertise: A good facilitator with some experience in scenario building. Quantitative scenarios require experience with modelling and more time to integrate quantitative elements.
- Time: At least several days of work.

Further information

InVEST uses scenarios, see factsheet in this Compendium; Ash et al. 2010.

See also http://www.aboutvalues.net/data/method_navigator/values_method_profile_scenario_development_planning.pdf

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[286] Evans et al. 2006; and Wollenberg et al. 2000

SOLVES – Social Values for Ecosystem Services

Can be used to assess the following social value types using preference surveys:

- Aesthetics
- Economic
- Learning
- Therapeutic
- Recreation
- Future
- Life-sustaining
- Biodiversity
- Historic
- Spiritual
- Cultural
- Intrinsic
- Subsistence

Best used when needing to

Assess and evaluate quantitatively the perceived social values of a landscape, for example, aesthetic, future, recreation, and so on, in a spatially explicit manner. SolVES is useful when comparing social values across a landscape between different stakeholder groups. For example, once two or more distinct stakeholder groups are identified and information collected regarding their preferences for particular social values attributed to specific places on the landscape, maps can be generated and areas identified where social values may differ on the landscape across stakeholder groups. This type of information can be useful in the context of analyzing and negotiating trade-offs between ES and social values. The quantitative 10-point social value index derived by SolVES facilitates trade-off analysis.

SolVES can help answer questions like:

- How can social values of a landscape be quantified?
- What is the spatial distribution of social values of different stakeholder groups across a landscape?
- How do social values of ES differ among stakeholder groups on a landscape?
- How can non-monetary social values be included in trade-off analysis of ES?
- How can different stakeholder perspectives, attitudes, and preferences be taken into account?

How it is done

Conduct a survey of stakeholder values, attitudes, and preferences. Different value typologies may be based on ecosystem values, landscape values, wilderness values, and so on, and should be relevant to the problem context/ project at hand. Download and install SolVES 2.1 (requires ArcGIS 10 or 10.1). A tutorial and user manual can be used to provide instructions on installation and use. Begin by selecting a public use and preference to define a stakeholder group. Data from surveys and environmental layers for the study area are analyzed by the program to map the social value type and to generate statistical models for the final value index. These metrics can then be used to generate a composite report. A separate model (value-transfer mapping model) can be used to generate a value index map with associated environmental metrics using the stakeholder group and social value type selected by the user.

How to optimize

The optimal use of SolVES involves integrating social concerns into ES valuation using primary data on user preferences and attitudes derived from surveys. Data collected aims to relate user preferences and values of different stakeholder groups for ES at specific locations on a landscape. A well-constructed survey tool designed by a social scientist that collects information from relevant stakeholder groups concerning how they use and perceive benefits on the landscape is necessary for input data. A sample survey for the Pike and San Isobel example below is provided on the US Geological Survey (USGS) website (http://solves.cr.usgs.gov/downloads/PSI_Final_Survey.pdf).

Strengths/advantages

The software is freely available to download from the USGS website and is designed to be used with ArcGIS software. Detailed instructions, a tutorial, and comprehensive user manual are available. Quantifying social values across a landscape in a spatially explicit way can produce valuable information that may be directly relevant to management planning.

Limitations/disadvantages

The method requires fairly sophisticated technical capacity with GIS software. Obtaining social value data that are spatially explicit requires primary data collection (e.g., surveys) which entails a large time investment. Availability of a value-transfer mapping model within SolVES can save time if environmental data are not available for the study site, but all of the limitations of transfer methods would apply, including how similar or not the site is to comparable sites from past studies.

Resource requirements

- Expertise: Experience with ArcGIS software.
- Time: Depends largely on availability of data, GIS proficiency, size of study area, and number of variables included in the analysis.
- Cost: Undetermined. SolVES software is freely available on the Internet.

- Access to information: Internet access to publicly available databases.
- Computer and Internet access.
- Software: SolVES 2.1 requires ArcGIS 10 or 10.1 software and the Spatial Analyst extension for working with grid-based data. SolVES 2.1 tool can be downloaded at http://solves.cr.usgs.gov/. Also requires Maxent maximum entropy modelling software (version 3.3.3e), .NET Framework, and Java.

Example

The Pike and San Isabel (PSI) national forest is the third most visited national forest in the US. The Shoshone National Forest (SNF) and Bridger-Teton National Forest (BTNF), adjacent to one another along the eastern and southern boarders of Yellowstone National Park in Wyoming, are in more rural areas than PSI but are experiencing growth in recreation and tourism. Other nearby activities to these parks include livestock grazing, timber harvesting, natural gas development, and agriculture.

Mandatory revisions of the forest plans for these three national forests involved the development and distribution of random mail surveys to the general public in the study site area, with a 34-percent response rate. Data collected from the surveys were then used as input to the SolVES source geodatabase. From this information, value maps of different stakeholder groups were generated for a variety of different activities in each of the three forests (e.g., illustrating spatially the recreation values assigned by stakeholder groups that either favour or oppose wilderness designation of the area). The resulting maps have helped managers to better understand complex relationships on the landscape such as the differences between areas where there is a negative correlation between recreation and wilderness (in the BTNF) and areas where there is no such correlation, which was found to be partly explained by the proximity of the wilderness area to populated centres. The finding is useful in the context of identifying areas in the park where social values are compatible with management status of the area.

Developers: US Geological Survey
Website: http://solves.cr.usgs.gov
Contact: Ben Sherrouse bcsherrouse@usgs.gov

Further information

Sherrouse et al. 2011; Sherrouse et al. 2014; and Van Riper et al. 2012.

See also http://aboutvalues.net/data/method_navigator/values_method_profile_solves.pdf

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STAKEHOLDER ANALYSIS

For a factsheet on this item see:

http://aboutvalues.net/data/method_navigator/values_method_profile_identification_of_stakeholders.pdf

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STATISTICAL ANALYSIS

Can be used to explain the condition and trends of ES, interactions among multiple ES, the production of ES, impact of drivers, and relationship between ES and benefits, among other things.

Best used when asking

Any question that requires some degree of support from available data. There are too many relevant questions and statistical approaches for answering those questions to list here. It is important to find the most appropriate statistical approaches to make sense of the data and it is recommended to consult with statistics experts if the expertise is not available in-house. Most models that are used in ES assessment are mathematical models[287] and the construction of the models is important to understand to interpret the results. It is particularly important to understand uncertainty and assumptions related to the chosen approach, and these should be reflected in the team's results.

Allows users to:

- determine with a degree of probability how things are changing or related to each other; and
- communicate trends and relationships in ES with a degree of power and credibility.

How it is done (this factsheet introduces)[288]

- Reporting means and variability
- Correlation and regression
- ES bundles

Reporting means and variability

The methods used for summarizing data on the condition and trends of ES will depend on the information to be provided. Some of the most common types of information provided in assessments of ES are measures of central tendency (i.e., the mean, median or mode, as appropriate) and measures of variability over space or time (i.e., the range or standard deviation). For any information provided in an assessment, it is important to note the degree of confidence that can be associated with the information. This can take the form of formal statistics (e.g., a confidence interval) for quantitative data or language that conveys uncertainty for qualitative data.

Statistical analysis is often used in ES assessments to summarize and present the average condition of ES in a particular area, at a particular point in time, as well as across time. For example, the average water quality in a lake over a particular summer may be the average value of one or several water-quality indicators collected weekly over that summer. The same type of analysis can be used to find the average value of drivers of change (e.g., mean temperatures for each month) and ES benefits (e.g., mean number of people benefiting from shade trees on a city block each day). An analysis of trends in ES applies the same approach but to multiple points across time. Remember to note down the chosen time period to summarize, how representative it is of the period of interest, and any issues with the data.

While assessments often focus largely on reporting means, reporting variability in ES over space and time is also very relevant. It is often the variability in the production of the service that most affects human well-being rather than the mean availability. For instance, freshwater availability in the driest month of the year, not the average annual freshwater availability, is the critical constraint on agricultural production. Calculating the range or standard deviation around the mean are the most common methods for assessing variability, and these statistics can be analyzed over time to see whether changes in variability have occurred.

Correlation and regression

Analyzing how different variables relate to one another can be very informative, but may require fairly sophisticated statistical techniques. For any information provided in an assessment, it is important to note the degree of confidence that can be associated with the information. This can take the form of formal statistics (e.g., a confidence interval) for quantitative data or language that conveys uncertainty for qualitative data.

Understanding relationships between different ES or between drivers of ecosystem change and ES can be very useful for assessing trade-offs between services or proposed management interventions. Relationships are often best conveyed graphically as biplots. The simplest statistical measure of a relationship between two or more variables is the correlation coefficient. For example, the impact of water contamination on

[287] A mathematical model is simply a description of a system using mathematical concepts and language. Conceptual models can also be very useful in ES assessment, see factsheet on *Conceptual Models* in this Compendium.

[288] Some of the following information comes from Ash et al. 2010.

the incidence of human disease could be estimated by correlating measures of contaminants in water supplies with measures of the incidence of gastrointestinal illnesses in the general population, controlling for other factors that might affect the relationship. Keep in mind, however, that correlation does not provide proof of a causal relationship. Causal relationships, and predicting changes in one variable from a change in another, are typically examined using regression analysis or more complex models, but regression does not prove a link either, although it creates a more plausible case. Regression analyses range from simple linear regression to highly sophisticated models with nonlinear relationships, many predictor variables, time delays, and causal hierarchies. For example, the impact of water quality on illness could also be estimated by using a dose-response function that relates the incidence of illness to the concentration of contaminants to estimate the increase in the probability of illness, then combining that with estimates of the population served by the contaminated water to arrive at a predicted total number of illnesses. Gelman and Hill provide a good coverage of these techniques.[289]

It is often challenging to link trends in drivers of change, ES, and human well-being, because of multiple confounding factors, and because the impacts of ecosystem change on services and human well-being are often subtle. For example, a small increase in food prices resulting from lower yields as a result of land degradation will affect the well-being of many people, even if none starve as a result. Analyses linking these systems components are most easily carried out at a local scale, where the linkages can be most clearly identified. In all cases, reporting levels of uncertainty is important.

ES bundles

A systems approach to understanding and assessing ES implies a need to consider more than single services in isolation. However, gathering information on every single service, the factors likely to influence them, and their impacts on well-being is impractical and unlikely to provide information that is easily interpreted. One way around this is to consider bundles of linked services and related metrics. Bundles may also be defined for specific sites or landscape features. For example, the services provided by a river, such as water for irrigation of agricultural crops, fish production, and hydroelectric power, could be considered as an ES bundle. Any changes to policy that affect the river system could impact on several of these services simultaneously, in turn affecting human well-being. This may then initiate the implementation of new or altered policies for managing the underlying social-ecological system, which again will affect the bundle of services. Analyzing the trade-offs that often exist among services will also require the consideration of multiple services and the interactions between them. For example, construction of a dam might increase water storage for agriculture and improve hydroelectric capacity, but result in reduced fish production further downstream.

The analysis of ES bundles has been approached in several ways. Generally, data for multiple ES should be transformed in such a way to make the numbers comparable (e.g., a maximum value of one might correspond to the maximum value of each service). Principal components analysis and cluster analysis are two statistical approaches to understanding how multiple ES shift together across space or time[290] (see *Figure 2.2* in *Chapter 2* as an illustration of how to communicate this graphically). Other approaches, such as an ES bundle index (EBI) that focuses on a system's potential for supplying ES bundles, are under development.[291] Drawing conceptual diagrams that show how ES within bundles interact may be the most useful approach for understanding bundles until quantitative methods are further developed. Once the conceptual diagrams have been drawn, specific relationships shown in the diagram can be explored further, and models can be developed to explain how bundles are likely to change. This is a relatively new approach to understanding multiple services, and some degree of creativity and context-specificity will be necessary to develop and apply bundle analysis in any given context.

Examples and further resources

Ziter et al. 2013; Statistics Canada 2013; Cimon-Morin et al. 2014.

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[289] Gelman and Hill 2007.
[290] See Raudsepp-Hearne et al. 2010; or Felipe-Lucia 2014.
[291] Van der Biest 2014.

STRUCTURED DECISION-MAKING (Decision-Support Framework/Approach)

Best used when needing a framework, with tools to work through challenging and often value-laden issues, designed to incorporate different kinds of qualitative and quantitative information.

How it is done[292]

Structured decision-making (SDM) follows a series of steps consistent with most decision-support frameworks:

1. Clarifying the decision context.
2. Defining objectives and evaluation criteria.
3. Developing alternatives.
4. Estimating consequences.
5. Evaluating trade-offs.
6. Implementation and monitoring.

To achieve these tasks, SDM uses a pallet of tools, as needed on a case-by-case basis, including, among many others:

- influence diagrams
- value trees
- inference trees
- eliciting expert judgements
- Bayesian networks
- strategy tables; consequence tables
- defined-level scales
- value models

There is a comprehensive guide book and website for SDM that explains all steps and tools.[293] SDM recognizes that decision-making processes involve understanding and integrating information about values and perceptions as well as facts. It considers both "tangible" and "intangible" concerns. When collecting information about possible consequences of alternative decisions, SDM uses multiple sources, for example, scientific knowledge, including expert judgment techniques, local knowledge, Indigenous traditional knowledge, emotions, and trust.

Key insights to guide SDM include:[294]

- separate facts and values
- measure objectives in terms that make sense
- create alternative responses to objectives
- simplify decision elements when possible
- address uncertainty and data gaps
- stay flexible and incorporate what is learned
- involve stakeholders in analysis and dialogue
- recognize value of common sense

> ***SDM is:*** "the collaborative and facilitated application of multiple objective decision making and group deliberation methods to environmental management and public policy problems." It is "an organized, inclusive, and transparent approach to understanding complex problems and generating and evaluating creative alternatives. It's founded on the idea that good decisions are based on an in-depth understanding of both values (what's important) and consequences (what's likely to happen if an alternative is implemented)."
>
> *(Gregory et al. 2012: 6)*

How to optimize

Although it is possible to "self-train" using the guide book and website, SDM requires specific expertise. Hiring a qualified SDM facilitator can be ideal but potentially costly if used on an ongoing basis, so training can be arranged by contacting the experts through the SDM website. Once a team of staff have been trained they can become facilitators within the organization.

Strengths/advantages

The interdisciplinary orientation, accommodation of quantitative and qualitative information, focus on environmental decisions in policy contexts, and practical tools make SDM very compatible with ES assessment for policy and decision-making.

Limitations/disadvantages

The approach is multi-faceted and best used with an expert SDM facilitator, which can be a constraint if time and resources are limited for learning the techniques or contracting out.

[292] Lists reproduced from www.structureddecisionmaking.org and added to from Gregory et al. 2012
[293] Gregory et al. 2012; www.structureddecisionmaking.org
[294] from Gregory 2014.

Resource requirements

- Expertise: SDM is interdisciplinary, drawing on decision sciences, multi-attribute utility theory, psychology, and economics to identify and assess diverse information. Best undertaken by an interdisciplinary team and led by an expert SDM facilitator.
- Time: Varies from days to months or even years depending on the case and methods used for analysis (see Gregory et al. 2012:7 for examples of different time considerations).
- Cost: Case specific.
- Access to information: Information is generated through participatory processes with experts and stakeholders, supported by existing documentation on any relevant issues.

Examples and further Information

Gregory et al. 2012 contains details of method with examples; www.structureddecisionmaking.org walks practitioners through all steps, tools, and applications of SDM; Gregory 2014 is a summary presentation of SDM.

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SURVEY QUESTIONNAIRE (Data Collection Method)

Best used when needing to understand how a human population behaves or views particular issues.

Allows users to gather information from experts or a general population about awareness, behaviour, priorities, values, activities, and knowledge (including ecological and social factors pertaining directly to ecosystem services).

The significant range of possible designs and modes of analysis makes this a flexible method that can be useful in both quantitative and qualitative analyses. Using existing survey data requires clear understanding of the methods used by the original researchers, including their objectives and any limitations.

How it is done

Survey methods are used in many different disciplines and can take many different formats. They can be used to gather fact- and opinion-based information. The common characteristics are that a series of questions are crafted that are designed to elicit information about specific subjects, a population of potential respondents is identified and contacted, the questions are presented, and responses are gathered, analyzed, and reported. A few key points on each step are offered here, and can help in gathering new data or in understanding what existing survey data may represent:

1. **Questions** may be very brief or may be detailed. In some cases, questions may be prefaced by explanatory text; this may be done to try to provide all respondents with a common baseline of awareness prior to answering the question(s). Researchers must avoid inserting their own biases and interpretations into the wording of questions. Questions must be unambiguous and as uncomplicated as possible. Standardization in survey design and elicitation are important to ensure results are comparable and, where relevant, can be aggregated. As with interviews, survey questions can be fully structured such that the respondent is given a limited range of possible answers to choose from; they can be semi-structured with a range of possible answers as well as an option to specify some other option and provide comments; or they can be fully open-ended, eliciting commentary from the respondent. Survey questionnaires may include graphic content such as maps to elicit place-based information, for example, places associated with important activities, or photographs to elicit evaluations such as preferences, for example, for landscape characteristics. The survey instrument (questionnaire) is normally pre-tested on a small population to check for irregularities, inaccuracies or other problems in instrument design, and revised accordingly before full implementation.
2. **Population** of potential respondents (known as a sample) is determined by the purpose for data collection. This includes deciding whether results are required to be statistically representative of a given population geographically, for example, "all Canadians," but could also be from within a clearly defined group based on some other criteria, such as "all members of *x* organization." In many cases, the objective is not representative samples, but to elicit information from "experts" or "locally knowledgeable individuals." A variety of sampling procedures exist, including random selection from postal address or telephone number databases, use of Internet or web panels, and point of access (e.g., visitors to a location such as a provincial park).
3. **Elicitation** of responses may be in print form (on paper), electronic (e.g., via Internet), and verbal (e.g., via telephone or face-to-face). There are well-researched protocols for soliciting participation in surveys—see "Further information" below for sources.
4. **Data analysis** is normally based on an analysis plan, through which the key data points and cross analyses desired from the data are identified. For larger surveys, data are normally processed and analyzed electronically using one of several available software packages. Data tables are typically prepared that summarize responses to each question, particularly for multiple-choice or numerical-format questions. Depending on the information sought from open-ended responses, content analysis software may be used, but it cannot discern nuances of meaning. That can only be achieved by reading or listening to each response or its transcription and most often using grounded-theory methodology to identify themes and meanings in the responses (see "Further information" below for sources on analysis, including grounded theory).

How to optimize

Consideration of the time commitment from respondents is important. Depending on the context, questionnaire design should aim for average completion time of not more than 30 minutes. Starting with questions that are simple to answer can engender comfort in respondents and increase their willingness to finish the survey. Complicated issues should be broken down into multiple questions that can be easily understood. If asking for respondent preferences and priorities regarding policy decisions, it is imperative that all possible steps are taken to ensure respondents are well informed about the issue and the implications of different policy outcomes. It is common practice to include a set of demographic variables in a survey to explore whether these variables influence the knowledge, behaviour, awareness, and opinions of respondents, but it may not always be necessary. Only ask questions that the answers are really needed for. If personal data are needed that respondents may be uncomfortable providing, consider using ranges for variables like age and income rather than specific numbers.

Strengths/advantages

Can be used to elicit information on a very wide range of issues to measure or describe the awareness, knowledge, behaviour or values of individual people about any subject depending on the approach used.

Limitations/disadvantages

Response rates, especially for print/mail surveys, are increasingly low, which can force the cost higher as the number of mailings may easily be five or more times the desired threshold of completed responses. Survey fatigue is increasingly causing contacts to refuse to participate. While fully structured surveys are easiest for respondents to answer and for analysts to process, that format is least able to capture information about understanding, priorities, values and experiences—those are best addressed using open-ended response options, which take more time and skill to analyze.

Resource requirements

- Expertise: Skill in social research methods and, depending on the format and purpose, may require expertise in statistics and economic analysis.
- Time: Larger surveys can take at least a year from start to finish, but smaller (e.g., local-scale) surveys can be designed and implemented in a matter of weeks. The mode of analysis will determine the time requirement for analysis and reporting; grounded methods take longer than computer-based methods.
- Cost: Range depending on scale - a statistically representative high resolution for a large population can cost in the millions of dollars, but small, local surveys may be completed for a few thousand dollars or less.
- Access to information: Survey design need not require data, but accessing existing survey data is possible through agreements (e.g., with Statistics Canada; proprietary research from Social/Opinion Research companies or academics) is typically available post-analysis in summary form.

Example

Surveys can be used to access many different kinds of information, for example, the *2012 Canadian Nature Survey* gathered information about awareness of ES, as well as extensive information about participation rates and monetary expenditures for a large number of nature-based activities. That data can be used to populate indicators for "recreation," and several other cultural ecosystem services.

For examples of choice experiments (contingent choice) and contingent valuation surveys that focus on monetary WTP data collection, see links to factsheets for those methods, above.

Further information

On survey methodology, see Dillman et al. 2008; Statistics Canada 2010; and Bernard 2013. On grounded theory, see Strauss and Corbin 1998. Standard university-level research methods textbooks typically contain chapters on survey methodology.

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TESSA – TOOLKIT FOR ECOSYSTEM SERVICE SITE-BASED ASSESSMENT (Analysis Tool)

Can be used to assess:

- Global climate regulation: carbon storage and carbon sequestration
- Water-related services: flood protection services, water supply services, and water-quality improvement services
- Harvested wild goods
- Cultivated goods
- Nature-based recreation

Best used when needing to

Provide a **rapid assessment** on site, with limited resources, including technical expertise, to inform decisions around land use. The approach helps with identifying who stands to gain or lose from changes in land use. TESSA uses a net benefits framework to compare ES for two states of a site to evaluate the potential impact of decisions. A variety of practical resources are included in the toolkit, including detailed interview guides and step-by-step screen guides for online databases and modelling applications. Decision trees help determine which tools to use in a particular case and general guidance is provided on confidence measures of ES estimates (low, medium or high) using different methods.

TESSA can help answer questions like:

- Which ES should be assessed for the selected site?
- What data are needed to measure the selected ES?
- What methods and sources of data are appropriate to use for the site context?
- How can the assessment results be best communicated for better biodiversity conservation?

How it is done

Request a copy of TESSA at http://tessa.tools/. The rapid appraisal involves first identifying the most relevant communities of people and stakeholders to engage in the process and then actively working with the stakeholders in workshops or other participatory processes. TESSA provides some guidance on considering social differences among groups and how to go about stratifying stakeholders to address important differences in how ES are understood and used by different groups of people. Multiple workshops and meetings with different groups that may be identified in the process of stratifying stakeholders are then used to identify what will change in terms of ES delivery as a result of a management or policy decisions and what the impact of this would be on different groups of people. Following the rapid appraisal and based on the decision context, determine the potential alternative state of the site (i.e., how the site might look and the ES it might supply under a different development scenario) and proceed with selecting appropriate methods for measuring ES. Some sources of data are supplied and advice is provided on data needs and possible sources for each method. Detailed decision-tree graphics and screen shots of online tools help to make the rapid appraisal approach more accessible. TESSA also provides advice on presenting and communicating the results of the rapid appraisal. Planning communication strategies in advance or keeping them in mind throughout the assessment would be useful and can be facilitated by reading this section of the toolkit in advance.

How to optimize

Optimal use of this approach involves using collaborative, multi-disciplinary teams and effectively engaging stakeholders.

Strengths/advantages

The toolkit is readily available from the www.birdlife.org website. Use of the toolkit requires only limited technical capacity and a relatively small investment of time and money to measure ES at a particular site. Detailed instructions on a variety of methods provide options for producing robust scientific information on ES and for comparing services to those at similar sites that have been altered. Emphasis on the implications of decisions is useful in terms of identifying who stands to gain or lose and for more generally appreciating the value of nature and consequences to humans of ecosystem degradation.

Limitations/disadvantages

Results gained through the approach are not rigorous enough to be used in applying payments for ecosystem services (PES) or Reducing Emissions from Deforestation and Forest Degradation (REDD+) projects. A limited set of ES are included in TESSA.

Resource requirements

- Expertise: Basic scientific training to understand sampling methods, statistics, and production of graphs; some training in socio-economic methods if looking at distribution of costs and benefits; computer skills and good level of numeracy.
- Time: Estimated minimum time to complete an assessment using TESSA is two months of staff time. If assessment includes socio-economic issues at the local level with primary data collection, then

substantially more time required.

- Cost: Undetermined (depends largely on the site). Necessary resources include computer with Internet connection, field equipment, and staff.
- Access to information: Internet access to publicly available databases.

Example

TESSA has been tested in at least 24 sites internationally, although none yet in Canada. Publications about cases can be accessed through the project website.

Developers: Anglia Ruskin University, BirdLife International, Cambridge University (Geography and Zoology Departments), Royal Society for the Protection of Birds, Tropical Biology Association and UNEP World Conservation Monitoring Centre.

Contact: TESSAtoolkit@gmail.com

Website: http://www.birdlife.org

Further information

Peh et al. 2013. (But note that a new version of TESSA was launched in Fall 2014.)

See also http://aboutvalues.net/data/method_navigator/values_method_profile_tessa_general.pdf

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TRAVEL COST (Economic Valuation Method)

For a factsheet on this item see: http://www.aboutvalues.net/data/method_navigator/values_method_profile_travel_cost.pdf

Further information

http://www.ecosystemvaluation.org/travel_costs.htm provides an extensive primer on travel cost and most other economic valuation methods in the context of ES.

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TOOLS – TAB 8 – ANSWERS TO FAQS (FREQUENTLY ASKED QUESTIONS)

Contents of Tab 8

Frequently asked questions (FAQs) are inserted in *Chapters 1* and *2* of this Toolkit, and are hyperlinked to their answers here. At the end of each question, the "back to chapter" link takes the user back to the place in the Toolkit where the question was first asked.

Questions from Chapter 1

1. What is the Canadian context for an ES approach?

Academic institutions, environmental non-government organizations (NGOs), and local, provincial, territorial, and federal levels of government are working to develop scientific knowledge and refine the use of methods for socio-cultural and economic evaluation of ecosystem services (ES) benefits, and to raise awareness across Canada of the links that exist between biodiversity, ES, and human well-being.

Canadian academic researchers are actively engaged in scholarly debate and publication in this field, and have contributed to the design and implementation of site-scale assessments as well as to the UN *Millennium Ecosystem Assessment* (MA); co-authored guidance documents about ES assessment for decision-makers[295] and practitioners;[296] and have participated in the establishment of the Intergovernmental Platform on Biodiversity and Ecosystem Services[297] (IPBES) and the development of its work programme and conceptual framework. The National Science and Engineering Research Council of Canada–funded Canadian Network for Aquatic Ecosystem Services,[298] established in 2013, involves over 30 researchers from 11 universities, and will develop tools and knowledge to understand different aquatic ecosystems in support of decision-making.

In Canada, ES considerations are increasingly used to inform land-use decisions, regulatory processes, policy development, and damage assessment and raise public awareness. Comparatively, few Canadian studies to date have described the causal linkages from changes in biodiversity to changes in ES and the implications for human well-being. These linkages are more often approached through separate studies that use different disciplines to understand direct relationships. For example, ecological studies are typically carried out to assess the impacts of changes in biodiversity to ecosystem process and services; and economic benefit transfer or values transfer approach is sometimes used to determine the economic implications of changes in ES. Socio-cultural implications of changes to ES are recently emerging as a priority in the Canadian assessment literature.

Since 2004, numerous analyses of ES values were published in Canada that used an economic "benefit transfer" or "values transfer" approach[299] to estimate monetary values for selected ES. Most of the published ES analyses in Canada were developed as communications tools to demonstrate to the public, business, and governments the practical importance of nature and ecosystems, and to attempt to estimate the economic value of many ES that are not priced commodities (particularly the regulating ES, most of the cultural ES, and the supporting/habitat ES). These reports address a range of environments in Canada, including boreal forest, wetlands, grasslands, and agricultural landscapes.

Some ES analyses conducted in Canada have been completed by governments looking to develop local policies or management strategies to protect ES. For

295 http://www.wri.org/publication/ecosystem-services
296 Ash et al. 2010.
297 http://www.ipbes.net/
298 http://www.cnaes.ca/
299 See *Tools – Tab 10, Canadian ES Assessments and Analyses Reference List* for examples.

example, four NGOs partnered with the provincial government and business in Prince Edward Island to complete a pilot study aimed at reducing agriculture-related issues, including reducing soil erosion, improving water quality, improving/increasing wildlife habitat, and reducing impacts of climate change.[300] The Alternative Land Use Services (ALUS) "payments for ecosystem services" (PES) program[301] that was implemented as a result of the study is reported as being measurably successful in meeting its objectives. It was renewed from 2013 through 2018. Alberta completed an extensive pilot project between 2007 and 2011 to establish practices for assessing wetland-based ES to inform provincial land-use planning and development.[302]

In 2014, the federal, provincial, and territorial governments adopted 2020 Biodiversity Goals and Targets for Canada in response to the Biodiversity Goals and Targets adopted for the UN *Convention on Biological Diversity* (CBD) by all Parties in 2010. Canada's Goal C states that "[b]y 2020, Canadians have adequate and relevant information about biodiversity and ecosystem services to support conservation planning and decision-making." Among the four associated targets is the aspiration that "measures of natural capital related to biodiversity and ecosystem services are developed on a national scale, and progress is made in integrating them into Canada's national statistical system."[303]

Additional collaborative work at the federal-provincial-territorial scale in Canada by the Canadian Council of Ministers of the Environment (CCME) resulted in guidance on economic valuation of water.[304] Collaboration through the Canadian Council of Resources Ministers produced new knowledge through the *Value of Nature to Canadians Study* (VNCS), a broadly interdisciplinary initiative of which this Toolkit is one component, as was the *2012 Canadian Nature Survey*, which collected statistically representative national data about Canadians' awareness of ES and their participation in nature-based activities quantifying the importance of several cultural ecosystem services (CES).[305]

Statistics Canada is an active participant in the development of the UN's System of Environmental-Economic Accounting (SEEA) and Experimental Ecosystem Accounting (EEA)[306] as well as the Wealth Accounting and Valuation of Ecosystem Services (WAVES) partnership led by the World Bank.[307] The *Measuring Ecosystem Goods and Services*[308] (MEGS) initiative among seven federal government departments and agencies between 2011 to 2013 was designed to develop statistical capacity to measure, map, and value natural capital and ES in support of national-scale accounting as well as regulatory analysis. Key outcomes include development of the MEGS geo-database and land-cover analysis. The related EPIC pilot project (*Ecosystem Potential Index for Canada*), developed jointly by Environment and Climate Change Canada and Natural Resources Canada, focused on developing methods for identifying the potential of an ecosystem to produce ES, with the Boreal zone as its subject area. MEGS-related work in Statistics Canada is ongoing. Since 2007, Environment and Climate Change Canada has managed and hosted the subscription-based *Environmental Valuation Reference Inventory* (EVRI)[309] as a resource database for economic valuation using benefit transfer.

The assessment of impacts to ES in socio-economic terms has become a component of evidence in environmental assessments and other regulatory processes since at least 2011.[310] Many environmental assessments to date have not explicitly considered the consequences of lost or degraded cultural ES to human well-being or the values of all ES in socio-cultural terms. Although cultural ES pertain to all people, there is increasing attention to Indigenous peoples' values relating to CES, for example, in the context of development, impact assessment, and environmental damages compensation.[311] Efforts to assess and report on such implications are demonstrated in a report by the Assembly of First Nations and David Suzuki Foundation on the cultural and ecological value of caribou habitat in Canada's northern regions.[312] The authors identify when different economic methods can be appropriate and give examples of their use, and they explain other kinds of methods, such as descriptive

300 Lantz et al. 2009.
301 http://www.gov.pe.ca/growingforward/ALUS2
302 See list of publications from that initiative in *Tools – Tab 10, Canadian ES Assessments and Analyses Reference List*.
303 Federal-Provincial-Territorial Governments of Canada 2014a and 2014b. Available at www.biodivcanada.ca.
304 CCME 2010.
305 http://www.biodivcanada.ca/default.asp?lang=En&n=24D8B61F-1 Products include: Haluza-Delay et al. 2009; DSS 2010; EcoRessources Carbonne 2011; Gislason 2011; Federal-Provincial-Territorial Governments of Canada 2014.
306 European Commission et al. 2013 and http://unstats.un.org/unsd/envaccounting/seea.asp
307 http://www.wavespartnership.org/
308 Statistics Canada 2013. MEGS was led by Statistics Canada with Environment Canada, Department of Fisheries and Oceans, Natural Resources Canada, Agriculture and Agri-Food Canada, Parks Canada, and Policy Horizons Canada.
309 https://www.evri.ca/Global/HomeAnonymous.aspx
310 For example, differences in conceptual approaches taken by Anielski 2012 for Enbridge, and Ruth and Gasper 2011 for Haisla Nation Council in the Environmental Assessment of Northern Gateway Pipeline resulted in very different analyses and outcomes. On ES in EA, see *Chapter 3,* section *3.3.-1*.
311 For example, Gregory and Trousdale 2009; Chan, Guerry et al. 2012. New advice on considerations for ES assessment involving Indigenous communities in Canada was developed for this Toolkit, see *Tools – Tab 3: ES Assessment Involving Indigenous Communities*.
312 Centre for Indigenous Environmental Resources 2013.

and participatory (e.g., ranking, appreciative inquiry, structured decision-making) that can be necessary to understand many socio-cultural values. Among the key messages in this work is that multiple benefits of ES are often obtained through a single activity. For example, subsistence hunting provides far more than the provisioning ES of food and raw materials, it also reinforces cultural identity, maintains language, builds knowledge, supports spiritual experience, and social relations—all of which are cultural ES.[313]

Numerous Canadian researchers are working on a range of issues related to ES in the biophysical and social sciences in several disciplines. This includes work to clarify practical approaches for assessing cultural ES and incorporating them in environmental decision-making.[314] A selection of Canadian examples are listed in *Tools – Tab 10: Canadian ES Assessments and Analyses Reference List* to highlight the use of different analytic methods and the application of ES for different kinds of decisions and uses.

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2. What is the international context for an ES approach?

International efforts to curb biodiversity loss were initiated in 1988 by the United Nations Environment Program (UNEP), resulting in the UN CBD[315] which was opened for signature at the 1992 UN Conference on Environment and Development. Canada was the first industrialized country to sign and ratify the CBD, and hosts its Secretariat in Montreal. Although it does not discuss ES explicitly, the Parties to the CBD adopted the "ecosystem approach" in 1995 to guide their implementation of the Convention. Also, in 1995, Canada's federal, provincial, and territorial governments completed the *Canadian Biodiversity Strategy*,[316] which contains strategic directions on "developing methodologies that permit an improved valuation of biodiversity."

International focus on biodiversity loss and sustainable use of the Earth's resources was the catalyst in 1998 for launching the UN MA[317] as the first global-scale effort to demonstrate the relationships between ES and human well-being, and to document large-scale degradation of ES. The MA makes it clear why this matters—its "findings support, with high certainty, that biodiversity loss and deteriorating ES contribute—directly or indirectly—to worsening health, higher food insecurity, increasing vulnerability, lower material wealth, worsening social relations, and less freedom for choice and action."[318]

Stemming directly from the MA, in 2007 the international community began planning for creation of the IPBES,[319] "a mechanism recognized by both the scientific and policy communities to synthesize, review, assess, and critically evaluate relevant information and knowledge generated worldwide by governments, academia, scientific organizations, non-governmental organizations and Indigenous communities." The IPBES was officially established in 2012.[320] An international expert working group developed an integrated, interdisciplinary conceptual framework for the IPBES which was adopted by member states in 2013. An international *Catalogue of Assessments on Biodiversity and Ecosystem Services*[321] is provided on the IPBES website. The 2014–2018 work program is delivering regional and thematic assessments, and a global assessment on biodiversity and ES.

Also responding to the MA results, the G8 Environment Ministers agreed in 2007 to initiate a global analysis of the economic benefits of biodiversity and costs of its loss. This "Potsdam Initiative"[322] is generally considered the impetus for launching *The Economics of Ecosystems and Biodiversity* (TEEB) to undertake this analysis.[323] As with the MA, TEEB produced some sobering findings about the extent and cost of biodiversity and ES loss based on "business as usual" and highlighted the need for ES assessment to support better decision-making by local communities, business, and national governments. TEEB authors pointed out that economic metrics could be rigorous and appropriate for assessing the significance of some ES, and that methods grounded in other social sciences should also be used to assess the significance of ES.[324]

In October 2010, all 193 Parties to the CBD adopted the new *Strategic Plan for Biodiversity 2011–2020*.[325] Target 1 is that "[b]y 2020, at the latest, people are aware of the

[313] See also Klain et al. 2014.
[314] For example, Chan, Satterfield and Goldstein 2012; Chan, Guerry et al. 2012; Satterfield et al. 2013.
[315] www.cbd.int
[316] http://www.biodivcanada.ca/default.asp?lang=en&n=560ED58E-1
[317] http://www.millenniumassessment.org/en/Index-2.html
[318] MA reports were published between 2003 and 2005. The Sub-Global Assessment Network that developed as a result of the MA remains active: http://www.ecosystemassessments.net/
[319] www.ipbes.net
[320] The Government of Canada is represented on IPBES by Environment and Climate Change Canada. Non-governmental experts, for example, from Canadian universities, may participate in IPBES expert working groups through formal selection processes.
[321] http://catalog.ipbes.net/
[322] http://www.g8.utoronto.ca/environment/env070317-potsdam.htm
[323] Principal TEEB reports were published between 2008 and 2011. TEEB continues to publish thematic guides and regional assessments. The *Cost of Policy Inaction* (COPI, in two volumes: Braat and ten Brink, eds. 2008, and ten Brink et al. 2009) was a key supporting analysis for TEEB.
[324] www.teebweb.org, see also Brondizio, Gatzweiler et al. 2010.
[325] http://www.cbd.int/decision/cop/?id=12268

values of biodiversity and the steps they can take to conserve and use it sustainably." Target 2 states "[b]y 2020, at the latest, biodiversity values have been integrated into national and local development and poverty reduction strategies and planning processes and are being incorporated into national accounting, as appropriate, and reporting systems."

The occasion of the new Strategic Plan adoption was also used to release the final report in the TEEB series and an announcement by the World Bank of an international partnership now known as WAVES.[326] WAVES focuses on developing natural capital accounting at a national scale to enhance existing systems of national accounts and thus support better-informed decision-making. It follows the UN standard on the System of Environmental-Economic Accounting Central Framework and its satellite experimental ecosystem accounting.[327]

The IPBES, TEEB, WAVES, and other international efforts to measure and assess natural capital or, where possible, ES, have all been responses to the MA. Countries have begun completing national ecosystem assessments, with the UK providing the first high-profile example.[328] Following adoption in 2012 of the EU *Biodiversity Strategy to 2020*, the EU committed significant resources and expertise to develop member states' capacity[329] to assess the diverse values of their biodiversity and ES. In 2015, the US President issued a Directive to all federal agencies in that country to consider ES in all planning and decision-making.[330] That Directive is supported by government-academic partnerships that have developed guidance and tools and have completed numerous case studies since 2010.[331]

Recognizing that the objectives of the 1992 Rio Summit and the CBD were far from being met, international organizations sponsored the launch of Future Earth at the 2012 Rio+20 summit to provide "knowledge and support to accelerate our transformations to a sustainable world."[332] Among many other issues, this interdisciplinary scientific initiative includes research on ES. The path forward is interdisciplinary, grounded in ecosystem science with social sciences, economics, and policy.

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3. What are the types of "value" that people attribute to nature that have been identified by researchers?

Approaches to the study of how people value nature build on a multidisciplinary and interdisciplinary foundation by seminal authors from the last 150 years, with a substantial increase in attention beginning in the 1950s. Environmental values typologies have been developed by scholars of human-environment fields in environmental philosophy, psychology, anthropology, land-use planning, conservation, and resource management, among others. These typologies focus on the identification of what is of significance, reflecting *how nature matters* to people in conceptual terms. Classifications of these "environmental values" since the 1980s are summarized in *Table T8.1*. While many of these values types align closely with the CES they apply to all types of ES and should be included as appropriate, using different logically suited methods, when assessing the significance of ES to beneficiaries. Although these typologies list economic values as associated with economic activity, the discipline of economics defines economic values differently, as explained in *Tools – Tab 6: Values and Valuation: Economic and Socio-cultural*. Briefly, from an economic perspective, value is measured by the most that someone is willing to give up in other goods and services to obtain a good, service or state of the world. There are no economic values *per se*, only values that can be expressed in economic (monetary or trade-off) terms.

326 http://www.wavespartnership.org/en
327 http://unstats.un.org/unsd/envaccounting/seea.asp
328 http://uknea.unep-wcmc.org/Home/tabid/38/Default.aspx
329 http://ec.europa.eu/environment/nature/biodiversity/comm2006/2020.htm The EU has funded two major research consortia for this purpose, OpenNESS and OPERAS.
330 Executive Office of the President of the United States 2015. See also the introduction to *Chapter 3* in this Toolkit.
331 See, for example, https://nicholasinstitute.duke.edu/focal-areas/national-ecosystem-services-partnership
332 http://www.futureearth.info/who-we-are and http://www.diversitas-international.org/activities/research/ecoservices

Table T8.1. *Summary of environmental values typologies from expert literature.*[333]

Value Type	Definition
Aesthetic	Sensory experience: beauty, sound, fragrance, views, sense of temporal flow, sense of the sublime; artistic. Beauty in life and landscape; physical appeal and beauty of nature; appreciation of nature from all five senses.
Cultural heritage, history	Bears witness to human history in place; community memory; historical record of human presence; landscapes as visible manifestations of activity and values over time, as archive.
Ecological	Recognizing relationships between ecosystem components that enable ongoing health of ecosystem and its functions—how aspects of nature are valuable to other aspects, not about humans or values that humans attribute to nature; importance of biological diversity.
Economic	Importance of nature for providing resources, income, and employment opportunities.
Embeddedness, interdependence	Humans are nothing without nature; it supports the basis of human society; seeing nature as the greater picture that humans are but a small part of; feeling a sense of community with nature; belonging to something bigger; nature provides a centre or constant; society is nature.
Emotive	Feelings of connectedness, affection, personal relationship with the Earth; wonder, happiness, joy; strong emotional attachment and love for aspects of nature.
Existence	The satisfaction and symbolic importance that come from knowing that it is there even if never seen or made use of.
Human health	Supporting physical and psychological health and well-being, healing and therapeutic.
Human home	Humans are part of nature, nature is home to humanity; belonging.
Identity	Nature links people to their physical setting through myth, legend, or history; certain landscapes have cultural meaning that creates connections between people and place.
Intrinsic[334]	Value inherent in nature in and of itself, not because it serves some human or biological or ecological need.
Irreplaceability	Nature is unique, irreplaceable, cannot be replicated by humans; recognition of nature's complexity and ingenuity.
Learning/scientific	Curiosity; discovery; nature appreciation; learning; education, research; valuing nature as a basis for creative or intellectual thought. The natural environment as a place for learning; experiences in nature increase knowledge and teach understanding, tolerance, and respect; the qualities of nature that enlighten the careful observer with respect to human relationships with the natural environment, and by extension, human relationships with one another, thereby creating respect and understanding.

Continued on next page…

[333] This chart is a combined summary of environmental values typologies developed from research by the following experts (listed alphabetically): Brown and Reed 2000; Callicott 1984; Davies 2001; Kalof and Satterfield 2005; Kellert 1980, 1985, 1993, 1996; Preston 2004; Putney 2003; Rolston and Coufal 1991; Satterfield 2001; Seymour et al. 2008.

[334] For an explanation and discussion of intrinsic values in relation to ecosystems and the major world religions and philosophical paradigms, see *Millennium Ecosystem Assessment: Framework* 2003 chapter 6, pages 140–146.

Value Type	Definition
Lifestyle, quality of life	Affording a valued lifestyle, providing enhanced quality of life. Nature as an integral part of daily life, contributing to a valued quality of life.
Moral, ethical: ecocentric	Obligation to protect for its own sake, for the well-being of all life on earth; obligation to respect and protect nature and other living things; natural rights: all things have a moral right to exist—NATURE-CENTRED.
Moral, ethical: anthropocentric	Obligation to respect and protect nature for its importance to human survival and society, for current and future generations; stewardship, duty to live sustainably—PEOPLE-CENTRED
Recreation: non-consumptive	Physical challenge (e.g., mountaineering); a show to be watched (e.g., bird watching); a place to build skills (e.g., by scouting organizations)—engaging in recreation such as hiking, climbing, canoeing, cycling, and so on, without removing anything permanently.
Recreation: consumptive	Hunting, fishing, or otherwise extracting from nature for recreational purposes.
Sense of place	(Including also place identity; community identity; pride of place) geographically and experientially place-defining; creating a sense of local distinctiveness; contributing to sense of community worth associated with deep sense of pride.
Spiritual/inspirational	Access to the divine, to "God"; metaphysical experience; reverence; affording repose and reflection; nature as a philosophical and religious resource, as inspiration for religious/philosophical/spiritual thought and experience.

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4. Why did the authors choose this ES typology? What about other ES typologies or classification systems?

The ES classification chosen for this Toolkit is based on review of the most prominent classifications, and combines the systems used in the MA and TEEB. The MA explains their reasoning in the following quote, which is consistent with an interdisciplinary approach:[335]

> *It is common practice in economics both to refer to goods and services separately and to include the two concepts under the term services. Although "goods," "services," and "cultural services" are often treated separately for ease of understanding, for the MA we consider all these benefits together as "ecosystem services" because it is sometimes difficult to determine whether a benefit provided by an ecosystem is a "good" or a "service." Also, when people refer to "ecosystem goods and services," cultural values and other intangible benefits are sometimes forgotten.*

This Toolkit combines the MA and TEEB classifications for simplicity and because they are well established and can be applied in a very wide range of uses, including, especially, site- and case-specific decision-making, and generating quantitative and qualitative information through diverse methods, as well as for national statistics. This typology enables evaluation of any type of ES from any perspective: biophysical, socio-cultural or economic. In the case of accounting and some uses of monetary valuation, it is necessary to approach ES with due attention to avoidance of double-counting.[336]

This Toolkit is designed to be flexible so that other classification systems can be used if desired. For example, the Common International Classification of Ecosystem Services[337] (CICES) was developed through the European Environmental Agency in support of the UN Statistical Division's SEEA EEA. Although SEEA is aimed firstly at national-level *accounting*, version 4.3 of CICES can be used in local-scale studies. The FEGS CS (*Final Ecosystem Goods and Services Classification System*) consists of over 350 specific, final ES provided

335 MA 2003: 56.
336 See section *T6.2-6 in Tools – Tab 6: Values and Valuation: Economic and Socio-cultural* for more on double-counting.
337 The most recent version of CICES is version 4.3, dated January 2013.

through 15 environmental subclasses.[338] The FEGS CS system is incorporated into the NESCS, or *National Ecosystem Services Classification System* for the US, which combines final ES (through FEGS CS) with the *North American Industry Classification System* and the *North American Product Classification System*, the "main economic classification systems" in North America used for national accounts.[339] Both CICES and FEGS CS are designed to avoid the challenge of double-counting in monetary valuation for accounting purposes.[340] Avoiding double-counting in these contexts is important, however, both of those classifications are highly detailed and oriented primarily to quantification. The broadly interdisciplinary approach taken in this Toolkit supports monetary- and accounts-focused work as well as analyses of biophysical conditions and changes, and analyses of the full range of social dynamics associated with ES that may require measures or descriptions of all ES, including intermediate ES (that are inputs to final ES), for which a single "total" metric is not the objective of analysis.

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5. Why should we assess multiple ES together?

- ES are rarely, if ever, produced in isolation from each other, so that a change to the source of one service will affect its provision and the provision of multiple other services.
- Likewise, the same individual or group of people will access and depend on multiple ES simultaneously.
- Different individuals and groups will access and depend on different sets, or bundles, of ES at the same time.
- Competing demand for benefits from ES can create inequity, hardship, and conflict and can lead to ecosystem degradation from overuse.[341]

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6. How can integrating the ecological, socio-cultural, and economic value domains affect analysis of trade-offs?

To examine values across the ecological, socio-cultural, and economic domains and test a practical method for integration to support further analysis, researchers assessed 11 ES (from the provisioning, regulating, and cultural categories).[342] They used different methods relevant to the biophysical, socio-cultural, and economic domains of values to generate new data on these different domains. The researchers concluded that commonly used and accepted methods in each domain generated different pictures of the values for each ES, and thus different trade-off outcomes. Among the results were that monetary methods ranked marketed services highest and regulating services lowest. Conversely, respondents directly ranked regulating services highest. Major conclusions were that (1) assessment method(s) used will have a significant impact on the results of trade-off analysis; and (2) the choice of methods is strongly implicated in the results of valuation: they are not neutral. The researchers found that privileging one set of values over another demonstrably creates imbalances. They recommended that a multi-dimensional approach be taken that accepts "multi-metric information about irreducible and incommensurable value dimensions" and that incorporates as much "variety of methods as complexity and value plurality exists in the system" being analysed.[343] Such an approach would increase the likelihood of greater reliability of results and in decisions that are informed by the results.

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7. What are some of the key principles of ES assessment?

- The concept of ES is an anthropocentric construct linking people and ecosystems. While all concepts emerge from human perspectives, ES is oriented to the human-ecosystem relationship.
- ES are a key component of integrated social-ecological systems.
- There are multiple ways of assessing ES.
- Institutions and governance systems can impact ES directly and indirectly.
- Relationships among ES and drivers of change arise from complex systems dynamics.
- Impacts of management practices and decisions can have cumulative effects on ES.
- ES supply and their beneficiaries cross multiple scales.
- Ecosystems can supply multiple benefits to a range of beneficiaries that may have competing needs or interests.
- The credibility and relevance of an ES assessment are maximized through a transparent process and the participation of key stakeholders.

338 Landers and Nahlik 2013. The FEGS CS system also seeks to make the connections between final services and the *beneficiaries* who receive them, identifying 38 subcategories of beneficiaries based on the types of activity through which people would obtain an ES benefit, for example, agricultural, industrial, subsistence, and recreational.
339 Sinha and van Houtven 2013. The purpose of the NESCS is to align measurements of ES with existing accounting systems to support "green accounting."
340 See Ringold et al. 2013; Wallace 2007; Boyd and Banzhaf 2006; Fisher and Turner 2008; and Costanza 2008.
341 For a more detailed explanation and advice, see answer to *FAQ 23*, below.
342 For details of this example, see Martín-López et al. 2014.
343 Martín-López et al. 2014: 227.

- Participatory processes can help with defining the problem and goal through shared learning among parties with potentially competing interests.

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8. Does ES assessment replace other approaches for assessing environmental conditions?

No. An ES approach, and ES assessment, are designed to allow multiple facets of ecosystems and the human dependence on them to be considered together. ES assessment focuses on the specific ways that human life-support, security, and well-being are dependent on the functions of healthy ecosystems, and on how changes in ecosystems affect the provision of ES. It is important, therefore, to note that ES assessments do not replace analyses that focus on ecosystem processes, species health, biodiversity, and other approaches oriented to measurement of nature alone. It draws upon results of such analyses and links them to analysis of ecosystem benefits to people. Understanding these linkages and making decisions based on this knowledge should support long-term sustainability of both ecosystems and human communities.

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9. How might different groups view ES assessment and the use of an ES approach?

ES assessment is a comparatively new (since the 1990s) way of conceptualizing the dynamics of human-environment relationships. Understanding how different groups in society may view ES assessment is important to planning for public involvement and/or communications. Because ES are generated at all spatial scales from global to small site, people depend on and are affected by ES at all scales. In many cases, people are unaware of the ecological processes benefiting them. Individuals and groups will have differing views and experiences of ES.[344]

Indigenous groups. Adoption of ES assessment by Canada's Indigenous communities is varied, just as it is among all other groups in society. Its usefulness in communicating the importance of ecosystems for subsistence and other traditional activities is increasingly recognized, while there is caution and can be rejection about trying to quantify some experiences and the meanings they have for people.

Business. ES assessment is becoming widely adopted by the business sector internationally, including in Canada. Many businesses are recognizing that ES provide benefits to business operations and are also part of their interest through corporate responsibility policies and programs. The Canadian Business and Biodiversity Council,[345] Network for Business Sustainability,[346] and Canadian Business for Social Responsibility network[347] are examples of Canadian organizations of businesses that want to show leadership in this area. Internationally, there are numerous guidance documents for the business sector on how to adopt an ES approach.[348]

General public. Results of the *2012 Canadian Nature Survey* indicate that over 90 percent of Canadian adults are aware of many ways that nature provides essential services and can identify what many of those services are, while nationally 69 percent had heard of the term "ecosystem services."[349] Research conducted for The Nature Conservancy in the US found that the public preferred the term "nature's benefits" over terms such as "ecosystem services" and "natural capital" typically used by experts and managers. Their study[350] also found that:

- 73 percent see it as "helpful" to calculate the benefits of nature in dollar terms;
- 84 percent see evaluating the benefits of nature through the number of jobs created as "helpful";
- 87 percent see evaluating the benefits of nature through the number of people who benefit as "helpful"; and
- 92 percent see evaluating the benefits of nature through the additional clean air and water that a natural area provides as "helpful."

Non-government organizations. Ducks Unlimited Canada, International Institute for Sustainable Development, David Suzuki Foundation, and some other Canadian NGOs have been actively supporting research and encouraging recognition of ES in planning and decision-making for more than a decade because they view it as a productive way of raising awareness of the importance of nature, or "natural capital," as an often overlooked aspect of decision-making.[351]

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344 See Hein et al. 2006 on ecological scale, ES, and stakeholders; see also definition for *Beneficiaries* in *Tools – Tab 9: Glossary.*
345 http://www.businessbiodiversity.ca/
346 http://nbs.net/about/
347 BSR 2013.
348 For example, Stephenson 2012 (OECD); Hanson et al. 2012 (WRI).
349 Federal-Provincial-Territorial Governments of Canada 2014b.
350 Metz and Weigel 2010.
351 http://www.ducks.ca/our-work/science/, http://www.iisd.org/topic/natural-and-social-capital http://www.davidsuzuki.org/search/?q=ecosystem+services&x=16&y=12

10. What are the main challenges to an ES approach?

ES assessment and an ES approach can be extremely useful and productive, and knowledge and resources are increasingly abundant in this interdisciplinary field. It is understandable that managers at all levels of authority ask whether there are limitations, potential risks or challenges associated with an approach that they may not be familiar with. The list below is based on the expert literature and should be understood as providing transparency about possible challenges—a form of due diligence. Many of the items here apply to other commonly used approaches as well.[352]

- Because the concept of ES focuses on the benefits from nature that people receive and rely upon, it is logically only applicable in contexts where people are present, may become present or benefit from a distance. This can result in greater emphasis and higher values being estimated for ES in more heavily populated areas where a greater number of people depend on the ES being provided by the local/regional ecosystems.
  - The concept and assessment of ES is not intended to displace other reasons for managing and protecting ecological integrity, such as the intrinsic value of species or ethical beliefs about human responsibilities toward nature. Knowing the ES profile of a wetland parcel, for example, *adds* to the information available for making ecosystem management decisions without detracting from any other scientific, economic or moral basis for decision-making.
- *Over*emphasizing a utilitarian view of nature may lead people to undervalue aspects of nature that are not directly benefiting them.[353]
  - A balanced approach in planning and decision-making and communicating the purpose of an ES approach as grounded in sustainability principles can contribute to avoiding this potential problem.
- Optimizing one ES may occur at the expense of one or more other ES.[354]
  - This can be partly avoided by optimizing for bundles of ES simultaneously. Advice on how to do this is provided through several steps in *Chapter 2*, including through the use of worksheets in *Tools – Tab 4: Worksheets for Completing ES Assessment.*
- Different groups in society have unequal access to ES, and unequal control over how they are managed. When ES assessment is initiated it is important to consider "who makes the choices regarding use; which values are included or highlighted and which are excluded or obscured; and who is impacted (positively or negatively) by choices regarding ecosystem service use."[355] Related questions are "who bears the cost?" and "who benefits?" Disadvantaged people (whether poor, undereducated, or by other means) often have greatest need and the least control over decisions affecting the flow of ES.
  - Recognizing the diversity of ES beneficiaries in any decision scenario is key to equitable outcomes. Using the *ES Priority Screening Tool (Worksheets 2* and *3* in *Tools – Tab 4: Worksheets for Completing ES Assessment)* can help to identify the breadth of beneficiary groups and associated potential issues. Engaging ES beneficiaries and other stakeholders in ES assessment from the outset is widely recommended.
- Ecosystem science has made major advances over the last several decades, however, ecosystems are so complex that science does not have a full understanding of how all of the parts of an ecosystem interact, and how changes in one component or process will affect all others across the system.
  - Primary data collection in ecosystem science is time consuming and potentially costly, and analysts often have to rely heavily on proxy data sets that have generally not been developed for use within an ES framework.
  - Models are designed to generalize as a way to reduce costs of primary data collection, but they can have important limitations such as their adaptability to unique case study sites. The limitations of these models and existing data sets will limit the reliability of analysis based on them.
  - In some cases, there may not be a reasonable proxy or a relevant predictive model to use.
- Socio-cultural values are also highly complex, and are often specific to a place and to individuals and groups.
  - Socio-cultural values are not inherently quantifiable, although methods have been developed to enable prioritization and ranking in some cases.[356] The drawback is that such methods can sometimes abstract away from the essence of what matters to people. As with all methods, their use should acknowledge both what they offer to decision-making and what is not captured.
  - Qualitative accounts of socio-cultural values provide greater precision than ranking or

[352] See also Kettunen and ten Brink 2013: 25-28; Sukhdev et al. 2014.
[353] Cimon-Morin et al. 2013; Delière 2014.
[354] See also Ingram et al. 2012 for consideration of benefits and challenges of adopting an ES approach.
[355] Jax et al. 2013.
[356] For example, SAB/EPA 2009; Fish et al. 2011b; Allen et al. 2009; Chan, Satterfield and Goldstein 2012; Gregory and Trousdale 2009; Stagl 2007; Satterfield et al. 2013.

scoring, and can capture important complexity. Social sciences have methods for measuring and describing human behaviours, attitudes, values, and beliefs. Some of these can be time consuming and potentially costly depending on the scale of analysis.
    - "Rapid appraisal" methods developed by sociologists and planners in response to these time and resource challenges can produce meaningful results for decision-making. These should still be understood as less thorough or accurate than what in-depth methods provide (see *Tools – Tab 7: Compendium of Data Sources, Analysis Methods, and Tools* for factsheets on rapid appraisal methods).
- Economic values are also very complex, and new data collection, as in ecosystem science and the other social sciences, can be time consuming and costly.
    - Economists have developed a variety of methods, including several cost-based approaches for assessing economic values associated with market and non-market ES in monetary terms to give weight to these values in decision-support.
    - Benefit transfer is a technique that allows analysts to use economic values assessed in one case to be adapted for another case. It can be thought of as a type of modelling and, as a result, it has many of the same limitations as ecological modelling, noted above.
    - Using dollar estimates to represent the importance of nature to people—particularly socio-cultural values that are based in experiences, relationships, and beliefs—has been contested by experts in several disciplines, and by many Indigenous groups and others in the general public.[357] Among the reasons given are microeconomic theory's focus on rational utility to the individual, which some experts consider logically inconsistent with such values. Many communities and individuals feel that it is disrespectful to attach monetary values to other living beings and to the Earth.
- There is expert and public concern that associating monetary values with the ES that are not normally priced in market economies may result in further degradation of ecosystems and inequity through the commodification of nature rather than ensuring decisions that support sustainability.[358]
    - In response to this concern, the leader of the G8-mandated TEEB initiative, banker Pavan Sukhdev, explains that "there is always the risk that misguided decision-makers or exploitative interests" may wish to use monetary valuation results for "wrong ends." He advises that it is "ethically valid if the purpose of that exercise is, *first and foremost, to demonstrate value in order to instigate change of behaviour, and to inform and alert decision-makers to damaging trade-offs based on the implicit valuations that are involved in causing the loss of biodiversity and degradation of ecosystems*."[359]

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Questions from Chapter 2

11. Why should we complete a priority screening to identify the ES to be assessed, rather than just focusing on the ones we think we are interested in?

Although it may seem desirable at the outset to simplify an assessment by focusing on a predetermined ES or specific set of ES, it is essential to consider the following four factors, and to work through the screening process in the *ES Priority Screening Tool (Worksheets 2* and *3* in *Tools – Tab 4: Worksheets for Completing ES Assessment)* to identify the actual high-priority ES:

- ES are rarely, if ever, produced in isolation from each other, so that a change to the source of one ES will affect its provision and the provision of multiple other ES;
- an individual or group of people will access and depend on benefits from multiple ES simultaneously;
- different individuals and groups will access and depend on different sets, or bundles, of ES at the same time;
- competing demand for benefits from ES can create inequity, hardship, and conflict and can lead to ecosystem degradation from overuse; and
- management and decisions focused on single benefits from nature, or single aspects of nature's processes have led to many lose-lose or win-lose trade-offs that diminish sustainability. Assessing related "bundles" of ES is more likely to result in equitable and positive options for decision-making.[360]

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357 For example, Church et al. 2011; Lele et al. 2013; Maxwell et al. 2011; Purushothaman et al. 2013; Gómez-Baggethun and Ruiz-Pérez 2012; Parks and Gowdy 2013; Haines-Young and Potschin 2009; McCauley 2006; Baveye et al. 2013; Aldred 2006; Spangenberg and Settele 2010; Tisdell 2011. See also Sukhdev et al. 2014.

358 See TEEB 2013; Schröter et al. 2014; Purushothaman et al. 2013; Salles 2011; Luck et al. 2012a; Gómez-Baggethun and Ruiz-Pérez 2011.

359 Sukhdev 2010; TEEB 2013; and see Sukhdev et al. 2014. In the context of economic trade-off analysis, it is sometimes argued that not attaching any values to ES implies a trade-off value of zero, which overlooks the often considerable importance of these services.

360 On ES bundles, see *Tools – Tab 9: Glossary*, and *Step 4* in *Chapter 2.*

12. Do cultural ecosystem services apply to all people, or only to Indigenous people and communities with distinctive ethnic or cultural identities?

CES apply to all people, of all cultures, in all parts of the world. See *Tools – Tab 3* for specific advice about assessing ES in the context of Indigenous communities.

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13. How are "cultural ecosystem services" different from "cultural values"? What steps can we take to include them in assessment?

For a full explanation, please see section *T6.1-3* in *Tools – Tab 6: Values and Valuation: Economic and Socio-cultural*.

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14. How do we know whether specific ES are actually benefiting different groups of people?

Establishing the link between an ecological resource (or ES) and human benefits from it entails sketching out a causal pathway between them. *Worksheet 2* prompts discussion in detail on how different beneficiaries may benefit from ES, including how their demand and access to ES may differ. At this stage (before any actual measurement has occurred), concrete evidence of links between ES and benefits to people is not required; links that are proposed can be investigated further during the assessment.

ES support human well-being through multiple pathways, and this is best captured by identifying specific benefits from ES to specific people or groups of people. Linking an ES to a benefit may involve several steps, especially if the ES in question is a supporting or regulating ES. Quantifying the key elements in this pathway is the next step, and will rely on using appropriate indicators at each step of the pathway. The indicators may be derived from observations, from models or (most likely) from some combination of both.

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15. Why is stakeholder involvement useful and important in ES assessment?

According to the Canadian Environmental Assessment Agency guide on public participation,[361] there are several tangible ways that stakeholder involvement can help in EA processes, and these are equally relevant in ES assessment:

- make better informed, better quality decisions;
- obtain valuable information about the environment and potential impacts;
- enhance understanding of the public's interests, concerns, and priorities;
- create a positive foundation for working with interested parties to build trust, resolve problems, make informed decisions, and reach common goals;
- increase communication, transparency, and accountability with the public;
- avoid or minimize adverse environmental effects;
- meet (departmental or agency guidelines or legislative obligations) for meaningful public participation;
- address public concerns early in the process, thereby reducing risk of conflicts, costly delays, stoppages, litigation, and so on;
- correct misinformation or rumours about proposed projects; and
- align the project design with public priorities and expectations before significant resources have been invested in detailed project planning.

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TIP: **The link between ES and "human well-being" is theoretically well established, but hard to demonstrate in assessments. It is difficult to separate other factors from the contributions of ES to human well-being, just as it is difficult to link single drivers of change to impacts on ES. This is not a problem unique to ES work, but an intrinsic feature of impact analysis in complex systems. (See FAQ 33 for more on this.)**

361 https://www.ceaa-acee.gc.ca/default.asp?lang=En&n=46425CAF-1

16. What do we need to consider when identifying resource requirements?

It is impossible to provide guidelines on how much time or funding to allocate to an ES assessment, as each will be very different, but the following points may be relevant to planning ES work:

- The larger the team, the more time will be required for learning and capacity-building related to ES concepts. For a full-scale assessment, set aside at least a month for the design stage. It may be most efficient to decide upon an approach as a smaller group before involving a larger team.
- Because a technical assessment is by definition based on existing data, avoid original research if possible, but set aside ample time for fieldwork or participatory approaches if they are required.
- Even with a small budget, an ES assessment can be carried out involving existing data and literature reviews.
- Set aside enough time to understand the ES assessment results and their implications. While the quantitative or qualitative analysis of ES may seem like the focus of the assessment, there needs to be time after this stage to analyze trade-offs among ES and beneficiaries or otherwise interpret the results in a manner that answers the specific questions guiding the team's effort. The assessment does not end after the initial analysis of individual ES.
- To produce credible, relevant information, set aside enough time to conduct a review process. Engaging the most relevant reviewers (subject-matter experts and decision-makers) early in the process can help secure their later participation.
- Funding may be required to hire additional experts to participate in assessment. The inclusion of consultants or outside experts will require time for capacity-building as well as the actual work.
- ES tools and approaches are being developed at a rapid rate and increasingly more efficient and credible tools will become available in the coming years. While approaches are still in the early stages of development, planning and execution of ES assessments may take more time than expected.

It will be helpful for the lead team to return and revise their initial estimates after completing a first draft of the detailed *Assessment Plan (Worksheet 6)*. The screening process *(Worksheet 2)* will have given a strong sense of which ES to assess, what the issues are, and what types of expertise will be needed.

The initial steps in *Chapter 2* can help to refine the team's sense of available information and should help to further clarify resource needs to complete the assessment. Key questions to answer at that time will include:

- For the purposes of the situation, will the assessment require very precise information?
- Will the team require highly detailed results?
- Are there local interests and knowledge that need to be accessed, in addition to existing data from published sources and databases?
- Does the time frame and budget allow for original research?

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17. What exactly does an advisory group do? Is it the same as a steering committee?

An advisory group plays an important role in the governance of an assessment. A governance structure, which includes the organization of the teams, how they interact, and how decisions are made, is important for ensuring the relevance and credibility of the assessment process and findings. The advisory group can range from being solely advisory (decisions are still made by the lead team), to having final decision-making responsibility (with the lead team and technical team executing the decisions). Because the advisory group can include stakeholders as well as experts, its role can be political as well as technical, and it can be involved in outreach and communication of results. An advisory group and governance structure that encourage iterative communication between scientific experts, decision-makers, and other stakeholders are likely to increase the transparency of the process, and therefore enhance the credibility and relevance of the assessment to all groups.

See Chapter 2 of Ash et al. 2010 for help with more technical aspects of this task.

EXAMPLE: Terms of Reference for Alberta Wetland ES Pilot Advisory Group

The key purpose of the Steering Committee was to ensure that the project outcome was accomplished and to provide oversight to project process and deliverables to that end. Committee member responsibilities included:

- providing guidance and advice to key stages of project setup, approach and delivery;
- confirming the need for the ES approach;
- confirming key questions framing the approach;
- contributing knowledge to the approach and assessments;
- contributing information and advice about ecological, social or economic systems from their area of expertise;
- approval of the project plan, including milestones and deliverables;
- reviewing and approving of draft and final materials and major deliverables; and
- ensuring that the project is credible, legitimate, and relevant to the decision-makers' needs.

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18. What are key considerations for establishing a technical expert team?

The choice of technical team members should be based on their **specific expertise**, and occur after choosing the ES that will be the focus of the assessment (after at least the first pass through the *Screening Tool (Worksheets 2* and *3)* identifies the highest-priority ES in the case). Assembling a team of technical experts is likely to be an iterative process. A project manager is indispensable for organizing the work of the team, and for planning the integration of information across disciplines. Ideally this should be someone familiar with working across disciplines to answer complex questions.

The specific expertise needed for the assessment will not be known until the ES to be assessed are identified. This is because relevant expertise for answering questions about specific ES is required. For example, if ES related to water are the focus of assessment, a hydrologist will be needed to lead the assessment of those ES. This may be further refined to, for example, a hydrologist with expertise in remote sensing of wetlands at a later stage. People who are familiar with what data are available will also be invaluable. Experts are also needed who know the study context well, to help to identify and describe important stakeholder groups and their priorities. If none of the technical team members are familiar with ES concepts, a period of learning and capacity-building will be required at the start of the assessment to build a common understanding of approaches to be taken. *Chapter 1* and *Step 1c* in *Chapter 2* provide key resources to do this.

The organization of the technical team must promote interdisciplinary thinking and problem-solving. It is more effective to organize the assessment team following a problem-oriented approach (i.e., organize the team around specific questions) than to have separate teams tackling the biophysical questions, the social questions, and the economic questions. One of the problems introduced by having different types of experts working separately on various questions is that they are bound to take different approaches, which may not be compatible or easy to integrate.

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19. What types of expertise should we be aware of and consider seeking to complete an ES assessment?

The possible breadth of expertise that can be valuable in completing an ES assessment is considerable, spanning the environmental and social sciences and economics. It is unrealistic to expect that an individual "natural scientist" or a "social scientist" would have the expertise of every field within those two very broad areas. The list below is not comprehensive. In most cases only a few of these would be necessary for an ES assessment—the selection should be based on specific needs identified through completion of *Worksheets 1, 2,* and *3*.

- Agronomy
- Anthropology (cultural, social)
- Archaeology
- Botany
- Business, economic development
- Chemistry
- Climatology
- Ecology (e.g., rangeland, forest, marine, urban)
- Economics (e.g., ecological, environmental, resource)
- Entomology
- Environmental engineering
- Environmental resource management
- Fisheries biology
- Forestry
- Geography (social, cultural, physical)
- Geology
- GIS, remote sensing
- Health sciences (human)
- History
- Human ecology
- Hydrogeology
- Hydrology
- Industrial engineering
- Land-use planning
- Marine biology
- Oceanography
- Political science, public policy
- Psychology (social, environmental)
- Sociology
- Tourism, leisure and recreation
- Wildlife biology (potentially by species)
- Soil science
- Toxicology
- Zoology

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20. When do we assign assessment tasks to the various experts on the assessment team?

An interdisciplinary team should work together to build an assessment plan before starting to assess ES. It is best not to assign separate tasks among experts from different disciplines until the purpose of the assessment has been identified clearly and a general approach and plan for assessing the prioritized ES have been developed together. The interdisciplinary team should work together to complete the worksheets (especially *Worksheets 2* through *8*).

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21. We've heard about the importance of maintaining relevance, credibility, and legitimacy in carrying out an ES assessment. How do we achieve these objectives? Is there a checklist of best practices?

Relevance refers to the significance of assessment information in relation to decision-making issues or priorities.

– *the information gathered and analyzed pertains to the specific issues and questions at hand*

Credibility refers to whether the assessment meets standards of scientific rigor and technical adequacy.

– *the procedures and outcomes of the assessment are robust and analytically sound*

Legitimacy refers to whether the assessment process is perceived as unbiased.[362]

– *the process is transparent, inclusive, and objective, and thus is accepted by stakeholders and observers*

More specifically:

- Use an agreed-upon conceptual framework to guide the overall work (see *Chapter 1*).
- Have the right skills and competencies involved. The assessment of each ES should be led by an individual or team with expertise in the specific science of that ES. Develop an interdisciplinary team to conduct the work. The use of relevant expertise and expert information is essential and involves both technical/professional experts and holders of local environmental knowledge. Diverse stakeholders have particular and unique knowledge about the social, economic, and ecological components of the systems in which they live and work, as well as about their own values and sense of well-being. Because the links between ES, benefits, and values are complex, contextual knowledge is important for understanding these relationships. *Tools – Tab 7: Compendium of Data Sources, Analysis Methods, and Tools* presents numerous tools for developing and assessing ES information using participatory approaches.
- Engage diverse stakeholders to identify issues and values, encourage equity, and reduce or avoid conflict.

  A participatory process involves having different stakeholders engaged in an interactive process that promotes knowledge and information exchange and allows them to express their positions and interests on issues and learn from each other. Stakeholders include the "client" or users of the assessment, including decision-makers, managers, and analysts, as well as individuals implicated in the decision such as the ES beneficiaries in the potentially affected area. Ensure that disadvantaged and less organized or less vocal groups are not overlooked.[363] For smaller assessments, stakeholder participation may involve the participation of key stakeholder representatives or a review process to check information with decision-makers and other stakeholders.
- Develop a consistent and efficient method to fill information gaps, identify where gaps remain, and clarify the consequences of those gaps.
- Uncertainty is a continuous part of ecology and ES assessments and must be dealt with in a transparent and consistent way.[364]

TIP: **The reason it is important to look at multiple ES simultaneously is that managing single resources is what we have always done in the past and it has, at times, led to unacceptable trade-offs with other resources that we also rely on. We can achieve greater success and more benefits from the land by aligning how multiple ES are managed. Considering multiple ES can contribute to ensuring that multiple trade-offs are characterized and accounted for.**

[362] For more on this topic, see Ash et al. 2010, and above sections about establishing a stakeholder group and technical team. Some additional considerations are noted in Statistics Canada's quality guidelines http://www.statcan.gc.ca/pub/12-539-x/2009001/introduction-eng.htm although these do not *all* apply to ES assessment.

[363] Most government agencies have guidance documents on stakeholder participation and include how to identify stakeholders. The Canadian Environmental Assessment Agency 2008 is a detailed guide on "meaningful public participation" in environmental assessment, most of which can easily be adapted for use in other environment-related situations.

[364] For advice regarding representing uncertainty, see *Issue 7* in *Tools – Tab 2: Cross-cutting Issues and Key Considerations.*

- Act even without complete data. Complete data for ES assessment are rarely available. Data available to understand the condition and trends of ES might refer to natural assets on the landscape, ecological functions, the actual services provided to humans, or the benefits that people get from ES. Indicators for any of these system components may be useful for understanding ES.
- Make the link to human well-being. In ES assessment it is important to determine what aspects of ecosystems are relevant to human beneficiaries. For example, the amount of water stored on a landscape may be less relevant than the amount of water stored that is accessible to people. For this reason, the choice of indicators is context-dependent.
- Understand the link between drivers of change and impacts from change first (compiling necessary supporting material for changes in ES), and then tailor the assessment. A scientific assessment of drivers of change (i.e., factors such as demographic or political change that are responsible for changes in land use or land management) is important for understanding the most pressing issues that may affect ES and human well-being.

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22. Why should we be trying to understand multiple ES and how different ES interact with each other?

Landscapes produce multiple ES, and most of these ES are connected to each other in some way. In some cases, the same ecosystem components can contribute to multiple ES, for example, when a row of trees along a river stops nutrients from polluting the water and also provides a windbreak for nearby houses. In other cases, the ES interact in some way, for example, when corn yields are increased through the addition of nutrients to a field, but some of the nutrients run off into nearby waterways and cause a decrease in water quality. The increase in corn yields versus the decrease in water quality is what is termed a "trade-off." It is important to try to understand how multiple ES interact to manage them simultaneously, encouraging positive synergies, and minimizing negative trade-offs.

In *Chapter 2, Step 4*, the different ways to analyze interactions among multiple ES are introduced, but **considering how multiple ES may be linked is important right from the beginning**. *Question 4* in *Worksheet 4* asks whether there are known interactions among the prioritized ES or other ES. It may be useful to draw a "connectivity diagram" (such as *Figure T8.1*) to see whether there are multiple connections among ES and how they might follow through to even more ES. In this way, the team can see and discuss the possible complexities in the system that might provide opportunities for managing multiple ES, or identify connections that need to be taken into consideration during management to minimize trade-offs. The *Cascade Tool (Worksheet 5)* can also be used to compare how different ES may be connected, by comparing the natural capital, functions, and benefits associated with each ES. If the same natural capital is needed to produce multiple ES, there is potential for synergistic management of those ES and the relationship may warrant further investigation.

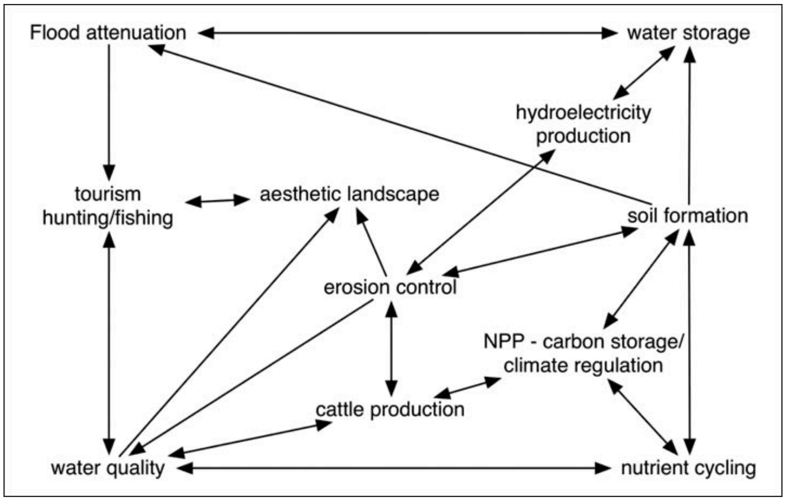

Figure T8.1. Example of a connectivity diagram. These ES are hypothesized to interact in the manner described by the single direction and double direction arrows. These interactions, based on the assessment team's hypotheses, can help the team to start thinking about how multiple ES may need to be understood and managed to improve benefits for people.

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23. How does the Cascade Tool (Worksheet 5) build common understanding of what needs to be measured or evaluated?

The flexibility of the ES concept may lead to confusion when assessors are trying to decide what needs to be measured in an ES assessment. Focusing on the cascade of system components (e.g., natural capital, functions, services and benefits—see *Conceptual and Analytical Framework* in *Chapter 1*) allows everyone to place their interpretations of what ES are into a common framework. A group exercise that identifies how systems produce functions, services, and benefits can lead to a clearer understanding of the whole concept and its flexibility, and steer discussion towards the practical next step of choosing indicators that are relevant to the problem context and for which data are available. When there is a clear understanding of how natural capital produces ES, and how ES produce benefits for people, it is easier to develop an approach for using the available tools and data to answer the specific assessment questions. This is part of following a problem-oriented process.

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24. How does biodiversity fit into Worksheets 4 and 5 (and more generally into ES assessment)?

Biodiversity can be assessed either as an element of natural capital or as a proxy for a particular ES. Biodiversity assessment is not always a component of an ES assessment. However, depending on the goal of the assessment and which decisions are being supported, information about biodiversity may be important to include. An additional question to ask in the planning stage of the assessment is, will biodiversity information contribute to a better decision in relation to the focal issue of the assessment?

Biodiversity could be considered a characteristic of natural capital that underlies the provision of some ES. The degree of concordance between ES and biodiversity on a landscape depends on complex (and, at present, little-understood) interactions between biodiversity and ES. Many ES may be unaffected by small losses of biodiversity, but they may deteriorate rapidly when, for instance, most of the elements of a functional group[365] are gone. The coincidence of biodiversity and ES management strategies is likely to increase as:

- an increasing number of services are considered;
- functional redundancy is valued as a buffer against random natural events (such as drought) and ongoing anthropogenic change; and
- the relative weight placed on biodiversity-intensive ES increases.[366]

Biodiversity could also be considered as a proxy for certain ES. In these cases, the aspects of biodiversity—and therefore the indicators chosen to represent biodiversity—should be as relevant as possible to the ES in question.

Mutually beneficial relationships exist between biodiversity and many ES that depend on a stock of natural capital. Management actions to conserve ecosystem processes that promote regulating, supporting, and cultural types of ES are often also good for biodiversity conservation. Many authors have highlighted the potential for trade-offs between biodiversity and ES. Most examples of win-lose interventions involve repercussions to biodiversity from increasing the supply of provisioning services. Examples include damming a river to improve the consistency of a water supply, replacing natural forests with crop cover or using pesticides to increase food production.[367]

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25. We are having a hard time identifying how each ES is produced and what contributes to its production. Are there resources available to help us answer all the questions in the worksheets?

If the assessment team is finding it challenging to identify how ES are produced, a good place to start is the Conditions and Trends Volume of the UN MA, which has a separate chapter for many important ES and describes many aspects of their production (http://www.unep.org/maweb/en/Condition.aspx). Two other solutions might be to consult an expert for help or to conduct a literature review. There is a large body of literature focused on ES and many reference documents that can help to identify what parts of an ecosystem contribute to ES production.

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[365] Functional groups are aggregated groups of species that share an important ecological characteristic and play an equivalent role in the community (e.g., species that disperse large seeds within one patch of forest). See *Tools – Tab 9: Glossary* for a clear definition of biodiversity with a statement on the relationship between biodiversity and ES. See also *Issue 6* on compatibilities and trade-offs between biodiversity and ES in *Tools – Tab 2: Cross-cutting Issues and Key Considerations*.

[366] Balvanera et al. 2013.

[367] Reyers et al. 2012.

26. How can we take into account in our assessment the cumulative effects of multiple drivers of change acting in combination on ecosystems and ES?

Concerns are often raised about the long-term changes that may occur as a result of the combined effects of multiple and successive drivers acting on the environment or specifically on ES production. Cumulative effects assessment (CEA)[368] is conducted to ensure the incremental effects resulting from the combined influences of various drivers are assessed. These incremental effects may be significant even when the effects of each driver, when independently assessed, are considered insignificant. Taking into account cumulative effects means paying particular attention to multiple drivers acting on the system component of interest. For each ES (or type of natural capital), all the drivers of change are listed that have occurred, exist now or may occur in the future. Some of these actions may be outside the study area if their influence extends for considerable distances and length of time. The total additive effect of all drivers and proposed actions are assessed, and this effect is compared to any thresholds, policies or implications for ES. The analysis of these effects use quantitative techniques, if available, based on best available data. This should be enhanced by qualitative discussion based on best professional judgment. Mitigation and monitoring are then recommended. See *Issues 4* and *5* in *Tools – Tab 2: Cross-cutting Issues and Key Considerations* for more on these subjects.

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27. How do we plan an assessment in a system that is constantly changing?

It is important to be aware that systems that include humans and ecosystems can change rapidly. In particular, things like social values, access to ES, and demand for ES can sometimes change almost instantaneously (e.g., when a global trend suddenly makes a particular ES increasingly desirable). Being familiar with the area where an ES assessment is being undertaken is very helpful in understanding the trends and drivers that are occurring there, which is why it is often important to consult with local people at the beginning and throughout an assessment. Scenario planning (see *Tools – Tab 7: Compendium of Data Sources, Analysis Methods, and Tools*) is a useful way to explore how the system might change in the future. At the very least, an analysis of drivers of change, thresholds, and trends in ecological and social dynamics can help in understanding a dynamic system.

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28. How can we determine the scale at which different processes are occurring?

Worksheet 4 and the *Cascade Tool (Worksheet 5)* are useful for making an inventory of everything in the system that contributes to the production of the ES that are the focus of the assessment. Once the natural capital, functions, services, and benefits are listed, each can be assigned a scale. Assigning the scale can be intuitive (e.g., the scale of fertilizer addition is the site scale, as fertilizer is added to each field) or may require some research (e.g., the scale of pollination is related to the distance that particular pollinators can travel). Through a combination of literature review and expert consultation, the team should be able to estimate the scale at which all relevant processes are occurring. By at least thinking about the scale of relevant processes and infrastructure, the team will be less likely to omit an important scale of analysis. See *Issues 1* and *2* in *Tools – Tab 2: Cross-cutting Issues and Key Considerations* for more about scale.

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29. Should we develop a list of indicators first, or start by investigating what tools, approaches, and data are available?

This is somewhat of a chicken and egg problem. If the team starts by looking at tools and approaches exclusively, they may not end up with results that are the most relevant to the assessment users. However, if the team strives to develop only the most relevant indicators, there may not be data or expertise to achieve the ideal result. First try to identify the most relevant indicators for answering the assessment questions, but keep an open mind to the idea that other indicators may be more workable (i.e., models or approaches exist to develop them) and may need to be substituted in. The team will need to work iteratively. If they decide to use a different indicator from the one originally identified, they need to be aware of what information is being lost and gained, and how this will affect the assessment outcomes in terms of relevance and uncertainty.

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368 See Hegmann et al. 1999 for more information in a Canadian context.

30. What if decision-makers are interested in types of indicators that cannot be developed or seem to be less relevant?

The kind of information that will be generated needs to be credible and relevant in the eyes of the intended assessment users. It is worthwhile to consult with assessment users throughout the process, and ask what form of data would be most useful and most relevant for answering the assessment questions. For example, if the end user of the assessment wants economic values to aid in decision-making, the assessment team should include economic indicators or provide a clear rationale as to why a different type of value may be more suitable. If particular indicators cannot be developed due to lack of data or expertise, work with decision-makers on choosing acceptable substitutes.

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31. Do we need to measure ecological functions to understand ES?

Some thought should be given to whether it is necessary to have indicators of the functions that underlie ES provision. In many cases, having a comprehensive understanding of ecosystem functioning may not be needed. However, understanding these variables could help in the design of condition/stock or benefit/impact indicators. For example, understanding the process of carbon sequestration will provide insight into how changes in the stock or condition of forest relate to changes in carbon stocks and hence climate regulation. Similarly, understanding the function of water flux (e.g., through rainfall and runoff) may assist in subsequent management and mitigation of impacts on hydrological services. It may be difficult to find or develop data on ecological functions, and so there should be a clear reason for wanting to include indicators of functions in the assessment.

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32. What are the different kinds of indicators available for assessing benefits from ES?

Rather than try to directly measure the impact of ES on human well-being, which is very difficult to do especially at smaller scales, measuring the benefits from ES that may contribute to well-being is more attainable and often more relevant, using a range of indicators.[369] It is very important to identify benefit indicators in collaboration with decision-makers, as this is often of great interest to them. These indicators should be context specific, and as relevant as possible to the assessment questions.

Indicators of human benefits from ES can be described as falling into 11 broad groups, listed with examples and considerations in *Tools – Tab 5: Indicators of Natural Capital, Ecosystem Services, and Benefits from Ecosystem Services*. It can be very helpful to consider these as the team composes lists of indicators for the assessment.

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33. Do we need to use both economic values and socio-cultural values to understand the benefits from ES or do they provide overlapping information?

It depends on the context and the questions being addressed. Both approaches can be important and helpful in decision-making. The information they produce is complementary rather than overlapping. Many ES can have different kinds of values associated with them that cannot all be reflected through a single technique. See *Tools – Tab 6: Values and Valuation: Economic and Socio-cultural* for an elaboration on issues related to economic and socio-cultural valuation.

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34. What are some different kinds of driver indicators and how are they incorporated into an ES assessment?

For the purposes of an assessment, it is important to identify which drivers of change may impact the ES of interest as well as how the drivers themselves are changing, and how quickly. For example, if decision-makers are interested in managing fish stocks more sustainably to protect fishing livelihoods, it is important to know how climate change, fish markets, and other drivers of change will impact fish stocks to develop appropriate management strategies. Decision-makers will be able to influence some drivers, but other drivers of change will be beyond their control.

Factors causing ecosystem change and changes to ES and the benefits humans derive from them can do so either directly or indirectly, the latter by affecting one or more direct drivers. There are five important groups of indirect[370] drivers to consider in ES assessment:[371]

- population change
- change in economic activity
- socio-political drivers
- cultural and religious drivers
- technological change

[369] Efforts are underway to improve them, see, e.g., Summers et al. 2012, and Smith et al. 2013.
[370] In some cases, these 'indirect' drivers can act directly on demand for or access to ES.
[371] Descriptions of important drivers can be found in Chapter 7, Scenarios Volume, *Millennium Ecosystem Assessment*.

Important direct drivers in ES assessment include:

- habitat changes (e.g., land-use/land-cover change)
- consumption/use/overexploitation
- invasive alien species
- pollution
- climate change

Each of these categories of direct drivers can be broken down into very specific drivers that can be described in detail for a specific context. For example, land-cover and land-use change includes specific drivers of change such as logging, cropland expansion, road building, residential development, and other types of infrastructure development.

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35. Where can we find some additional information about ES indicators, their purpose, and suitability?

Canadian Environmental Sustainability Indicators (CESI) at http://ec.gc.ca/indicateurs-indicators/default.asp?lang=En; de Groot, Alkemade et al. 2010; Failing and Gregory 2003; Feld et al. 2010; Ferrari and Geneletti 2014; Kandziora et al. 2013; Keeney and Gregory 2005; Layke 2009; Müller and Burkhard 2012; ten Brink 2006. See also *Tools – Tab 5: Indicators of Natural Capital, Ecosystem Services, and Benefits*.

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36. We cannot find data about ES benefits, what should we do?

Local- and regional-scale data describing specific ES, and especially benefits from ES, are generally difficult to find. For example, the majority of metrics used in the sub-global assessments of the UN MA was related to ecosystem structure (extent/condition), followed by metrics of benefit and value. There were some measures relating to the output/ES delivered by the ecosystem, and very few relating to ecosystem functioning. If the team cannot find data on ES benefits, there are several ways to proceed. First, literature reviews may yield relevant information for similar systems (e.g., benefits from similar types of wetlands may be somewhat consistent or could be adjusted for specific populations). Second, focus groups or asking experts or local stakeholders for their opinions may yield more context-specific information. The priority will be to obtain information that is most relevant for the assessment end-users.

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37. When collecting new data from experts or stakeholders, how can we know if the data are credible and representative?

The tools used to gather data should be used appropriately, ethically, and with an appreciation of what the results represent. Depending on how the information will be used, the information may need to be validated somehow, for example, through triangulation, consulting with multiple experts or stakeholder groups, or other methods. Collecting information from a smaller group and subjecting the data to a broader review process is another way to validate the information.

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38. We only have access to remotely sensed data. Can we trust this source to deliver credible results in our assessment even though we cannot validate the findings separately?

Satellite data are accessible when many other forms of data are not, and are thus an appealing form of information to add to an assessment. Satellite data contribute to several types of information needs for assessments of ecosystem condition, including land cover and land-cover change mapping, habitat mapping for biodiversity, wetland mapping, land-degradation assessments, and measurements of land-surface attributes as input to ecosystem models. The most important caveat in using satellite data is to know what they represent and do not represent (i.e., they might be used as a proxy for an ES, even when not representing the actual ES very precisely), and think carefully about whether they are a relevant indicator for the elements in the system being measured.

A key element in the interpretation of remote-sensing data is calibration and validation with *in situ* data. Ground-based data aids the interpretation of satellite data by identifying locations of specific features in the land surface. These locations can then be pinpointed on the satellite image to obtain the spectral signatures of different features. Ground-based data are also critical to test the accuracy and reliability of the interpretation of satellite data. Linking ground-based data with satellite data poses logistical challenges if the locations required are inaccessible. Moreover, the land surface is often heterogeneous so that a single pixel observed by the satellite contains multiple vegetation types. The ground observations then need to be scaled to the spatial resolution of the sensor. Despite these challenges, ground-based data for calibration and validation are central to the effective use of satellite data for ecosystem assessment.

If validation of satellite data on the ground is not possible, the use of the data should be questioned. In some cases, it may be acceptable to decision-makers to use non-validated data if the data will not be used in a controversial manner (e.g., simply to get an idea of what ES may be in an area). In some cases, local experts may be able to offer input on whether particular data are accurate.

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39. The questions we are asking are complex and require a lot of data to match our multiple indicators. Some of the data exist and some do not, what should we do?

Even when answering relatively simple questions about ES, there is likely to be a need to integrate different forms of information. The team may need to collect new data or revisit the indicators chosen to enable a match with existing data. Both quantitative and qualitative data are important to address the multifaceted nature of ES.

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40. Is it realistic to expect to be able to collect new data?

There are many techniques for collecting new data, if necessary. Each has varying degrees of time and funding requirements that will determine whether it is realistic for a particular assessment. For example, workshops, short surveys, and expert consultations are some forms of new data collection that can be completed in a relatively short period of time. Ecological fieldwork is generally more time consuming and costly. If it is needed, it may be useful to focus the fieldwork in areas where relevant changes are expected to occur. For advice about many different data sources, data collection methods, and analysis methods and tools, review the factsheets in *Tools – Tab 7: Compendium of Data Sources, Analysis Methods, and Tools*.

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41. What time frame should we include in the assessment?

The time frame for analysis depends on the questions being asked. The time frame should be based on what is a reasonable amount of time for the main issues of concern to be explored or managed. Slow processes, such as buildup of phosphorus in soil, may need to be analyzed over many decades. Fast processes, such as deforestation, can occur rapidly, and either recent or more long-term rates of deforestation may be of interest. The current condition of particular ES can be determined using data collected over a very short period of time, from as recently a period as possible. When analyzing trends in ES, the team can think of including the "relevant past" to the "predictable future." ES trends are predictable for a limited period of time, but the length of time depends on the trends in question.

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42. Do we need to determine a baseline for ES condition?

Baseline conditions have historically been used to compare reference conditions (considered to be "pristine") to areas with varying degrees of human intervention to gauge the extent of impacts of human activities on ecosystems. ES assessment frameworks generally do not assume any "natural" state for the systems in which ES are produced, and instead treat the system conditions as a dynamic response to changes in drivers. Another form of baseline condition is the current or recent condition of ES, which is then compared to current or projected future conditions to determine whether these ES are increasing or decreasing in quality or quantity. Also important is knowing the level at which people would like to have access to ES, identifying any thresholds related to ES production, and understanding the level at which ES production and use would be considered sustainable.

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43. How can we use information gathered during the assessment to understand potential future impacts or trends?

In addition to analyzing current ecosystem conditions and trends, assessments may need to explore the implications of current and future system changes for humans and ecosystems. Scenario exercises can be used to explore the future when there are high levels of complexity and uncertainty associated with future trends. See *Tools – Tab 7: Compendium of Data Sources, Analysis Methods, and Tools* for more information on scenario work.

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44. How does the concept of resilience relate to ES? How can it be assessed?

Resilience refers to the ability of a system to maintain the same structures and functions in the face of change. Scientists and managers are embracing the concept because it recognizes the fact that change is occurring constantly, and is useful in this age of high uncertainty and global connectivity, where nonlinear change and surprises are the norm. ES resilience can be described as the ability of a system to continue to produce desirable ES in the face of change. Assessing the resilience of ES may require (1) identification of thresholds past which

ES are no longer produced at acceptable levels; (2) understanding slowly changing variables in the system that support resilience (often associated with regulating ES such as erosion control); (3) understanding how system diversity may improve the resilience of ES production and benefits; and (4) examining policies and management approaches for how they reflect resilience principles, as well as social justice and other human development concerns. See *Tools –Tab 2: Cross-cutting Issues and Key Considerations* for more information on the resilience of ES.

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45. How can the results of an ES assessment be interpreted in a credible and transparent way?

The scope of ES assessment work can be large, and the assessment results are rarely comprehensive due to gaps in data, methods, and understanding. It is, therefore, very important to be able to interpret and communicate assessment results in light of the limitations and assumptions associated with the work that was completed. Based on best practices developed during more than 15 years of ES assessment work, principles to follow when deciding how to use ES assessment results include:

- providing information about levels of certainty/uncertainty;
- being transparent about limitations of information, data, and understanding;
- being mindful that ES considerations are just one framework for approaching an issue, and other approaches may be equally or more valid depending on the questions being asked and the stakeholders involved;
- emphasizing information about any known ecological thresholds because these point to highest risk;
- communicating all values associated with ES—socio-cultural, ecological, and economic—in terms that respect the different ways these values were identified (reducing to a single metric may reduce the validity and reliability of the final results);
- applying the precautionary principle;
- not directly applying results to other social or geographic contexts (e.g., ES that are produced in one wetland will probably not equal ES produced by another wetland, because both the ecosystem and the beneficiaries will change);
- being wary of providing perverse incentives (e.g., incentives to produce more of one ES may negatively affect other ES);
- being aware of interactions among ES;
- being aware of equity issues regarding trade-offs; and
- not assuming that values will not change, sometimes rapidly (especially social values, but also ecological and economic values, due to unexpected changes, global market unpredictability, demographic change, social media campaigns, and so on).

It can be helpful to list any issues relating to this set of principles and keep a record of how each issue is dealt with. Transparency will promote the credibility of the final outputs of the ES assessment. All of these issues are addressed in various parts of this Toolkit, whether in the chapters or the Tool Tabs. Toolkit users are strongly encouraged to read through all three chapters and at least browse each of the Tool Tabs before making decisions about how to proceed.

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TOOLS – TAB 9 – GLOSSARY

Definitions in this glossary are oriented to the use of terms in the context of ecosystem services (ES) work. Many of the terms used in this Toolkit have different meanings for practitioners within the different disciplines that participate in ES assessment (e.g., values). Note especially the "***core***" definitions indicated by purple text in this glossary.[372]

Aboriginal traditional knowledge: *See Indigenous traditional knowledge.*

Adaptive management: A systematic process for continually improving management policies and practices by learning from the outcomes of previously employed policies and practices. In active adaptive management, management is treated as a deliberate experiment for purposes of learning.

Assessment: *(generally)* Adding value and relevance to data by organizing, analyzing, and evaluating, and showing connections and meaning that were not available in the raw data.

Attribute: A measure that can be used to characterize a specified subject and is used as an indicator for that subject. Attributes should ideally be unambiguous, comprehensive, direct, operational, and understandable. The three types of attributes are natural (direct measure), constructed (when no direct measure exists), and proxy (indirectly reflects a major characteristic of the subject). *(See factsheet on Constructed Scales in Tools – Tab 7: Compendium of Data Sources, Analysis Methods, and Tools.)*

Beneficiary (of ES): Because the concept of *ecosystem services* is meant to focus attention on the *benefits* that humans receive from the underlying processes and functions of ecosystems, the relationship of interest is between *ecosystem services* and human *beneficiaries* of those services. An ES beneficiary is anyone who benefits from one or more ES. Beneficiaries can be individuals and groups of people, an important fact when assessing the equitable access to/distribution of ES benefits. Beneficiary groups are defined as those people who benefit from the same ES. To the extent that the following characteristics influence access to ES, beneficiary groups may be further defined by:

- geographic location relative to each ES;
- commercial users of specific ES;
- ethnic or cultural identity and associated practices and beliefs;
- socio-economic status and resulting needs and access;
- present or future time frame (intra-generational and inter-generational equity); and
- the extent to which an ES is an optional preference (i.e., life support is not optional, but some quality-of-life ES may vary in their importance to different people). ***Core***

Benefits (from ES): ES provide benefits to people, but ES are not the same as the benefits.[373] Briefly, a benefit supports the maintenance or "positive change in well-being from the fulfilment of needs and wants"[374] or the measure of the benefit to human well-being, in terms of increases in health, income, livelihood, resilience, safety, stability, freedom of choice, and so on. Benefits are often assessed as a proxy for measurements of the ES themselves. Examples of the benefits derived from individual ES are provided in *Tools – Tab 1: Ecosystem Service Descriptions.* ***Core***

372 Some definitions are reproduced from the UN *Millennium Ecosystem Assessment* (MA 2005).
373 Haines-Young and Potschin 2009: 56.
374 Kumar 2012.

Biodiversity (biological diversity): The UN *Convention on Biological Diversity* (CBD) defines biodiversity as "the *variability among living organisms from all sources including, [among other things], terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems*."[375] Biodiversity underpins the ability of ecosystems to produce ES and contributes to their quality, but biodiversity is not an ES and is not equivalent to ES.[376] ***Core***

Complex system: Systems composed of parts that give rise to the collective behaviours of the system, and how the system interacts with its environment. (NB: for additional definitions see http://serc.carleton.edu/NAGTWorkshops/complexsystems/definitions.html.)

Conceptual framework: (in this context) A concise summary in words or pictures of relationships between people and nature, including the key components of interactions between humans and ecological systems. *(See Chapter 1 for the conceptual framework guiding the approach in this Toolkit.)*

Condition: A "snapshot" of the condition of ES or human well-being in a given area and at a particular time, usually the present or recent past. Can include the health, integrity or level of degradation of ecosystems, or the stock, yield or value of ecosystem services, or the capacity of an ecosystem to yield services, relative to its potential capacity.

Credibility: In the context of an ES assessment, refers to whether the assessment meets standards of scientific rigor and technical adequacy.

Critical natural capital: Refers to physical components of ecosystems that are not substitutable—or more particularly, the components that produce ecosystem services that are not substitutable *(see: Substitution.)* According to experts these ecosystem components cannot, therefore, logically be assessed in terms of *trade-offs* for decision-making, but must be protected.[377] "*If [critical natural capital] is deteriorated, radical undesired changes of ecosystems (such as crossed thresholds, tipping points and nonlinearities) may occur. Owing to the complexity and uncertainty of ecosystems it is not always possible to identify which natural capital is 'critical'.*"[378] ***Core***

Culture: Classically defined as "a transmitted pattern of meanings embodied in symbols, a system of inherited conceptions expressed in symbolic form by means of which people communicate, perpetuate, and develop their knowledge about and attitudes towards life." All humans belong to, and are influenced by, one or more cultures. *(See difference between CES and "cultural values" in Tools – Tab 6: Values and Valuation: Economic and Socio-cultural.)*

Cultural ES: The nonmaterial benefits people obtain from ecosystems that inform human physiological, psychological, and spiritual well-being, knowledge, and creativity. *(See Tools – Tab 1: Ecosystem Service Descriptions for details, and see difference between CES and "cultural values" in Tools – Tab 6: Values and Valuation: Economic and Socio-cultural.)*

Cultural values: *See **socio-cultural values**, below.*

Cumulative effects: The incremental effects of multiple, interacting stressors on ecosystems and social-ecological systems through time. *(For more detail, see Tools – Tab 2: Cross-cutting Issues and Key Considerations.)*

Customary Use: (Note that this is not a formal legal definition, but is rather a description to assist managers and analysts.) For thousands of years, Indigenous peoples in Canada have depended on the land, water, and resources that healthy ecosystems provide to meet their physical, social, cultural, and spiritual needs. Many Indigenous peoples continue to have an intimate cultural relationship with the landscape and the resources derived from the land and water. The customary use of biological resources, including such activities as hunting, fishing, trapping, and gathering, is an important element of this relationship. This customary use of biological resources may be exercised by Indigenous communities under their law-making authority for their resources. It may also be exercised by those communities having indigenous or treaty rights to do so.

[375] CBD 1992.
[376] Haines-Young and Potschin 2010: 113. See Balvanera et al. 2013; and Cardinale et al. 2012 review two decades of research on biodiversity and its role in ecosystems and ES. Also Elmqvist et al. 2010; Luck et al. 2009; and Mace et al. 2012.
[377] Chiesura and de Groot 2003.
[378] TEEB 2013: 13. See de Groot et al. 2003, and Ekins et al. 2003 on how to determine criticality; and see Brand 2009 on critical natural capital (CNC) and ecological resilience for a summary of CNC perspectives.

Decision-maker: Any individual or organization in a position to make a decision about governance or management.

Demand (for ES): How much of a service is consumed or wanted.

Double-counting: Erroneously including the same ES more than once in calculations, particularly of numeric values. *(For more detail, see Tools – Tab 6: Values and Valuation: Economic and Socio-cultural.)*

Driver of change: External factors that both directly and indirectly contribute to change in ecosystems, and thus ES provision. *(See conceptual framework for ES Assessment in Chapter 1.)*

Ecological function/process: See *Ecosystem process*.

Ecological integrity: 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. In other words, ecosystems have integrity when their native components are intact. *(source: Parks Canada)*

Ecological production function: "A formula used to estimate the level of service provisioning at a particular location given the biotic and abiotic characteristics of that site. Ecological production functions may be empirical (e.g., regression) models, ecological process models, or a priori rule-based models of ES supply. Examples: the RUSLE, which models erosion as a function of rainfall, soil characteristics, topography, and vegetation cover, is often used as an ecological production function for the ESs erosion control and water quality." *(source: Andrew et al. 2015)*

Economic valuation: The process of estimating and expressing the worth of a good or service as determined by people's preferences and the trade-offs they choose to make given their scarce resources, or the value the market places on an item. Economic value is commonly represented by the maximum amount an individual is willing to pay for an item in a market economy. However, market value represents the minimum amount a consumer is willing to pay. Economic value thus often exceeds market value. The fact that many benefits that people obtain from nature are not priced does not mean that they lack economic value. Rather, it implies that the market indicators of the value do not currently exist.

Ecosystems: Are "*the dynamic complex of plant, animal, and micro-organism communities and their non-living environment interacting as a functional unit. Humans, where present, are an integral part of ecosystems. Examples include a rainforest, desert, coral reef, or a cultivated system. Ecosystems vary in size and complexity of interactions, and are interconnected and impacted by natural processes and human-induced factors. Ecosystems have no fixed boundaries; instead their parameters are set to the scientific, management, or policy question being examined. Depending upon the purpose of analysis, a single lake, a watershed, or an entire region could be considered an ecosystem*."[379] Even small urban spaces can be ecosystems. ***Core***

Ecosystem approach: A strategy for the integrated management of land, water, and living resources that promotes conservation and sustainable use. An ecosystem approach is based on the application of appropriate scientific methods focused on levels of biological organization, which encompass the essential structure, processes, functions, and interactions among organisms and their environment. It recognizes that humans, with their cultural diversity, are an integral component of many ecosystems.

Ecosystem process: An intrinsic ecosystem characteristic whereby an ecosystem maintains its integrity. Ecosystem processes include decomposition, production, nutrient cycling, and fluxes of nutrients and energy. *(See conceptual framework in Chapter 1 for role in ES.)*

Ecosystem service: Is a concept developed to focus the attention of decision-makers, business, and the general public to the many ways that humans benefit from and depend on healthy functioning ecosystems. This dependency extends from essential support for life (e.g., because ecosystems produce oxygen and food) to security (e.g., by mitigating extreme weather events) and quality of life (by supporting, e.g., cognitive development and psychological well-being). Natural processes within ecosystems result in the provision of these "services" that benefit all species, but the concept of *ecosystem services* focuses attention particularly on *human* dependence on these processes. ES are produced in all environments—urban, rural, and wilderness *(see Table 1.1)*. Although ES are categorized by types, in reality they are often interacting (*see Ecosystem service bundles*). The terms "ecosystem goods and services" and "ecological goods and services" are synonymous with ES. *(See Table of ES Descriptions in Tools – Tab 1.)* ***Core***

[379] Global Reporting Initiative 2011:6.

Ecosystem Service Assessment: Is an interdisciplinary analysis of the ES produced and/or received within a defined study area. An ES assessment requires (to varying extents) biophysical measures and description of the ecosystems and the dynamics involved in the production of ES that they provide. It also includes a description of the human benefits of ES and the dynamics of how benefits are distributed among different beneficiary groups. An ES assessment may also include identifying the significance of those benefits to people through socio-cultural and/or economic valuation. To every extent possible, an ES assessment makes use of existing scientific and social scientific data, but may involve collection of new data if necessary. ES assessment can address all ES and all beneficiaries. ES assessment can measure changes in natural capital, changes in the provision of ES benefits, and changes in human well-being. Details on the various aspects of ES assessment are provided in *Chapter 2* and supported by the *Tool Tabs*. ***Core***

Ecosystem service bundle: A set of ES that co-vary in space or time. *(See "bundles" on Statistical Analysis Factsheet in Tools – Tab 7: Compendium of Data Sources, Analysis Methods, and Tools.)*

Expert opinion: Is one of many methodologically established data sources. Experts may include credentialed professionals in the natural sciences, social sciences, economics, and policy areas as well as locally recognized holders of local and traditional knowledge.[380] When asking ES beneficiaries who are *not* classed as "experts" about issues and values, reliability is supported by:

- obtaining views from a statistically representative sample of the population;
- obtaining views from locally recognized knowledgeable and engaged individuals (who collectively reflect the diversity of the population); and/or
- considering stated values alongside existing scientific and social scientific research publications (triangulation) where possible.

Externality: A consequence of an action that affects someone other than the agent undertaking that action and for which the agent is neither compensated nor penalized, for example, through the markets or regulations. Externalities can be positive or negative, although the term is typically used to refer to negative effects (positive effects are sometimes referred to as "co-benefits").

Final ecosystem services: ES that are consumed, used or enjoyed directly by humans. Term most often used in discussion of avoiding double-counting—contrasted with intermediate ES, which contribute to the production of final ES. *(See answer to FAQ 5 in Tools – Tab 8.)*

Flow (of ES): Quantity of a service that provides benefits to humans per unit of time.

Functional redundancy: A characteristic of ecosystems in which more than one species in the system can carry out a particular process. Redundancy may be total or partial—that is, a species may not be able to completely replace the other species or it may compensate only some of the processes in which the other species are involved.

Governance: The process of regulating human behaviour in accordance with shared objectives. The term includes both governmental and nongovernmental mechanisms.

Human well-being: A context- and situation-dependent state, comprising basic material for a good life, freedom and choice, health and bodily well-being, good social relations, security, peace of mind, and spiritual experience. The concept of ES was created to demonstrate the essential role of viable ecosystem functioning to human well-being.[381]

Index: A numerical scale used to compare variables with one another or with some reference number.

Indicator: A measure or metric based on verifiable data that conveys information about more than itself. It is information packaged to communicate something important to decision-makers. *(See Step 4 in Chapter 2 and associated FAQ answers in Tools – Tab 8.)*

[380] See *TIP box on Expert Opinion* and what to do when experts disagree in *Chapter 2, Step 4.* See *Tools – Tab 3: ES Assessment Involving Indigenous Communities* for specific advice about accessing Indigenous traditional knowledge.
[381] See, for example, MA 2005.

Indigenous: In Canada, refers to First Nations, Inuit, and Métis peoples.

Indigenous traditional knowledge: The term Indigenous traditional knowledge (ITK) can be used interchangeably with many other terms such as traditional knowledge (TK), Inuit Qaujimajatuqangit (IQ), Indigenous knowledge (IK) and Indigenous local knowledge and the term, traditional ecological knowledge. No standard definition of ITK exists, and many Indigenous groups believe a universal definition is not desirable. The assessment team should consider using a definition that is developed by the Indigenous groups involved in the assessment. The Canadian Institutes of Health Research, the Natural Sciences and Engineering Research Council of Canada, and the Social Sciences and Humanities Research Council of Canada recently developed and agreed upon the following definition, which may be helpful as a departure point in discussions between the assessment team and Indigenous groups for developing a context-specific definition:

> Traditional knowledge – The knowledge held by First Nations, Inuit, and Métis peoples, the Indigenous peoples of Canada. Traditional knowledge is specific to place, usually transmitted orally, and rooted in the experience of multiple generations. It is determined by an Indigenous community's land, environment, region, culture, and language. Traditional knowledge is usually described by Indigenous peoples as holistic, involving body, mind, feelings, and spirit.[382]

Interdisciplinary: Refers to the collaborative planning, design, and implementation of work among experts from different disciplines. It involves developing common understanding of essential concepts, which often vary between disciplines. Interdisciplinarity can optimize ES assessment outcomes by identifying relevant linkages between issues, methods of analysis, and knowledge that each discipline can bring to bear on each aspect and phase of a case. This is distinguished from multidisciplinarity, which refers to contributions from experts in different disciplines who work separately from each other. An interdisciplinary approach is essential to understand the links between ES and human well-being. *(See Conceptual and Analytical Framework in Chapter 1, Step 3 in Chapter 2, and answers to FAQs in Tools – Tab 8.)* ***Core***

Intermediate ecosystem services: ES that are required to produce final ES.

Intrinsic value: The value (significance) of someone or something in and for itself, irrespective of its utility for people. *(See answer to FAQ 3 in Tools – Tab 8.)*

Iteration/iterative: Repetition (e.g., for the purpose of learning, improvement).

Keystone ecosystem service: Just as a "keystone species" is a species whose effect on ecosystem functioning is particularly pivotal, relative to other species, a "keystone ES" can be understood as one which has a higher order of effect in the landscape and for human beneficiaries. For example, the "regulating ecosystem service" of pollination is essential for the production of most plant-based foods and other plant-based "provisioning ecosystem services." Pollination is also essential in maintaining biodiverse ecosystems and the "supporting/habitat ecosystem service" upon which many species depend.

Legitimacy: In an ES assessment, refers to whether the assessment process is perceived as fair, appropriate, and unbiased. *(See answers to FAQs 21 and 22 in Tools – Tab 8.)*

Measure: A (numeric) value that is quantified against a standard at a point in time.

Metric: A measure, normally in numeric form. Can be a set of measurements or data collected and used to underpin an indicator.

Mitigation hierarchy: The "mitigation hierarchy" for environmental sustainability has as its primary objective the avoidance of impact, and if that is not fully possible, to *minimize* impact through careful design. If residual impacts cannot be avoided, the impacted ecosystem should be *rehabilitated* or restored. When that is completed but still insufficient, the damage may be *offset* by enhancing ecosystem viability in another location to achieve no net loss, and potentially taking other additional conservation actions to achieve *net positive impact*.

[382] TCPS 2010 Chapter 9: Research Involving the First Nations, Inuit and Métis Peoples of Canada.

Natural capital: An economic-based term referring to the biophysical components of the environment as assets. Natural capital can be defined[383] as the stock of natural resources (biotic and abiotic), including the flows of "ecosystem goods and services" or ecosystem services, that exist in a region at a given point of time. The concept of *capital* is sometimes applied to things that have the capacity to provide benefits over time without necessarily being consumed (and thus reduced in extent or in quality). It is a metaphor,[384] as explained in a recent report, "*Nature, in providing a series of benefits to society and the economy, can be understood as doing so through service flows generated by stocks of natural assets, which are increasingly being referred to as 'natural capital'.*"[385] *Figure T9.1* illustrates these relationships. *(See: Critical Natural Capital.)* ***Core***

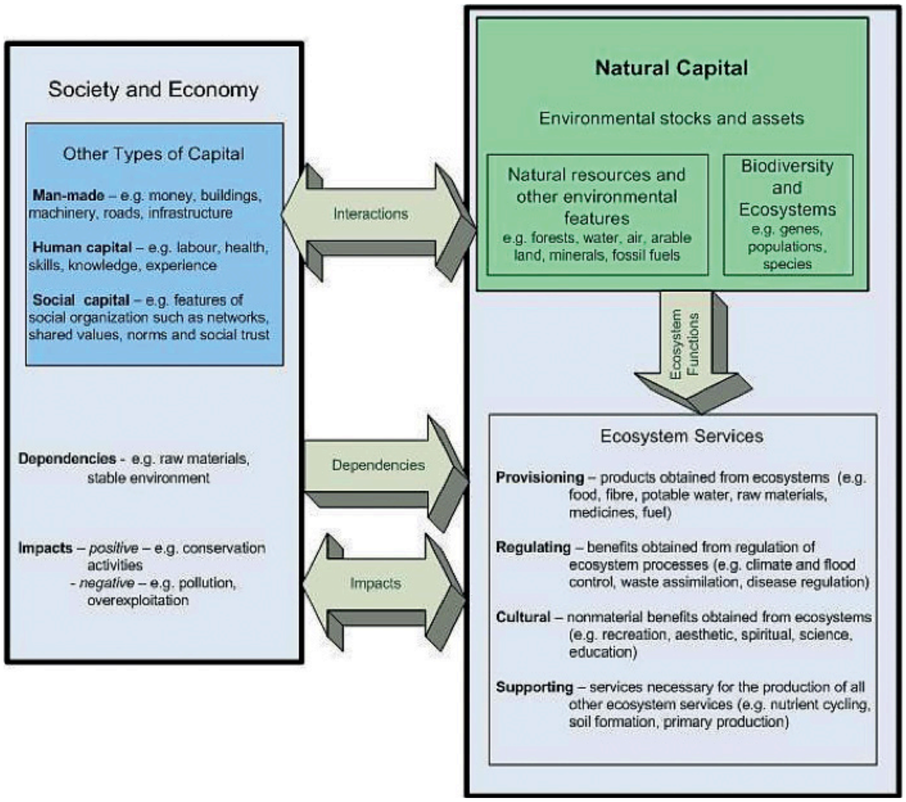

Figure T9.1. *Natural capital, other types of capital, and human well-being. (Adapted from Bonner 2012.)*

Non-linearity: A relationship or process in which a small change in the value of a driver (i.e., an independent variable) produces an disproportionate change in the outcome (i.e., the dependent variable). Relationships where there is a sudden discontinuity or change in rate are sometimes referred to as abrupt and often form the basis of thresholds. In loose terms, they may lead to unexpected outcomes or "surprises." *(See Issues 3 and 4 in Tools – Tab 2: Cross-cutting Issues and Key Considerations.)*

Participatory approach: An approach that includes the participation of diverse groups of stakeholders and decision-makers. Participation may range from consultation to direct participation in research and assessment direction. *(See discussion in Tools – Tab 6: Values and Valuation: Economic and Socio-cultural.)*

Precautionary principle: "When human activities may lead to morally unacceptable harm that is scientifically plausible but uncertain, actions shall be taken to avoid or diminish harm. ... Actions should be chosen that are proportional to the seriousness of the potential harm."[386] *(See Cumulative Effects in Tools – Tab 2: Cross-cutting Issues and Key Considerations.)*

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383 Daly and Farley 2004.
384 Aronson et al. 2010. The concept of "capital" is used to characterize other aspects of society the same way, resulting in concepts of financial capital, social capital, human capital, built or physical capital, and natural capital.
385 TEEB 2013:15. Important note: Barbier 2013: 215 advises that "although they are the source of ecosystem services, the structure and functions of an ecosystem are not synonymous with such services."
386 Iverson and Perrings 2011.

Problem-oriented approach: Identifying precise objectives (for the ES assessment) and then orienting every step of the assessment process towards meeting these objectives. *(See Step 1 in Chapter 2.)*

Provisioning ES: The result of ecosystems processes and functions that provide goods or products that humans obtain and rely upon; often with some human inputs of labour and financial and social capital. *(See Tools – Tab 1: Ecosystem Service Descriptions.)*

Proxy: A substitute measure used to provide insight into the area of interest when it is not possible to measure the issue directly. *(See Indicators, above.)*

Regulating ES: The result of ecosystem processes and functions that regulate all aspects of the environment, providing security and habitable conditions that humans rely upon. *(See Tools – Tab 1: Ecosystem Service Descriptions.)*

Relational worldview: In many cultures, it is understood that for all living beings, from the time of their birth, relationships are the foundations of "personhood" (the condition of having conscious, autonomous agency), society, and culture. Humans, other animals, spirits, and some other aspects of the natural world are understood to have this personhood. This worldview is particularly relevant for many Indigenous cultures. Survival, personhood, individuality, languages, societies, cultures, and worldviews are only possible because they emerge in and through living in relationships with others. Humans and other non-human "persons" engage with each other through intentional, respectful, and reciprocal relationships. Maintaining the integrity of these relationships is essential to maintaining the integrity and stability of all life in the world. This means that not only do humans depend on the animals and other non-human persons for their subsistence, they recognize that these other non-human persons also have subsistence needs, families, and lives of their own, and that together they are part of a "Great Community of Persons."[387] So, impacts to other species and the environment have impacts on humans in very complex ways that are at the core of what it means to be a human and a "person."[388]

Relevance: In ES assessment generally, refers to the significance of assessment information in relation to decision-making issues or priorities.

Resilience: Resilience relates to a system's capacity to recover from, or adapt to disturbance, ongoing stress from different impacts, and change. Resilience depends on ecological dynamics as well as the organizational and institutional capacity to understand, manage, and respond to these dynamics. *(See Issues 3 and 4 in Tools – Tab 2: Cross-cutting Issues and Key Considerations.)*

Review process: Involving experts, stakeholders, and decision-makers to verify the results of an assessment, in terms of credibility, completeness, clarity, and relevance. *(For more, see Step 3 in Chapter 2.)*

Scale: The measurable dimensions (extent) of phenomena or observations. Expressed in physical units, such as metres, years, population size, or quantities moved or exchanged. In observation, scale determines the relative fineness and coarseness of detail (grain) and the selectivity among patterns these data may form. *(See discussion in Tools – Tab 2: Cross-cutting Issues and Key Considerations.)*

Scenario: A plausible and often simplified description of how the future may develop, based on a coherent and internally consistent set of assumptions about key driving forces (e.g., rate of technology change, prices) and relationships. Scenarios are neither predictions nor projections and sometimes may be based on a "narrative storyline." Scenarios may include projections but are often based on additional information from other sources. *(See Factsheet on Scenarios in Tools – Tab 7: Compendium of Data Sources, Analysis Methods, and Tools.)*

Social costs and benefits: Costs and benefits as seen from the perspective of society as a whole. These differ from private costs and benefits in being more inclusive (all costs and benefits borne by some member of society are taken into account) and in being valued at social opportunity cost rather than market prices, where these differ. Sometimes termed "economic" costs and benefits.

Social-ecological system: An ecosystem, the management of this ecosystem by human actors and organizations, and the rules, social norms, and conventions underlying this management.

[387] Reference to the "Great Community of Persons": R. Preston 1997; on relational worldviews, see also Scott 1996.
[388] For information about relational *values* in Indigenous *and* non-Indigenous cultures for ES assessment, see Chan et al. 2016.

Socio-cultural values: Individuals and groups collectively attribute or assign values through shared experience of the valued subject, as well as through group discussion or negotiation. This can happen even while values are being elicited for research. When values are shared by people in social groupings, those values can be considered "social" rather than only individual. When these values become part of the group of symbols and meanings that inform the shared identity of a particular culture group, they are "cultural" values. The term "socio-cultural values" is often used to refer to either or both of these.

Socio-cultural valuation: Refers to the use of data collection and analysis methods from a range of social sciences that do not use economic theory or economic approaches to identify the importance of a particular subject to people. Results typically take the form of priority ranking or description. *(see Tools – Tab 6: Values and Valuation: Economic and Socio-cultural for details.)*

Stakeholder: A person, group or organization that has an interest or concern in a thing, or can be affected directly or indirectly by the conditions of the thing in which they have a stake. The role of stakeholders in ES assessment can be extensive—see all steps in *Chapter 2*.

State: A "snapshot" of the condition of ES or human well-being in a given area and at a particular time, usually the present or recent past. Can include the health, integrity or level of degradation of ecosystems, or the stock, yield or value of ES.

Stock (of ES): The current amount or biomass of a resource, usually expressed in units of quantity.

Substitution: In the context of ES substitution refers to the replacement of an ecosystem, part of an ecosystem, or an ES with another, based on the expectation that the replacement fills the human benefit functions that were provided by the original. This is particularly the case with ES offsets (for discussion of ES offsets, see *Chapter 3*). In the context of ES, the perceived substitutability of an ecosystem or ES is based on its *known* utility to people. It does not account for as yet *unknown* benefits to people, which is an important consideration as understanding of ecosystem processes continues to be developed. Further, the emphasis of ES on human well-being means that substitution of ES is very unlikely to account for the importance of the affected ecosystem components to other species. Substitutability is further complicated because of the interconnectivity in ecosystems, so that substituting one ES may not account for others that are co-produced by the same ecosystem components (or natural capital)—see Raudsepp-Hearne et al. 2010 for an illustration of this point. *(See: Critical Natural Capital.)*

Supply/provision (of ES): Quantity available for use.

Supporting or habitat ES: The underlying ecosystem processes and functions that are necessary for the production of all other ES, creating the biological environment. *(See Tools – Tab 1: Ecosystem Service Descriptions.)*

Sustainability: A characteristic or state whereby the needs of the present and local population can be met without compromising the ability of future generations or populations in other locations to meet their needs.

Threshold: A point or level at which new properties emerge in an ecological, economic or other system, invalidating predictions based on mathematical relationships that apply at lower levels. For example, species diversity of a landscape may decline steadily with increasing habitat degradation to a certain point, then fall sharply after a critical threshold of degradation is reached. Human behaviour, especially at group levels, sometimes exhibits threshold effects. Thresholds at which irreversible changes occur are especially of concern to decision-makers. *(See Issues 3 and 4 in Tools – Tab 2: Cross-cutting Issues and Key Considerations.)*

Total economic value (TEV) framework: A widely used economic framework to disaggregate the components of utilitarian value. It is the sum of direct use value, indirect use value, quasi-option value, bequest value, altruistic value, and existence value. The framework identifies the different types of economic analysis techniques suited to each type of economic value, applied to marginal changes in the benefits humans receive from ES generated by natural capital.[389] *(See Tools – Tab 6: Values and Valuation: Economic and Socio-cultural.)*

Trade-off: Management choices that intentionally or otherwise change the type, magnitude, and relative mix of services provided by ecosystems. *(See Chapter 2, Step 5.)*

[389] See Pascual et al. 2010, notably figures 5.1 and 5.3.

Transect walk: Participatory research method that produces "a record of what a community consultant describes and comments on during a guided walk of the site. The idea is to include one or two community members as research team members in order to learn about the site from the community member's point of view."[390] This information may be oriented to any aspect of the community and the site/environment.

Transparency: Characterized by visibility or accessibility of information, especially concerning governance and decision-making.

Trend: Analysis of the change in state over time.

Triangulation: The use of multiple distinct research methods to address a single question. Recommended for studies combining qualitative and quantitative methods. Five purposes for triangulation are (1) convergence of results (if conclusions derived from all methods are consistent, results are affirmed as valid); (2) unexpected facets of the subject of study may be revealed; (3) cumulatively building understanding; (4) revealing contradictions or fresh perspectives; and (5) adding scope and breadth to the study. A robust way to test the appropriateness of method choice and question design, and to "neutralize" researcher bias.[391]

Uncertainty: An expression of the degree to which a condition (e.g., of an ecosystem) is unknown. Uncertainty can result from lack of information or from disagreement about what is known or even knowable. It may have many types of sources, from quantifiable errors in the data to ambiguously defined terminology or uncertain projections of human behaviour. Uncertainty can therefore be represented by quantitative measures (e.g., a range of values calculated by various models) or by qualitative statements (e.g., reflecting the judgment of a team of experts). *(See Issue 7 in Tools – Tab 2: Cross-cutting Issues and Key Considerations.)*

Use values and non-use values: Economists group values in terms of their "use" or "non-use," each of which is associated with a selection of valuation methods. Use values relate to the current or future uses of a resource or ES. Non-use values are based on the preference for nature's existence without the valuer using it. (See *Tools – Tab 6, Values and Valuation: Economic and Socio-cultural,* section *T6.2-4*.)

Value, values, and valuation: Three terms that are approached very differently in different disciplines. The physical sciences, anthropology, philosophy, psychology, economics, and others each use the terms to conceptualize "significance" differently, using different analytic methods. An interdisciplinary assessment includes each of these approaches without attempting to filter results into a single discipline's frameworks or metrics.[392]

Value: Refers to significance, and can be measured and reported using a wide range of methods that are numeric and/or descriptive. The contribution of an action or object to user-specified goals, objectives or conditions. The Canadian Oxford Dictionary defines *value* as an amount of something used as a medium of exchange; the worth or quality of something compared to the price paid for it; and the "*worth, usefulness, or importance of a thing; relative merit or status according to the estimated utility of a thing.*"[393]

- In the ***physical sciences***, a value refers to any unit of measure and is typically reported numerically.
- In the ***social sciences,*** the value or significance of a thing may be assessed and reported both qualitatively and quantitatively. Things are perceived by people as having value if a degree of importance is attributed to the thing. Such importance can be informed by the person's interaction with the subject (tangibly or intangibly), or it can be understood as intrinsic to the thing itself[394] (such as an animal or plant species) regardless of human interests.
- In ***economics***, value is a measure of the utility that a thing has to people, using the metric of money when appropriate and feasible. In economic theory, there is no intrinsic value of goods and services. Rather, things become valuable solely by individuals desiring to have them. This implies that "worth" is in the mind of the user. For this reason, a good can have great value to one economizing individual, little value to another, and no value at all to a third, depending upon the differences in their requirements and available amounts.[395] ***Core***

[390] Low et al. 2005: 189.
[391] This definition adapted from Creswell 1994.
[392] Gómez-Baggethun et al. 2014.
[393] Barber 2004.
[394] Chan 2011.
[395] Menger 1994.

Values: Values are individual orientations about what is most desirable. They are grounded in beliefs and emotions, they influence attitudes and behaviours, and they can be shared among groups of individuals.[396] Two main types are "held" and "assigned" values. Held values inform people's beliefs and assessments of right and wrong. Assigned values deal with the *relative attribution of significance* to things and experiences. In other words, assigned values are about how important something is to people. Assigned values can be assessed through socio-cultural and/or economic valuation *(see next definition).* Values can be shared among groups of people, but people within the same social or other kind of group will have multiple and varying values towards the same subject. ***Core***

Valuation: Refers to the process of measuring value. ***Economic*** valuation refers to monetary and non-monetary assessment of market and non-market values based on concepts specific to economic ways of explaining human preferences and choices. ***Socio-cultural*** valuation uses concepts and methods from a range of other social sciences (i.e., not including economics) to identify and analyze the importance of a particular subject to people. Results typically take the form of priority ranking or description. ***Ecological*** (or biophysical) valuation can be numeric measures of extent and condition, measures of integrity within the processes and functions of an ecosystem, and resilience.[397] Techniques for valuation are chosen for the relevance of the concepts (i.e., theory) that underpin the different types of analysis, as well as for the type of "units" of value that they can provide. Additional considerations in selection of techniques include demand for precision and expediency, and the type of decision to be made.[398] Any of these three types of valuation is likely to be an element in making decisions in the public realm, or in any kind of social setting, so that choices can be made to achieve a particular goal. ***Core***

Watershed (also catchment basin): The land area that drains into a particular water course or body of water. Sometimes used to describe the dividing line of high ground between two catchment basins.

Wildlife: Uncultivated flora (e.g., plants, fungi) and wild fauna (e.g., mammals, amphibians, insects).

[396] Dietz et al. 2005 provide a substantial review of "environmental values." On held and assigned values, see Brown 1984; Seymour et al. 2010, citing Lockwood 1999, McIntyre et al. 2008, and Brown 1984. On importance to environmental management, see Seymour et al. 2008; Fulton et al. 1996; Kennedy et al. 2009; Manfredo 2008; Belsky and Williams 2012.

[397] Gómez-Baggethun et al. 2014:12-13 provide a concise description of the types of ecological values. Resilience value is sometimes also called "insurance value." In general, this Toolkit uses the more familiar term "biophysical measures" rather than "ecological values," but both are correct.

[398] For details on socio-cultural and economic valuation, see *Tools – Tab 6: Values and Valuation: Economic and Socio-cultural*. In this Toolkit, ecological valuation is referred to as "biophysical measures" rather than being treated as a type of valuation.

TOOLS – TAB 10 – CANADIAN ES ASSESSMENTS AND ANALYSES REFERENCE LIST

This Tab is a linked bibliographic list of reports and publications that contain results of ecosystem service (ES) assessment, including, most often, valuation. Most of these publications are readily available online. Most examples are reports produced for non-government organizations (NGOs) or governments, and some are articles from peer-reviewed scientific journals. The emphasis is on cases that occur within Canadian ecosystems. It is not a comprehensive list and users of this toolkit are encouraged to notify the authors of other analysis of ES in Canada that could be added.

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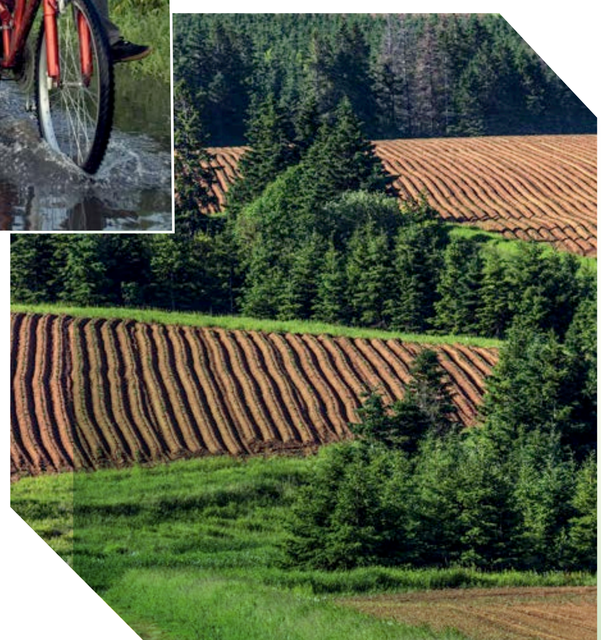

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