

Assessing success at achieving biodiversity objectives in managed forests

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Abstract

Managing for biodiversity is an integral part of achieving sustainable forest management. Because of the complexity of ecosystems and ecosystem processes, much uncertainty faces forest managers as they attempt to design and implement forest practices to maintain biodiversity across their land base. To reduce this uncertainty, scientists and policy-makers recommend adopting an adaptive management process—a research approach that provides forest managers with a mechanism to obtain and input new information into their management plan, and to adjust the plan accordingly to meet desired forest management objectives. This process relies heavily on *effectiveness monitoring*; that is, assessing the extent to which management strategies were effective in achieving desired outcomes. Forest managers need to know what to monitor and how to monitor it; however, it is important to formulate these decisions within the recommended steps of the adaptive management program. This extension note provides forest managers with an overview of how adaptive management can work to help achieve forest management objectives around maintaining biodiversity, with a particular emphasis on monitoring to determine the effectiveness of the chosen strategy. We describe the four steps in the adaptive management process, explain how effectiveness monitoring fits into the process, and provide a case study that describes how this process is currently used in British Columbia. In the summary section, we provide a list of additional resources on adaptive management and effectiveness monitoring in British Columbia.

KEYWORDS: *adaptive management, biodiversity, effectiveness monitoring, forest management.*

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Introduction

Increased public concern and market pressures have broadened the goals of forest management to include public values such as biological diversity within sustainable forest management planning. Biological diversity (or biodiversity) refers to life in all its forms, and the habitats and natural processes that support life. The term encompasses:

- *genetic diversity*, or the genetic variation among individuals of the same species;
- *species diversity*, or the number of different plants, animals, fungi, and simple organisms such as bacteria and protozoa; and
- *ecosystem diversity*, or the variety of ecosystems and the different ways they function. Ecosystem diversity can include both the organisms and the interactions between them and their environment (e.g., fire, climate, decay, and predator–prey relationships) (British Columbia Ministry of Environment, Lands and Parks and B.C. Ministry of Forests 1999).

Biodiversity is a concern because it is highly valuable. It yields economic benefits through healthy and functioning ecosystems, has intrinsic value as it is essential to maintain life, and offers other benefits such as recreational opportunities (Bunnell *et al.* 2004). Conserving biodiversity within British Columbia's publicly owned forests is a core objective of provincial legislation through the *Forest and Range Practices Act (FRPA)*. Conservation of biodiversity is also a core objective of third-party forest certification schemes, such as those developed by the Forest Stewardship Council (FSC), the Canadian Standards Association (CSA), and the Sustainable Forests Initiative (SFI). The Canadian Council of Forest Ministers (CCFM; www.ccfm.org) also designates biodiversity conservation as one of the six core objectives, or *criteria*, that must be addressed for a company to achieve sustainability in its forest management practices (Canadian Council of Forest Ministers 2003). To address both legislated requirements and requirements of certification schemes, forest managers must measure the strategies designed to conserve biodiversity and determine whether they are actually achieving this objective on managed forest land.

Forest management for biodiversity is challenged by great uncertainty over how ecosystems work and how they are affected by both stochastic variation and forestry practices (Noss and Cooperrider 1994; Mulder *et al.* 1999; Lindenmayer and Franklin 2002). Natural and human-induced alterations in forests can generate

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unpredictable changes that are difficult to modify because of long rotation times. Facing uncertainty, managers must take an ongoing learning approach, where management interventions are treated as “experiments” and new information is collected through monitoring. Such an accelerated learning process is referred to as “adaptive management” (Holling 1980; Walters 1986). Lindenmayer and Franklin define adaptive management as:

the acquisition of additional knowledge and the utilization of that information in modifying programs and practices so as to better achieve management goals. (Lindenmayer and Franklin 2002:260)

Adaptive management recognizes the lack of knowledge about biodiversity and ecosystem function, and integrates a continual learning process into management.

The adaptive management process relies on monitoring. Monitoring is essential to assess the level of success at achieving objectives, and consequently to improve management (Noss and Cooperrider 1994; Mulder *et al.* 1999; Prabhu *et al.* 2001; Lindenmayer and Franklin 2002; Bunnell *et al.* 2003). Ongoing monitoring helps to adjust management decisions and strategies, revise and rank monitoring questions and data needs, shorten lists of focal species and other measures, revise thresholds, and validate and improve models. Without monitoring, forest managers are unable to make necessary adjustments to meet the goals and targets of sustainable forest management.

In this extension note, we explain how to assess success at achieving biodiversity objectives. We describe the main steps of the adaptive management process and focus on the importance of *effectiveness monitoring* as a critical component of the learning cycle used in adaptive management.

The approach outlined here summarizes information from the “Biodiversity and Forest Management in British Columbia” Web site (Bunnell *et al.* 2004;

www.forestbiodiversityinbc.ca). This Web site examines management for biodiversity objectives in the forests of British Columbia, and provides current and feasible examples of indicators used to assess the effects of forest practices on biodiversity. A case study at the end of this extension note illustrates how these indicators have been implemented, or explored, by Weyerhaeuser, Canadian Forest Products, and Tembec. Additional resources on adaptive management and effectiveness monitoring as they relate to forest management in British Columbia are also noted in the final section. Ultimately, this extension

note provides forest managers with a general guide on how to implement a biodiversity effectiveness monitoring strategy within an adaptive forest management program.

Assessing Success at Achieving Biodiversity Objectives

Figure 1 outlines the main steps for assessing whether you have been successful at achieving biodiversity objectives within an adaptive management framework. For an adaptive management program to reach its

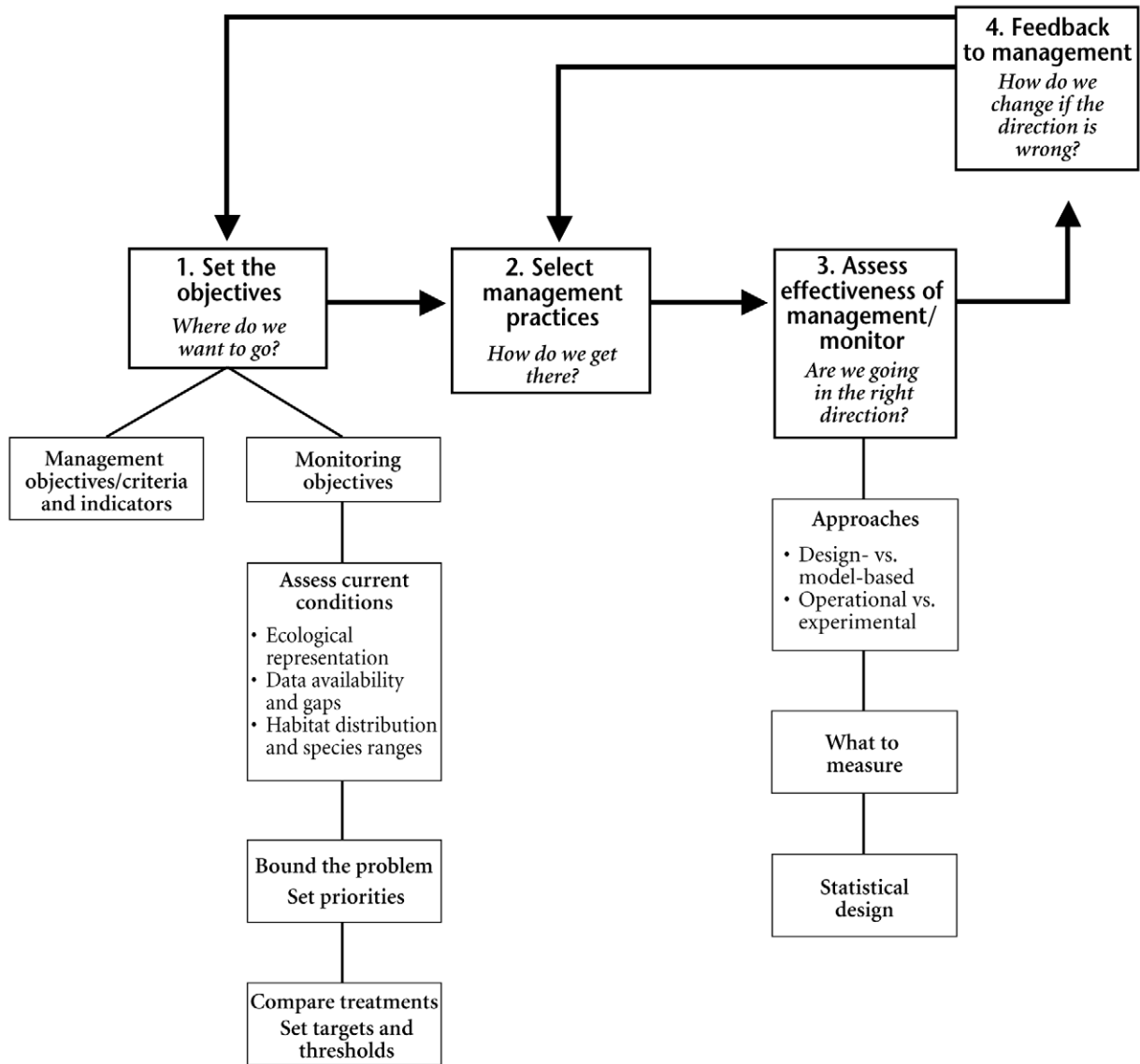


FIGURE 1. Steps to assess success at achieving biodiversity objectives based on the main steps of an adaptive management process. Source: Bunnell *et al.* (2004).

theoretical promise, it must address the following four questions faced by managers (Bunnell *et al.* 2003).

1. Where do we want to go?
 - Setting clear objectives and criteria
 - Setting initial thresholds, targets, or comparisons
2. How do we get there?
 - Choosing the management practices
 - Providing comparisons and mechanistic explanations
3. Are we going in the right direction?
 - Assessing the effectiveness of management (monitoring)
 - Assessing thresholds and evaluating comparisons
4. How do we change if the direction is wrong?
 - Providing feedback to management

We briefly describe each of these steps and emphasize how they can help to define what should be monitored in order to determine the effectiveness of forest management practices at achieving biodiversity objectives.

STEP 1: Where Do We Want To Go?

Setting clear objectives for forest management is critical. The fundamental goal of monitoring is to assess whether the objectives have been attained. Monitoring for success thus requires clear objectives. Usually two groups of objectives are important—the objectives of management, and the objectives of the monitoring program. Management objectives apply to the entire tenure or management area; the objectives of the monitoring program may only apply to specific features of the management area.

Management Objectives

The overarching objective of forest management is often set within a “Criteria and Indicator” framework. This framework provides a consistent method of describing the objectives and of measuring progress towards achieving those objectives. *Criteria* are the core components that must be addressed to meet the broadest objective (i.e., sustainable forest management). Success in addressing the criteria can be quantitatively and qualitatively described using *indicators*, or entities that are believed to be measurements of each criterion. The underlying assumption is that indicator measurements taken over time will show trends in the progression towards achieving the overarching objective of sustainable forest management. Throughout the learning process, the objectives may change in response to shifting values, and require adjustments of the practices.

Monitoring Objectives

In the case of the criterion related to sustaining biodiversity, the monitoring program evaluates the success of forest practices in achieving this broad criterion. Inevitably, more uncertainty exists about planned forestry activities than can be monitored within a single program. To be effective, the monitoring itself must be focused. To define focused monitoring objectives, the following three steps should be addressed.

1. Ask the key questions – Key monitoring questions will depend on the specific objectives, the practices implemented to achieve those objectives, and what we know about the current conditions. These questions provide a set of hypotheses and direct monitoring to areas in which management requires information to adjust activities and avoid unplanned and undesirable outcomes. In this sense, the link between monitoring and decision making begins with the formulation of monitoring questions (Mulder *et al.* 1999; Bunnell *et al.* 2003). To determine important questions, undertake the following steps.

- Consider the overarching objectives set by Criteria and Indicators (see, for example, www.ccfm.org/2000pdf/CI_Booklet_e.pdf) or by FRPA or other relevant legislation.
- Consider the management objectives specific to an area or company, such as Land and Resource Management Plans (LRMPs), Sustainable Forest Management Plans (SFMPs), or similar management plans. A management plan will determine which management practices should be adopted. The management practices then become hypotheses to be evaluated by the monitoring process (Noss 1999).
- Identify the current state of biodiversity in the area of concern. Managers must be informed about the biological significance of the managed forests to avoid inappropriate management decisions that would compromise biodiversity (Noss 1999). Current conditions may be assessed first by evaluating the ecological value of the reserve areas and ecosystem representation in the management unit. This approach determines whether a reasonable proportion of each ecosystem type is maintained in an unmanaged state over the long term and helps to identify the ecosystem types that will most likely be lost or affected by forest practices (Perry and Huggard 2003; Wells *et al.* 2003). Existing data and knowledge gaps also should be identified. Finally, establishing the spatial distribution of ecosystems, selected structural components, and ranges of species of concern may raise issues otherwise left undefined.

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2. Reduce to manageable scope, or bound the problem

– In most cases, when biodiversity is initially assessed, more questions remain than resources to address them. Bounding the problem helps to identify the areas of uncertainty and risk that require immediate attention. The process of bounding the problem begins with asking the key monitoring questions. These questions provide a set of hypotheses that direct monitoring to areas in which management requires information to adjust activities and avoid unplanned and undesirable outcomes. Bounding the problem identifies the relevant monitoring questions and sets priorities to determine the main questions or problems on which the adaptive management program should focus.

Available resources for monitoring are likely limited; therefore, ranking or setting priorities shifts the focus to questions that present higher uncertainty and risks. Questions selected for monitoring should be ranked according to priority and assigned to specific objectives. Which practices and objectives require immediate attention and are more likely to have an effect on biodiversity? Data needs may then be ranked accordingly.

3. Assess how questions might be answered – We can answer a question either by comparing management alternatives to see which is better at meeting objectives, or by comparing management options to external targets or thresholds. Knowing which comparisons are most informative and whether targets or thresholds are needed (and the ability to define those) will influence the type of questions asked, the priorities allocated to those questions, and the management objectives set.

Management practices can be compared when we know which alternative management actions are operationally realistic (e.g., clearcutting vs. 15% variable retention vs. 30% variable retention), and which are outside the range of normal operations (e.g., 70% retention to achieve a specific local need or restoration activities).

Targets and thresholds are rarely available in resource management, although natural benchmarks (e.g., unmanaged areas such as old growth, or intensively managed areas such as clearcuts) may be used. Targets are often set to avoid crossing ecological thresholds. They can be established by governments through regulations (e.g., the “Results-based Code” may require low turbidity levels in water), by certifying bodies (e.g., certifiers may require that a certain proportion of each ecosystem be kept unmanaged), or by scientific evidence (e.g., the literature may indicate “natural” amounts of snags for an ecosystem).

Thresholds are used to specify amounts or levels of different resources that will trigger a management action. They serve as “early warning systems.” Reaching a threshold does not imply irreparable damage; rather, it indicates the need to examine, identify, and possibly implement corrective measures. Although no universal standards exist, we can set initial thresholds by using syntheses of available data, model projections of known relationships, or reasoned guesses (for more details on thresholds, see Bunnell *et al.* 2004). Initial thresholds will require refinement within the adaptive management program. Monitoring may reveal the need to adjust thresholds instead of taking management actions.

STEP 2: How Do We Get There? Selecting Management Practices

The planning and practices implemented must be selected before designing a monitoring plan. Sustainable forestry cannot be implemented without a plan that includes practices intended to achieve specified objectives. Before assessing the effectiveness of management, we must first select what we will do to attain success (Bunnell 2003; Bunnell *et al.* 2003). The right questions can only be asked, and possibly answered through monitoring, when a specific set of practices believed to help achieve the goals is first adopted and implemented.

STEP 3: Are We Going in the Right Direction? Assessing Effectiveness of Management by Monitoring

Kinds of Monitoring

The level of success at achieving objectives is assessed by monitoring at various spatial and temporal scales (Noss and Cooperrider 1994; Mulder *et al.* 1999; Prabhu *et al.* 2001; Lindenmayer and Franklin 2002; Bunnell *et al.* 2003). Five broad types of monitoring used with natural resources include the following:

compliance, implementation, validation, effectiveness, and refinement monitoring.

Compliance monitoring assesses whether the required management guidelines defined by regulations and certification schemes were implemented as planned (e.g., wildlife tree patch size). It is a comparison to external regulations (Noss and Cooperrider 1994; Bunnell 2003; Bunnell *et al.* 2003). It answers the question: “Have we done what we were told to do?”

Implementation monitoring assesses whether practices were implemented as planned and scheduled within the management plan. It is a comparison to internal expectations (Noss and Cooperrider 1994; Bunnell 2003; Bunnell *et al.* 2003). It answers the question: “Have we done what we said we would?”

Validation monitoring determines whether goals were actually met as a consequence of the management activities, rather than because of other factors. It may be used to validate processes such as ecosystem mapping and models. It answers the question: “Were the goals met because of what we did?”

Effectiveness monitoring assesses the extent to which management strategies were effective in achieving their goals (Noss and Cooperrider 1994; Mulder *et al.* 1999; Bunnell 2003; Bunnell *et al.* 2003). It answers the question: “Did our actions achieve our objectives?” For example, monitoring post-harvest retention of downed wood alone provides no information about potential, positive effects on biodiversity. Monitoring the persistence of a population that depends on downed wood should, on the other hand, indicate whether downed wood retention was effective in contributing to biodiversity. Effectiveness monitoring also evaluates and refines initial ecological thresholds. It may reveal the need to adjust thresholds.

Further developed, effectiveness monitoring becomes “refinement monitoring.” *Refinement monitoring* answers the question: “Can we achieve our objectives better, faster, or more cheaply?” It extends knowledge beyond common practices, usually with very specific questions in mind, and requires an experimental design. It may sample the widest range of available practice including rare, but informative, extremes or combinations. The approach is synonymous with research. Refinement monitoring is most helpful when the learning is focused on probable causal mechanisms of response, potentially new but relatively untried management practices, or ways of increasing cost effectiveness (Bunnell 2003).

Approaches to Effectiveness Monitoring Design

When designing a program for effectiveness monitoring, there are two major distinctions in the approaches to take. One is the distinction between using a design-based versus a model-based approach (Bunnell 2003). The other distinction is between undertaking active (experimental) adaptive management and passive (operational) adaptive management. The choice of approach depends largely on the question addressed; monitoring programs usually benefit from some combination.

Design-based approaches rely on the sampling design to gather the information. Sampling design must be carefully planned. The sample size must be large enough to make reliable inferences about the investigated population (assuming that the designs are applied correctly); however, large samples may be costly. Design-based approaches are useful when comparing different treatments (e.g., dispersed vs. group retention in a variable retention harvesting system).

Model-based approaches rely on a relatively small number of representative sites, sometimes called “sentinel sites” (Bunnell 2003). Sentinel sites are intensively studied to construct a detailed model of some ecological process. Each site is selected to represent a certain class of ecosystem, and is sensitive to specific stressors for which detection of trends should be relatively easy (Jassby 1998). This model is then applied more widely to similar sites or locations. Model-based approaches can be more efficient at collecting and using a variety of information. It can prove extremely difficult, however, to find “representative” sites. Site selection may be problematic and depends mainly on how well we understand the variability, the magnitude of the “noise,” and responses to specific stressors in ecosystems (Jassby 1998). Thus, it may be difficult to generalize, or extrapolate, results from sentinel sites.

The operational approach (i.e., passive adaptive management) uses operational sites that are immediately available. It is useful when comparing current harvesting or silvicultural methods, and can include retrospective studies of sites harvested in the past (Lindenmayer *et al.* 2000). This approach is necessary to evaluate operational performance, but treatment comparisons may be limited.

The experimental approach (i.e., active adaptive management) creates and tests a wide range of treatments against each other. It offers greater possibilities for comparison of treatments, and contributes to

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refinement monitoring as well as effectiveness monitoring (Mulder *et al.* 1999; Bunnell 2003; Bunnell *et al.* 2003). This approach often is used to test or evaluate existing models; however, it can be more costly than the operational approach.

What to Measure?

Measures and sampling units are selected based on the monitoring questions derived from the indicators of biodiversity (e.g., the case study at the end of this paper provides possible indicators and associated measures of biodiversity). When collecting data, we must ask:

- What will we do with these data? and
- Will the data and design be sufficient to answer the question?

Useful measures generally have some of the following characteristics.

- They are relevant to the management activities.

- They are practical and easy to measure in a cost-effective manner.
- They are sensitive to stresses on the system.
- They respond to stresses in a predictable way.
- They predict changes that can be averted by management actions.
- They reflect known or suspected cause–effect relationships between system components and reflect underlying ecosystem processes.
- They have a high signal-to-noise ratio (i.e., information can be differentiated from background variation).

For more information on what makes a good indicator, see www.for.gov.bc.ca/hfp/frep/3_indicators.html and Bancroft *et al.* 2005.

Table 1 presents the advantages and disadvantages of monitoring habitat versus species. Both should be

TABLE 1. Monitoring forest habitat components versus species (Bunnell *et al.* 2004)

Monitoring forest habitat components		Monitoring species	
Advantages ^{a,b}	Disadvantages ^b	Advantages ^b	Disadvantages ^{b,c}
<ul style="list-style-type: none"> • Cost-effective • Already established inventory programs (e.g., forest cover) • Forest management is focused on vegetative communities • Permits comparisons to habitat benchmarks 	<ul style="list-style-type: none"> • Alone, it may fail to indicate whether the provision of habitat structure retained (in harvestable and protected areas) can maintain productive populations of species over time 	<ul style="list-style-type: none"> • Species indicate whether the provision of habitat retained is sufficient to maintain populations of species over time • Permits comparisons to habitat benchmarks. Trends in population provide an early warning system • Helps refine relationships with habitat to allow modelling over long time periods and large areas • Helps identify problems with population persistence where fine-scale monitoring needs to be focused • The public sees maintaining species as the ultimate measure of success or failure at maintaining biodiversity 	<ul style="list-style-type: none"> • Costly • Its application may be unsuccessful if inappropriate species are selected • Limited resources and logistic issues do not allow the monitoring of all species. Informative taxa must be selected • Selection of species is controversial • Misleading tendency to use single species (often rare or vulnerable) or groups of species as direct indicators of biodiversity throughout the whole landscape

^a Bunnell *et al.* (2003)

^b Mulder *et al.* (1999)

^c Lindenmayer *et al.* (2000), Lindenmayer (1999), Kneeshaw *et al.* (2000), Lindenmayer and Franklin (2002), Noss (1990), Landres *et al.* (1988), and Lambeck (1997).

monitored to determine whether the habitat retained actually maintains productive populations of species over time.

Statistical Design

The objective in monitoring is to attain credible guidance from statistical inference (Bunnell *et al.* 2004). The monitoring program implemented must therefore collect unbiased measurements of operational performance over time, and have sufficient statistical power to detect meaningful changes in the values of the indicators. Sampling methods should be selected according to appropriate temporal and spatial scales and appropriate measures.

A number of papers have discussed the importance of statistical design in monitoring (e.g., see Lindenmayer *et al.* 2000). To be robust, a statistical design should:

- compare management options using a number of treatments;
- have a sufficient number of replicated treatments to account for spatial heterogeneity and random variation, and to provide error estimates;
- disperse the replicates among several locations to avoid bias due to characteristics of specific areas;
- use stratification to detect the interactions between treatments and environmental variables;
- allocate enough time to the monitoring process to establish treatment effects and distinguish them from climatic fluctuations and stochastic events;
- meet the statistical assumptions (e.g., the populations are normally distributed); and
- consider statistical power when determining sample size (Bunnell *et al.* 2004).

To ensure that the statistical design is adequate, a statistician should be consulted when designing adaptive management programs and determining indicators.

STEP 4: Feedback To Management

The adaptive management framework integrates a continual learning process through a management loop. Planning must ensure that the management loop will be closed to allow feedback to management. Consider the following points.

- The management system must formally incorporate ways to receive information and adjust planning and practice. The monitoring plan must integrate details such as “who” will analyze and interpret the data,

and “how” the information will be maintained and transmitted to managers.

- Monitoring results must be presented simply, point out relative weaknesses, show improvement; the decision-making groups must assess what the best options are, or if current ones are satisfactory (Bunnell *et al.* 2003; Bunnell and Dunsworth 2004).
- Any decisions on best options must be based on values, especially tolerance of ecological risk and assumptions about the relative values of the managed land base. For example, potentially competing values exist around sapsuckers, timber loss, and worker safety. The decision does not rest solely with scientists (Bunnell *et al.* 2003).
- Sufficient funding must be provided to analyze, interpret, maintain, and transmit the data and results to managers.

Implementing an Effectiveness Monitoring Program: Case Study

In this section, we describe a criterion and broad indicators that have proven effective at guiding adaptive management and monitoring for biodiversity on forest land in British Columbia. This scheme has been implemented through the Coast Forest Strategy on Weyerhaeuser’s managed forest lands in coastal British Columbia, in which stand-level variable retention and landscape zoning are used to maintain biological diversity and ecological processes on Weyerhaeuser’s Coastal Timberlands (see www.forestry.ubc.ca/conservation/forest_strategy/default.htm for more information). The approach was developed through a partnership involving Fred Bunnell, Laurie Kremsater, and David Huggard, of the University of British Columbia’s Centre for Applied Conservation Research, and Weyerhaeuser.

The Criterion

Establishing clear objectives for biological diversity is particularly difficult because of the complexity in defining biodiversity for operational purposes (Bunnell 1998; Delong 1996). Because a scientifically credible and operational definition of biological diversity remains elusive (DeLong 1996), interim measures of biological diversity must be used. We must define biodiversity in a scientifically credible way that will guide management decisions. A scientifically credible surrogate for the complexity embedded in the term “biodiversity” is the objective, or criterion, of *maintaining well-distributed, productive populations of species and their associated values*

(Bunnell 1998). Associated values include ecosystem processes and habitat structures and patterns necessary to sustain species.

The Indicators

To assess whether the objective (criterion) has been attained, three broad indicators have been developed.

- Indicator 1 is a coarse-filter approach using ecological representation – Ecologically distinct ecosystem types are represented in the non-harvestable land base to maintain lesser known species and ecological functions.
- Indicator 2 is a medium-filter approach, maintaining habitat – The amount, distribution, and variability of stand and forest structures important to sustain biological diversity are maintained over time.

- Indicator 3 is a fine-filter approach, maintaining organisms – Productive and well-distributed populations of forest-dwelling species are maintained over time.

The Sub-indicators

Table 2 presents several sub-indicators, or measures, for each of these broad indicators. Note, however, that sub-indicators for Indicator 3 (organisms) will vary across the province and for particular questions (Bunnell *et al.* 2003). When selecting focal species for monitoring, a number of points should be considered. These points include selecting a focal species that is forest-dependent and sensitive to change in its habitat. A change in population should result from forest management rather than from other changes in the system. The focal species monitored should represent a range of body sizes, life

TABLE 2. Example of sub-indicators for ecological representation (Indicator 1) and habitat (Indicator 2) (Bunnell *et al.* 2004)

Sub-indicators for ecological representation	Sub-indicators for habitat and landscape features
<ul style="list-style-type: none"> • Amount of forest that will not be harvested by ecosystem type (biogeoclimatic ecosystem classification variant or site series grouping) • Amount of forest that will not be harvested by type and degree of constraint (e.g., fully protected over the long term, inoperable, ungulate winter ranges, wildlife habitat areas, old growth management areas, unstable slopes, riparian areas, commercially non-productive forest, partially constrained for visuals) • Amount of forest interior that will not be harvested • Age-class distribution of forest that will not be harvested • Site-productivity distribution of forest that will not be harvested 	<ul style="list-style-type: none"> • Live trees (species, DBH, height, canopy height) • Snags (species, DBH, height, decay class) • Coarse woody debris (species, diameter, length, height above ground) • Cover layers (litter, moss, herb, shrub, canopy) • Dominant vegetation species • Site series • Horizontal heterogeneity • Growth and decay of live tree • Fall and decay of deadwood • Age-class distribution • Patch-size distribution (although defining a patch is problematic and arbitrary) • High contrast edge length • Road densities • Roadless areas • Stream crossings

histories (e.g., specialists and generalists, various trophic levels, residents and migrants), and habitat features, and should respond at various scales. A cost-effective sampling protocol should be available. The focal species should include species other than those Blue- and Red-listed by the British Columbia Conservation Data Centre because rare species usually are not useful for evaluating effectiveness of practices or for assessing whether the first two indicators capture the needs of most species. Stewardship responsibility, borne by the government of British Columbia or the company, should also be considered during species selection.

Feedback to Management

Examples: Representation

Management feedback from the monitoring of ecological representation would focus on identifying poorly represented ecosystem types or concerns with the spatial distribution of the non-harvestable land. Management tools to improve weaknesses in representation include:

- designating or relocating Old Growth Management Areas;
- enhancing stand-level retention practices in poorly represented ecosystems;
- moving discretionary reserves;
- developing alternative strategies (e.g., old-growth restoration or conservation covenants); and
- buffering non-harvestable areas with higher retention stands or using landscape planning tools to enhance interior, non-harvestable forest.

Representation monitoring also indicates priority ecosystems for the other portions of the monitoring program. Areas most critical to monitor are those with the least amount left in the unmanaged land base.

Examples: Habitat and Landscape Structures

Feedback to management from monitoring stand-level retention focuses on identifying the weakest points by comparing managed stands to benchmarks or to known habitat requirements of organisms. Comparisons of alternative practices can suggest best options to improve weak points, or improvement can come directly from changes in operational practices in the field. Monitoring operational blocks through time can document progress towards improving stand-level habitat retention. Feedback at the landscape level most likely will be through simulations of alternative planning scenarios. The weakest points in habitat structure retention, at

harvest or projected through the rotation, can help focus the organism monitoring on groups that are most sensitive to those structures. Alternatively, organism studies may identify additional habitat features that should be incorporated into the structural monitoring. Habitat structure monitoring also will contribute to refining our definitions of “ecologically distinct ecosystem types” used in monitoring Indicator 1.

Examples: Organisms

Information on species feeds back into management in several ways.

- Occurrence of species can be used to examine reductions or expansions in ranges to indicate potential problems or successes.
- Trends in populations can trigger closer scrutiny to discover mechanisms.
- For species whose occurrence or population can be linked with habitat elements or landscape features, management actions to increase the supply of those elements can be implemented.
- Information on species–habitat associations helps refine relationships to allow modelling over large areas and long timeframes. As models increase in their predictive ability, they are better able to guide and improve practices.

An example of feedback and the challenges associated with creating feedback are discussed in Bunnell and Dunsworth (2004).

Conclusion and Additional Resources

Effectiveness monitoring is an integral part of the adaptive management process to achieve biodiversity objectives. In this extension note, we described the four steps in the adaptive management process, with an emphasis on how effectiveness monitoring can determine whether the key objectives regarding maintenance of biodiversity are being met. The approach described here is summarized from the “Biodiversity and Forest Management in British Columbia” Web site (see www.forestbiodiversityinbc.ca). This site is authored by scientists from the University of British Columbia’s Centre for Applied Conservation Research and co-sponsored by three British Columbia government ministries and the FORREX Forest Research Extension Partnership. This approach was implemented in a very comprehensive manner by Weyerhaeuser to evaluate and refine the Coast Forest Strategy (see www.forestry.ubc.ca/conservation/forest_strategy/)

Effectiveness monitoring is an integral part of the adaptive management process to achieve biodiversity objectives.

[default.htm](#)). It is also being explored by at least two other companies in British Columbia.

Other resources on adaptive management and effectiveness monitoring, particularly as they relate to forest management within British Columbia, are presented below. Although these resources are related to British Columbia, they can point readers to additional Canadian and international information on the issues of adaptive management and effectiveness monitoring within natural resource management.

Resources on Adaptive Management and Monitoring in British Columbia

- The British Columbia Ministry of Forests and Range has amassed considerable information on adaptive management, including case studies, publications, and links to other adaptive management Web sites, at: www.for.gov.bc.ca/hfp/amhome/amhome.htm
- Among other goals, the *Forest and Range Practices Act* Resource Evaluation Program (FREP) aims to assess the effectiveness of *FRPA* in achieving stewardship of the 11 resource values identified under the *Act*. A number of resources on adaptive management and effectiveness monitoring (as well as other types of monitoring) are available at: www.for.gov.bc.ca/hfp/frep/index.html
- In collaboration with the B.C. Ministry of Water, Land and Air Protection, the University of British Columbia, and Symmetree Consulting Group, the B.C. Ministry of Forests produced a training guide for a one-day workshop on monitoring and evaluation approaches. This document provides a framework for monitoring and evaluation as part of the adaptive management approach, and describes four case studies. Links to more detailed information on the four case studies reviewed are also included. This document is available at: www.for.gov.bc.ca/ftp/HFP/external!/publish/FRPA%20Evaluation%20Program/repository/EE_Compilation.pdf

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Test Your Knowledge . . .

Assessing success at achieving biodiversity objectives in managed forests

How well can you recall some of the main messages in the preceding extension note?

Test your knowledge by answering the following questions. Answers are at the bottom of the page.

1. This paper emphasizes that effectiveness monitoring is required to determine how well your management practices are meeting objectives. Of the statements below, which one is most likely to have resulted from data collected in an effectiveness monitoring program?
 - A) Our monitoring program tells us that we have left an average of four wildlife trees per hectare, so we know we have met the retention objective required by regulations.
 - B) Through monitoring, we have determined that we have met our management target for the quantity of downed wood left following variable retention harvest.
 - C) Our monitoring program tells us that woodpecker population levels have remained constant in areas harvested with 20% dispersed retention, while populations decreased in areas harvested with 10% retention.
 - D) We have monitored our practices and determined that we are meeting our target of 80% of roads being de-activated following harvest.
2. Which of the following is the first step in setting up an adaptive management and monitoring program?
 - A) choosing appropriate measures for your monitoring program
 - B) gathering knowledge about what exists in your forest management area
 - C) finding someone to help you with data analysis and management
 - D) using the information collected from your ongoing monitoring program to plan your management strategies
 - E) developing clear objectives for your management practices
3. This paper introduces three indicators for the objective or criterion of “maintaining well-distributed, productive populations of species and their associated values.” Assuming your monitoring program reveals a problem with Indicator 1 (“ecologically distinct ecosystem types are represented in the non-harvestable land base to maintain lesser known species and ecological functions”), which of the following management options can help to address this problem?
 - A) relocating Old Growth Management Areas
 - B) enhancing stand-level retention practices in poorly represented ecosystems
 - C) using landscape planning tools to enhance interior, non-harvestable forest
 - D) all of the above