FIA Activity Guidance Document

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Activity Description - Terrestrial Biological and Physical Monitoring and Aquatic Biological and Physical Monitoring

Biodiversity Monitoring Guideline

This biodiversity monitoring guideline accompanies the FIA Activity Biodiversity Monitoring Standard and Checklist.

This guideline is intended to assist PwC and Recipients in developing and reviewing projects which are intended to monitor success (effectiveness) in sustaining biological diversity related to forest practices.

Managers and scientists are limited by great uncertainty about how ecosystems work, how they are affected by stochastic variation, and the effects of forest practices.[1,2,3] Both natural and human-induced changes in forests can generate unpredictable changes that are difficult to modify. Within this context, we need to improve and evaluate efforts intended to sustain biological diversity in managed forests. Management for biodiversity has increasingly attempted to learn from the consequences of management actions: "adaptive management". Adaptive management relies on monitoring of effects of management actions, then adjusting practices and policy in response to observed changes.[3]

Adaptive management recognizes the limited knowledge of biodiversity and ecosystem functions, and integrates a continual learning process within management. Lindenmayer and Franklin[4] 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*. Adaptive management seeks progressive improvement by clearly defining the problem, exploring alternatives and key uncertainties, treating each management intervention as an experiment, monitoring its development, and applying the outcomes through feedback to management.[4,5,6] Rather than relying solely on basic research, adaptive learning through management learns from experience and can proceed more quickly and more efficiently.[2,4]

Acknowledging that we have much to learn about managing for biodiversity, the 'biodiversity monitoring standard and checklist' are based on the main steps of an adaptive management process (Figure 1). For an adaptive management program to reach its theoretical promise it must address four questions faced by managers[7:]

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

3) **Are we going in the right direction?**
   Assessing the effectiveness of management (monitoring)
   Assessing thresholds and evaluating comparisons
   Comparisons and mechanistic explanations

4) **How do we change if the direction is wrong?**
   Feedback to management

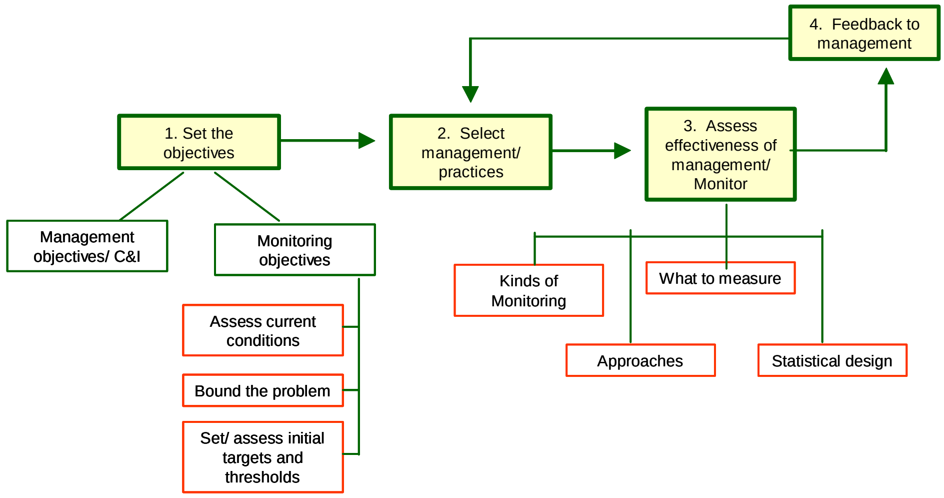

Figure 1. The main steps to adaptive management process.

Issues with adaptive management

The adaptive management approach has become widely accepted and integrated into policy. However, most challenges in applying the adaptive management approach are similar to those facing ecosystem management. Barriers lie in the socio-political arena and are not due to lack of scientific knowledge or capability. Examples of such barriers include the unwillingness of agencies or corporations to try new things or to risk short-term losses for possible long-term gains, or to change in response to new information.[8, 9, 10,11]

[1] Noss, R.F. and A.Y. Cooperrider. 1994. Saving natures legacy: Protecting and restoring biodiversity. Island Press, Washington, D.C. 416pp.
[2] Mulder, B.S., B.R. Noon, T.A. Spies, M.G. Raphael, C.J. Palmer, A.R. Olsen, G.H. Reeves and H.H. Welsh. 1999. The strategy and design of the effectiveness monitoring program for the northwest forest plan. USDA Forest Service, Pacific Northwest Station. PNW-GTR-437.
[3] Walters, C.J. 1986. Adaptive management of renewable resources. Collier MacMillan, New York, NY.
[4] Lindenmayer, F.B. and J.F. Franklin. 2002. Conserving forest biodiversity: A comprehensive multiscale approach. Island press, Washington, DC. 351pp.
[5] McComb, W.C., T.A. Spies and W.H. Emmingham. 1993. Douglas-fir forests. Managing for timber and mature-forest habitat. Journal of Forestry December: 31-42.
[6] Taylor, B., L. Kremsater and R. Ellis. 1997. Adaptive management of forests in British Columbia. BC Ministry of Forests, Forest Practices Branch, Victoria, BC. 93 pp.
[7] Bunnell, F.L., B.G. Dunsworth, D.J. Huggard and L.L. Kremsater. 2003. Learning to sustain biological diversity on Weyerhaeuser's coastal tenure. The Forest Project, Weyerhaeuser, Nanaimo, BC.
[8] Johnson, BL. 1999. Introduction to the special feature: adaptive management – scientifically sound, socially challenged? Conservation Ecology 3(1):10
[9] Walters, C. 1997. Challenges in adaptive management of riparian and coastal ecosystems. Conservation Ecology 1(2):1.
[10] Adaptive ecosystem management in the Pacific Northwest: a case study from coastal Oregon. Conservation Ecology 4(2):6.
[11] Bunnell, F.L., and B.G. Dunsworth. 2004. Making adaptive management for biodiversity work - the example of Weyerhaeuser in coastal British Columbia. Forestry Chronicle 80: 80:37-43

Adaptive management step 1 – Where do we want to go?

Setting the objectives

Setting objectives is critical. The fundamental goal of monitoring is to assess whether or not objectives representing success have been attained. Monitoring for success thus requires *clear objectives that describe success*. Usually two groups of objectives are important: objectives of management and objectives of the monitoring program. Management objectives apply to the entire tenure or management area, objectives of the monitoring program usually apply to *specific features* of the management program.

1. Management objectives

The overarching objective, such as successful sustainable forest management, often is set in a Criteria and Indicator framework. That framework provides a way to describe the overarching objective and to measure progress towards achieving it. Objectives also may be specified for the 11 values recognized within FRPA. At least three of these (Fish, Biodiversity and Wildlife) are components of biodiversity.

A set of core objectives or criteria allow the broadest objective to be conceptualised easily. *Criteria* are the core components that must be addressed to meet the broadest objective, such as 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 the criteria. Indicator measurements, taken over time, are intended to show trends in the progression towards achieving the overarching objective.

There are several similar frameworks of criteria and indicators for sustainable forest management, including those developed by the Canadian Council of Forest Ministers (CCFM) and the Montreal Process.[1] These provide guidance to the development of local criteria and indicators, particularly for companies seeking certification. Below are a criterion and broad indicators that have proven effective at guiding adaptive management and monitoring for biodiversity on forest land in British Columbia.

- **The Criterion.** Establishing clear objectives for biological diversity is particularly difficult because of the complexity in defining biodiversity for operational purposes.[2,3] Because a scientifically credible and operational definition of biological diversity remains elusive[2], interim measures of biological diversity must be used. We must define biodiversity in a scientifically credible way that will guide management decisions. The objective or Criterion of:

  maintaining well distributed, productive populations of species and their associated values

  is a scientifically credible surrogate for the complexity imbedded in the term biodiversity.[2]

  Maintenance of native species richness over large areas and long time periods is fundamental to sustaining biological diversity. Associated values include ecosystem processes, and habitat structures and patterns necessary to sustain species.

- **The indicators.** Three broad indicators of biological richness have been developed to assess whether or not the objective (Criterion) has been attained.

  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, directed to organisms: *Productive and well-distributed populations of forest-dwelling species are maintained over time*.

There usually will be several sub-indicators or measures for each of these broad indicators. Species Accounting Systems noted below attempt to integrate all these indicators into a summary expression of relative success.

Example sub-indicators (or measurables) for representation:

- Amount of forest that will not be harvested by ecosystem type (BEC 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 in forest 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
- Applied examples in British Columbia include [4,5,6]

Example sub indicators (or measurables) for habitat and landscape features:

- Habitat elements:
  - 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
  - Applied examples in BritishColumbia include [7, 8, 9]

- Habitat structure:
  - Horizontal heterogeneity
  - Vertical complexity
  - Systems capable of application are being developed for naturally complex forest types in BC.[8]

- Processes (for projection models):
  - Growth and decay of live trees
  - Fall and decay of deadwood
  - Approaches are being developed for application on Weyerhaeuser's coastal tenure.[10]

- Landscape features
  - Age class distribution
  - Patch size distribution (although defining a patch is problematic and arbitrary)
  - High contrast edge length
  - Road densities
  - Roadless areas
  - Stream crossings
  - Applied examples include [4, 11, 12]

Example sub indicators (or measurables) for organisms:

There are two broadly different approaches to addressing organisms: indicator species and species accounting systems. Indicator species will vary across the province and for particular questions.[7] The following features should be considered when selecting indicator or focal species:

- Ecological criteria:
  - Select species that are forest dependent and sensitive to change in their habitats.
  - Avoid selecting a species for which a change in population might not directly result from forest management but rather indirectly from other changes in the system.
  - Represent a range of body sizes and a range of life histories (specialists and generalists, various trophic levels, residents and migrants).
  - Select species that can be readily sampled; rare species cannot be.[7]
  - Choose species that use a range of habitat features and respond at a variety of scales.

- Methods criteria:
  - Choose species for which a sampling protocol is available,
  - Select species that are distributed so that statistically valid sampling is possible; sampling should be cost effective,
  - Ideally, select species that have control areas available.

- Status criteria:
  - Evaluate whether species listed by the BC Conservation Data Centre or SARA will be useful (usually rare species are not useful for evaluating effectiveness of practices or for assessing if the first two indicators are indeed capturing the needs of most species). There may be legal requirements for monitoring some forest-dwelling species listed by SARA.
  - Consider species whose population trends are declining or habitat is declining,
  - Choose species for which BC (or the company) bears considerable stewardship responsibility.

In short, informative focal species are forest-dwelling, sensitive to forest practices, practical to monitor, and provide information that can guide management. Disadvantages of selecting indicator species are summarized in Table 2. To create a useful approach typically requires careful design and several years of data. Examples that have reached that state in British Columbia include [8, 13, 14, 15]

Species accounting systems attempt to integrate all three indicators of biological diversity into a system that accounts for most organisms in the area.[16] By integrating what is known for the management area, the system itself helps reveal not only what practices are most likely to be having negative impacts, but what species most merit attention during monitoring. The systems help escape some of the initial guess work in determining indicator species. Such systems are still in their infancy. Examples in British Columbia include [8, 16, 17]

[1] Brand, D.G. 1997. Criteria and indicators for the conservation and sustainable management of forests: progress to date and future directions. Biomass and Bioenergy 13 (4/5): 247-253. See also www.forestbiodiversityinbc.ca/manage_approach_1.asp?id=174 and Mendoza, G. A and R.. Prabhu. 2003. Qualitative multi-criteria approaches to assessing indicators of sustainable forest resource management. Forest Ecology & Management. 174(1-3): 329-343.

[2] Bunnell F.L. 1998. Overcoming paralysis by complexity when establishing operational goals for biodiversity. Journal of Sustainable Forest Management 7:145-164.

[3] Delong, D.C. Jr. 1996. Defining biodiversity. Wildlife Society Bulletin 24:738-749.

[4] Huggard, D. and G. Dunsworth. 2003. Representation of ecosystems in non-harvestable forests. Weyerhaeuser Forest Project, Technical Project Summary #5.

[5] Wells, R.W., F.L. Bunnell, D. Haag, and G. Sutherland. 2003. Evaluating ecological representation within different planning objectives for the central coast of British Columbia. Canadian Journal of Forest Research 33: 2141-50.

[6] Wells, R.W., D. Haag, T. Braumandl, G. Bradfield and A. Moy. 2004. Ecosystem representation in the East Kootenay Conservation Program Study Area. Forest Investment Account Report. Centre for Applied Conservation Research. Vancouver, B.C. www.sfmportal.com/fia_listing.asp?Division=Radium

[7] Bunnell, F.L., B.G. Dunsworth, D.J. Huggard and L.L. Kremsater. 2003. Learning to sustain biological diversity on Weyerhaeuser's coastal tenure. The Forest Project, Weyerhaeuser, Nanaimo, BC.

[8] Gillingham, M.P., and J. Psyllakis. 2004. Lifeforms: structure and biodiversity. Partnership Agreement between Lignum Ltd. And the University of Northern British Columbia.
[9] Huggard, D. 2004. Weyerhaeuser BC Variable Retention Adaptive Management Program Habitat Monitoring 1999 to 2004 – Summary and Data Report. Prepared for: Bill Beese, Weyerhaeuser BC.
[10] Work funded by the FSP, preliminary reports are available from Fred Bunnell or Laurie Kremsater at UBC.
[11] See work on the Stream Crossing Quality Index by P. Beaudry and Associates with Canadian Forest Products, CACR at UBC, and BC MoWLAP.
[12] Weyerhaeuser (Coast) has performed analyses for various landscape-level features including road density, forest interior, and edge. The International Science Panel was unable to provide advice on credible thresholds of these measures to use to guide management action.
[13] Chan-McLeod, A, and P. Vernier. L. 2005. Effects of Variable Retention Harvesting on Songbirds 2004-05 Data Consolidation Report to Weyerhaeuser, Nanaimo, BC.
[14] Ovaska K. and Sopuck. L. 2005. Terrestrial Gastropods as indicators for monitoring ecological effects of variable retention logging practices: synthesis of field data, fall 1999 – 2003. Report to Weyerhaeuser, Nanaimo, BC.
[15] Pearsall, I. 2004 Study to assess efficacy of carabid beetles as ecological indicators in Operational VR sites in West Vancouver Island. Isobel A. Pearsall. Report to Weyerhaeuser, Nanaimo, BC.
[16] Bunnell, F.L. 2005. A species accounting system for northeastern British Columbia. Report to Canadian Forest Products.
[17] Bunnell, F.L.. 2003. Species accounting system for the east Kootenays. Report ot Tembec (BC) Inc.

2. Monitoring objectives

The monitoring program necessarily evaluates the success of the broad criterion or objective specified for sustaining biodiversity. However, there inevitably will be more uncertainty about the complex of activities that comprise forestry than can be monitored within a single program. The monitoring itself must be focussed to be effective. There are three important steps when defining monitoring objectives:
a) ask the key questions,
b) determine the effective scope of the monitoring (bound the problem), and
c) determine ways of answering the question.

a) Ask the key questions

Have our practices met our management objectives (desired outcomes)? Not all possible questions can be answered because of various constraints (funding, time, practical issues).

A monitoring design must ask the right questions to reduce statistical uncertainty, properly estimate parameters from noisy data, and assign probabilities to alternative hypotheses.[1] Monitoring questions depend on the objectives, the practices, and on what we know of the current conditions. They provide a set of hypotheses, and direct monitoring to areas where management requires information to adjust activities and avoid unplanned and undesirable outcomes. For this reason, *the link between monitoring and decision-making begins with formulating the monitoring questions.*[1,2]

Identify key questions by:

- Considering the overarching objectives set by Criteria and Indicators or FRPA.
- Considering management objectives specific to an area or company such as SFMPs or similar management plans.
- Establishing a plan and determining which
- management practices are to be adopted. The management practices become hypotheses to be evaluated by the monitoring process.[2,3]
- Identifying current state of biodiversity in the area of concern.

It is not critical to have extensive inventories to ask key questions. Often, choosing the most revealing questions simply means being well informed about the status of biodiversity in the management area. Such information is becoming increasingly available.[4] Current conditions

Why assess current conditions?

Because managers must be informed about the biological significance of the forests being managed, and avoid inappropriate management decisions that would compromise biodiversity [3]

For example, managers should assess the current situation of rare and ecologically important ecosystem types in their management unit. Integrating this information into decision making reduces the chances of compromising important ecosystems and associated species.

are then assessed to delineate what we know from what we don't know. For example, assessing current conditions can document what the habitat conditions are in the protected and managed areas, what types of data exist, and where knowledge gaps are prominent.

Information may be collected and synthesized to determine the extent, distribution, and condition of existing ecosystem types and selected species.[5,6] The synthesis helps identify knowledge gaps, data needs and helps develop robust models of species-habitat relations.

Four approaches are recommended:

- **Evaluate reserve areas for ecological value** – or perform an ecological representation or ecosystem analysis for the management area. Ecological representation is a coarse filter approach that determines whether forest planning maintains a reasonable proportion of each ecosystem type in an unmanaged state over the long term.[5,6] It helps identify the ecosystem types most vulnerable and likely to be affected by forest practices.

- **Identify existing biodiversity-related data** in the management area, and in surrounding or similar areas. Observations in other areas with similar types of ecosystems provide additional information often relevant to the management unit.

- **Determine spatial distribution** of ecosystems and selected structural components, and estimate known and extrapolated population ranges of known species of concern. Examining the spatial distribution of ecosystems and species may raise issues otherwise left undefined.

- **Assess impacts of proposed practices** on biodiversity in the management area. The practices may be novel, but there usually is sufficient information that probable impacts can be assessed or major information gaps exposed that aid focus on the most important questions.[2,7]

[1] Mulder, B.S., B.R.Noon, T.A.Spies, M.G.Raphael, C.J.Palmer, A.R.Olsen, G.H.Reeves and H.H. Welsh. 1999. The strategy and design of the effectiveness monitoring program for the northwest forest plan. USDA Forest Service, Pacific Northwest Station. PNW-GTR-437.
[2] Bunnell F.L., B.G. Dunsworth, D.J. Huggard, and L.L. Kremsater. 2003. Learning to sustain biological diversity on Weyerhaeuser's coastal tenure. The Forest Project, Weyerhaeuser, Nanaimo, BC.
[3] Noss, R.F. 1999. Assessing and monitoring forest biodiversity: A suggested framework and indicators. Forest Ecology and Management 115: 135-146.
[4] See pamphlet "Forest-dwelling endemics of British Columbia" from the Centre of Applied Conservation Research at UBC and www.forestbiodiveristyinbc.ca
[5] Huggard, D. and G. Dunsworth. 2003. Representation of ecosystems in non-harvestable forests. Weyerhaeuser Forest Project, Technical Project Summary #5.
[6] Wells, R.W., F.L. Bunnell, D. Haag, and G. Sutherland. 2003. Evaluating ecological representation within different planning objectives for the central coast of British Columbia. Canadian Journal of Forest Research 33: 2141-50.
[7] Bunnell, F.L., L.L. Kremsater, and M. Boyland. 1998. An ecological rationale for changing forest management on MacMillan Bloedel's forest tenure. Publication R-22, Centre for Applied Conservation Biology, University of British Columbia.

b) Determine the effective scope of the monitoring (bound the problem)

Step a) identified key questions and began bounding the problem. That step should have determined major issues, clarified management objectives and identified the management plan and practices to meet those objectives (those tasks are repeated below as a reminder). Often more questions will remain than resources to address them. Bounding the problem is meant to circumscribe the monitoring by focussing on areas of uncertainty and risk that require immediate attention, and avoiding issues subject to large influence beyond the practitioners' control. Priorities are then set defining questions or problems that are the main focus within the adaptive management program.

The following tasks are involved:

- **Determine the issues.** Specific issues will be raised following the assessment of current conditions. For example, the identification of rare and vulnerable ecosystem types will indicate areas of concern.
- **Establish the management objectives.** Setting management objectives will help define the problem and identify the areas that require immediate attention. Objectives, or criteria of success, must be stated clearly so that the means of assessing proximity to objectives are likewise clear.[1, 2, 3, 4, 5] If the objectives are unclear, the monitoring design may be poor (e.g. measuring the wrong variables), the results inconclusive, and the rest of the adaptive management cycle will be clouded with uncertainty.[1, 2, 6]

- **Identify the management plan and practices**. Managers must establish a plan and determine which management practices are to be adopted. The management practices become hypotheses to be evaluated by the monitoring process.[2, 7]

- **Identify data needs**. Assessment of current conditions indicates the broad knowledge gaps. Immediate needs in terms of specific data best suited to answer the specific monitoring questions must be identified.

- **Identify the relevant monitoring questions.** A monitoring design must ask the right questions to reduce statistical uncertainty, properly estimate parameters from noisy data, and assign probabilities to alternative hypotheses.[5] Monitoring questions depend on the objectives, the practices, and on what we know of the current conditions. They provide a set of hypotheses, and direct monitoring to areas where management requires information to adjust activities and avoid unplanned and undesirable outcomes. The link between monitoring and decision-making begins with the formulation of an agreement on the monitoring questions[2,5].

- **Rank the objectives/ questions, and data needs.** Available resources for monitoring will be limited. *Ranking or setting priorities is the most important step* because it focuses on questions that present higher uncertainty and risks. Questions selected for monitoring should be ranked according to priorities and assigned to specific objectives. What practices and objectives require immediate attention and are more likely to have an impact on biological diversity? Data needs may then be ranked accordingly.

[1] Noss, R.F. and A.Y. Cooperrider. 1994. Saving natures legacy: Protecting and restoring biodiversity. Island Press, Washington, D.C. 416pp.
[2] Bunnell F.L., B.G. Dunsworth, D.J. Huggard, and L.L. Kremsater. 2003. Learning to sustain biological diversity on Weyerhaeuser's coastal tenure. The Forest Project, Weyerhaeuser, Nanaimo, BC.
[3] Noss, R.F. 1990. Indicators for monitoring biodiversity: A hierarchical approach. Conservation Biology 4(4): 356-364.
[4] Noss, R.F. 1999. Assessing and monitoring forest biodiversity: A suggested framework and indicators. Forest Ecology and management 115: 135-146.
[5] Mulder, B.S., B.R.Noon, T.A.Spies, M.G.Raphael, C.J.Palmer, A.R.Olsen, G.H.Reeves and H.H. Welsh. 1999. The strategy and design of the effectiveness monitoring program for the northwest forest plan. USDA Forest Service, Pacific Northwest Station. PNW-GTR-437.
[6] Bunnell, F.L., and M. Boyland. 2002. Decision-support systems: it's the question not the model. Journal for Nature Conservation. 10:269-279
[7] Davis, L.S., K.N. Johnson, P.S. Bettinger and T.E. Howard. 2001. Forest management to sustain ecological, economic, and social values. 4th ed. New York, NY.

c) Determine ways of answering the questions

Often the best way to answer a question and to improve management is to compare management alternatives to see which is better at meeting objectives. That can determine which existing practice does better, provided an objective is clearly specified. Usually the context for better must be specified by comparison to some external targets (e.g., natural benchmarks) or estimated thresholds. Targets and thresholds are rarely well-established for resource management. Which comparisons are most informative, and whether targets or thresholds are needed (plus the ability to define those) will influence the type of questions asked, the priorities allocated to these questions, and the management objectives set.

Comparisons may be selected by…

- identifying alternative management actions that are operationally realistic (e.g., clearcutting, vs 15% variable retention, vs 30% variable retention)
- identifying alternative practices outside the range of normal operations (e.g., 70% retention to achieve a specific local need, restoration activities)
- identifying benchmarks to include in the comparison (e.g., unmanaged areas such as old growth, or intensively managed areas such as clearcuts)

Targets may be set by…

- governments through regulations (e.g., results based legislation 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)
- by scientific evidence (e.g., the literature may indicate 'natural' amounts of snags for an ecosystem). Targets based on scientific evidence would include areas for which literature or previous studies indicate amounts of habitat or structures that are needed for particular species or ecological functions. We may have evidence, for example, that 2 to 3 large snags per ha would be a useful target to maintain many woodpeckers

Sometimes targets are set to avoid crossing estimated ecological thresholds.

Thresholds are…

- *not* necessary if the adaptive management program is designed to compare responses among different treatments. It is still necessary to specify variables that will define the "better" response.

- used to specify amounts or levels of different resources that will trigger a management action.

- intended to be precautionary. Initially, thresholds must be estimated so that 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.

- rare in resource management. There are no universal standards to show how soon early action is needed.

- an integral part of effectiveness monitoring or adaptive management. Initial thresholds can be no more than estimates and will require refinement within the adaptive management program. Monitoring may reveal that the thresholds need adjusting instead of management actions being taken..

- relevant at both upper and lower levels (Figure 2).

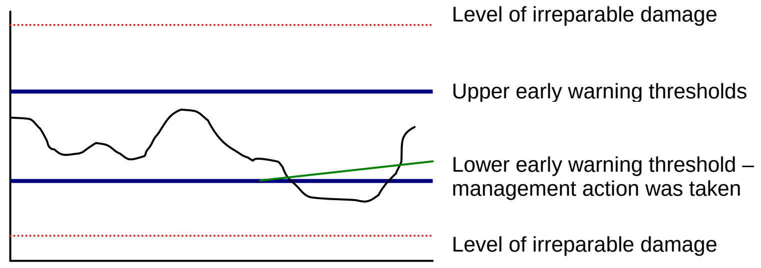

Figure 2. Resource over time. Upper, lower, and early warning thresholds.

For example, if amounts of a particular resource (e.g., dead wood) fall *below* a specified level, changes to forest planning and practices should be considered. For other resources the threshold specifies an upper limit. For example, if the per cent of harvested area *exceeds* a particular level of soil displacement, causes should be identified and practices altered to reverse the trend.

Three ways to estimate initial thresholds:

- **Synthesis of available data.** Data already collected by various groups (government agencies, naturalists, and consultants) can be synthesized and analyzed.

- **Projecting known relationships.** Consequences of forest practices are manifest over long periods and large areas. Present conditions and actions can have large future consequences. For example, the sustained provision of large snags 200 years from now requires that some trees be planted or designated now that will provide those future snags. Estimating *sustained* provision of a resource requires projecting relevant relationships now using simulation models. In this example, relevant relations include mortality rates, snag fall rates, and decay rates of trees.

- **Reasoned guesses.** Data are sometimes insufficient to permit reliable estimates of thresholds. For example, researchers relating coarse woody debris to forest-dwelling organisms have no agreed-upon protocols, so studies are extremely difficult to summarize and compare. That makes extraction of a threshold difficult but permits a reasoned guess.

The difficulties in establishing thresholds, and paucity of targets means that often the best way to improve management is to compare alternative practices with each other or to unmanaged or intensively managed benchmarks.

Adaptive management step 2 – How do we get there?

Selecting management practices

During adaptive management, the planning and practices to be implemented must be selected prior to 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, it is essential to identify what will be done to attain success.[1, 2] The right questions can only be asked or answered through monitoring, if a specific set of practices believed to help achieve the goals is first adopted and implemented. Some refer to these practices as "best management practices". This term is misleading. Practices should be termed "better" only if their outcome was monitored and proven favourable in helping to meet the objectives. Practices can only be "best " if compared with other practices through some experimental design.

Approaches to forest planning and practice are selected for social, economic and ecological reasons. MacMillan Bloedel chose to implement variable retention on its coastal holdings primarily for social reasons, but the ecological contributions had to be assessed.[3] Similarly, in the Interior Douglas-fir Zone, structure-based management appears the most effective approach to sustain vertebrate populations. Lignum (now Tolko) supported development of an approach to effectively relate vertebrates to the stand structures resulting from rather complex forest practices.[4] Where forests are simpler in species composition and structure, as in boreal forests, practices to maintain specific structures are not as necessary.[5,6]

[1] Bunnell, F.L., B.G. Dunsworth, D.J. Huggard and L.L. Kremsater. 2003. Learning to sustain biological diversity on Weyerhaeuser's coastal tenure. The Forest Project, Weyerhaeuser, Nanaimo, BC.
[2] Bunnell, F.L. 2003. Monitoring to Sustain Biological Diversity in British Columbia. Report to BC Ministry of Water, Land and Air Protection,Victoria, BC.
[3] Bunnell, F.L., L.L. Kremsater, and M. Boyland. 1998. An ecological rationale for changing forest management on MacMillan Bloedel's forest tenure. Publication R-22, Centre for Applied Conservation Biology, University of British Columbia.
[4] Gillingham, M.P., and J. Psyllakis. 2004. Lifeforms: structure and biodiversity. Partnership Agreement between Lignum Ltd. And the University of Northern British Columbia.
[5] Sustainable forest Management Plan for Fort St. John TSA at http://fsjpilotproject.com/sfmp.html
[6] Bunnell, F.L. 2005. A species accounting system for northeastern British Columbia. Report to Canadian Forest Products.

Adaptive Management step 3 – Are we going in the right direction?

Assessing effectiveness of management

Effectiveness of management, or the level of success at achieving objectives, is assessed by monitoring.[1, 2, 3, 4] There is no way to determine whether management strategies are effective, and no way to identify ways to improve management, without rigorous monitoring at various spatial and temporal scales.[2, 4, 5] Monitoring is the "process of checking, observing, and measuring outcomes for key variables, or specific ecological phenomena against a predefined quantitative objective or standard ".[6] Monitoring is the only way of assessing whether better or more effective practices are used, or of determining if targets or goals are met. It also is important in refining thresholds and indicating proximity to these. It helps evaluate initial thresholds and may reveal needs for adjustment.

Why monitor?

In a context of uncertainty, limited knowledge, and continuous learning, efforts to evaluate success of management practices proceed best through the framework of adaptive management. Effectiveness of management, or the level of success at achieving objectives is assessed through monitoring and results are used to continuously improve management.[1, 3, 4, 5] There is no way to determine whether management strategies are effective without rigorous monitoring at various spatial and temporal scales.[2 4, ,5]

[1] Lindenmayer, F.B. and J.F. Franklin. 2002. Conserving forest biodiversity: A comprehensive multiscale approach. Island press, Washington, DC. 351pp.
[2] Noss, R.F. and A.Y. Cooperrider. 1994. Saving natures legacy: Protecting and restoring biodiversity. Island Press, Washington, D.C. 416pp.
[3] Mulder, B.S., B.R. Noon, T.A. Spies, M.G. Raphael, C.J. Palmer, A.R .Olsen, G.H. Reeves and H.H. Welsh. 1999. The strategy and design of the effectiveness monitoring program for the northwest forest plan. USDA Forest Service, Pacific Northwest Station. PNW-GTR-437.
[4] Bunnell F.L., B.G. Dunsworth, D.J. Huggard, and L.L. Kremsater. 2003. Learning to sustain biological diversity on Weyerhaeuser's coastal tenure. The Forest Project, Weyerhaeuser, Nanaimo, BC.
[5] Prabhu R., H.J.Ruitenbeek, T.J.B. Boyle and C.J. Pierce Colfer. 2001. Between voodoo science and adaptive management: The role and research needs for indicators of sustainable forest management. Pp. 39-66 *In* Raison, R.J., A.G. Brown and D.W. Flinn. Criteria and indicators for sustainable forest management. CABI Publishing. IUFRO Research Series 7. Vienna.
[6] Dunster, J. and K. Dunster. 1996. Dictionary of natural resource management: The comprehensive single-source guide to natural resource management terms. UBC Press, Vancouver, BC. 363pp.

a) Kinds of monitoring

Monitoring natural resources in the United States commonly recognizes four broad types of monitoring: compliance, implementation, effectiveness, and validation monitoring.[1] These types can be refined by considering the specific questions the monitoring attempts to answer. The questions are presented in an order of increasing acceptance of responsibility below.

- *Have we done what we were told to do?* **Compliance monitoring** determines if the required management practices or guidelines defined by regulations and certification schemes were implemented as planned (e.g. wildlife tree targets). It is a comparison to external regulations.[1, 2 ,3]

Both **effectiveness monitoring and refinement monitoring** are part of adaptive management. Whereas effectiveness monitoring evaluates current practice, refinement monitoring asks questions like, do I have sufficient confidence in the underlying relations to apply them in novel ways?" or "can I attain the same ends more cheaply?"

- *Have we done what we said we would?*
  Implementation monitoring assesses if practices were implemented as planned and scheduled within the management plan. It is a comparison to internal expectations or plans. [1, 2 .3]

- *Did our actions achieve our objectives?*
  Effectiveness monitoring assesses the extent to which management strategies were effective in achieving their goals.[1, 2 ,3 ,4] For example, simply monitoring retention of downed wood after harvesting offers no information about whether this had a positive effect on biodiversity. However, a monitoring scheme that measures and assesses persistence of populations dependent on downed wood, can be used to assess whether its retention was effective.

- Were the goals met because of what we did?
  Validation monitoring determines whether goals were actually met as a consequence of the management activities, rather than because of other factors.[1,3] It may be used to validate processes like ecosystem mapping and models. Does the ecosystem mapping adequately reflect the actual ecosystem distribution in the field? Can the relationships modelled be generalized accurately?

- *Can we achieve our objectives better, faster, or more cheaply?*
  Refinement monitoring samples 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. Creating learning opportunities through experimental treatments beyond the normal operational range also is an integral part of refinement monitoring. In this case, 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.[3]

[1] Noss, R.F. and A.Y. Cooperrider. 1994. Saving natures legacy: Protecting and restoring biodiversity. Island Press, Washington, D.C. 416pp.
[2] Bunnell, F.L., B.G. Dunsworth, D.J. Huggard, and L.L. Kremsater. 2003. Learning to sustain biological diversity on Weyerhaeuser's coastal tenure. The Forest Project, Weyerhaeuser, Nanaimo, BC.
[3] Bunnell, F.L. Monitoring to sustain biodiversity in British Columbia. Module 1: Overview – goals, actions, monitoring, and indicators. Biodiversity Branch, BC Ministry of Water, Land, and Air Protection. Victoria.
[4] Mulder, B.S., B.R. Noon, T.A. Spies, M.G. Raphael, C.J. Palmer, A.R. Olsen, G.H. Reeves and H.H. Welsh. 1999. The strategy and design of the effectiveness monitoring program for the northwest forest plan. USDA Forest Service, Pacific Northwest Station. OR.

b) Approach to designing a monitoring program

There are two major distinctions in the approach to designing a monitoring program. One is the distinction between design-based versus model-based inference.[1] The other is between active (experimental) adaptive management and passive (operational) adaptive management. The distinctions help to determine the appropriate monitoring protocol.

Design-based versus model-based inference

- **Design-based approaches** derive their strength from the sampling design used to gather the information. A sufficiently large sample is randomly drawn from a specific target population (likely based on some stratification). Inferences from the sample to the population at large follow naturally. An advantage of design-based approaches is that there should be no question about the populations to which the findings apply (assuming that the designs are correctly applied). They are thus useful for comparisons between different populations (e.g., dispersed and group retention).

- A major drawback with design-based approaches is that they can require large sample sizes and the probabilistic sampling called for in the design can increase the cost of collecting data substantially. Careful attention to probabilistic sampling and the use of appropriate sampling designs can help alleviate some of these problems.

- **Model-based approaches** do not rely on random sampling, but on representative sites (sometimes called sentinel sites).[1] Sentinel sites are relatively small in numbers, and intensively studied for the purposes of constructing a detailed model (form of relationship) 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.[2] This model is then applied more widely to similar sites or locations. Model-based approaches can be more efficient than design-based approaches at collecting and using a variety of information.

- However, for model-based approaches it can prove extremely difficult to find "representative" sites. Using a small number of sites as indicators for the population at large, the so-called sentinel-site approach, is especially problematic. Site selection depends mainly on how well we understand the variability, the magnitude of the "noise", and responses to specific stressors in ecosystems.[2] Thus generalization, or extrapolation of results from sentinel sites may be difficult.

Operational versus experimental approaches [3]

- **The operational approach** (passive adaptive management) uses operational sites that are immediately available. It is useful for comparisons between current harvest or silvicultural methods. It thus can be important in effectiveness monitoring. The operational approach also includes retrospective studies of sites logged in the past to help collect information on forest disturbance relatively quickly and compensate for time lags.[4] Monitoring operational sites is necessary to evaluate operational performance but treatment comparisons are limited. It promotes adaptive management as an integral part of operations rather than being a separate research effort.[3]

- **The experimental approach** (active adaptive management) deliberately creates a wide range of treatments tested against each other. When well designed they contribute to refinement monitoring as well as effectiveness monitoring.[1, 3 ,5] The approach often is used to test or evaluate existing models used to project future consequences of different practices. The experimental approach offers larger possibilities for comparison of treatments but can be more costly than the operational approach. Each approach requires thoughtful design and each has advantages and disadvantages. The choice of approach depends largely on the question addressed. Monitoring programs usually benefit from some combination of the approaches.[3]

[1] Bunnell, F.L. Monitoring to sustain biodiversity in British Columbia. Module 1: Overview – goals, actions, monitoring, and indicators. Biodiversity Branch, BC Ministry of Water, Land, and Air Protection. Victoria, BC.
[2] Jassby, A.D. 1998. Interannual variability at three inland water sites: Implications for sentinel ecosystems. Ecological Applications 8(2): 277-287.
[3] Bunnell F.L., B.G. Dunsworth, D.J. Huggard, and L.L. Kremsater. 2003. Learning to sustain biological diversity on Weyerhaeuser's coastal tenure. The Forest Project, Weyerhaeuser, Nanaimo, BC.
[4] Lindenmayer, D.B., C.R. Margules and D.B. Botkin. 2000. Indicators of biodiversity for ecologically sustainable forest management. Conservation Biology 14(4): 941-950.
[5] Mulder, B.S., B R. Noon, T.A. Spies, M.G. Raphael, C.J. Palmer, A.R. Olsen, G.H. Reeves and H.H. Welsh. 1999. The strategy and design of the effectiveness monitoring program for the northwest forest plan. USDA Forest Service, Pacific Northwest Station. PNW-GTR-437.

c) Making comparisons or evaluating mechanisms

Learning occurs either by making comparisons or by understanding mechanisms. Data in themselves (e.g. large snags/ ha) do not improve learning nor help guide management unless compared to something or used to clarify a mechanism.[1] Making comparisons or exposing explanatory mechanisms both have advantages and drawbacks (Table 1). However, both should be considered in effectiveness monitoring design. Mechanistic explanations are often considered research, not monitoring, but are also necessary components to meet monitoring goals of efficient precision and generality of application.[1, 2] Without generality, findings or estimates cannot be projected over larger areas.

Table 1. Advantages and drawbacks when using effectiveness monitoring to make comparisons or clarify mechanisms in an adaptive management framework.

Comparisons	Mechanistic explanations
e.g.: Snag density under different levels of patch retention vs results from an alternative harvest method, a natural benchmark, or a target density established independently. *Possible outcome: recommendation of which patch retention method to favour to retain large, old snags – recommendation on which of the patch retention methods better met predetermined target values.*	*e.g.: Study of the mechanisms creating levels of snag retention – e.g. the rule of thumb fallers use to decide which snags to leave or to fall under different logging conditions.* *Possible outcome: Explanatory model designed to predict snag retention under a wide variety of real and proposed management options – possible predictions of additional variables not measured directly in the comparative approach (e.g., short snags, or non-merchantable live trees).*
Easier	More complicated (requires better understanding of the system – more measurements)
Precise	More assumptions
Lower cost	Higher cost
Application of the results limited to the specific cases compared	Has the potential to apply in a wide range of situations
	Permits generality and allows inference among comparisons not sampled directly. e.g., using habitat data to predict or explain species distribution.

[1] Bunnell, F.L. B.G. Dunsworth, D.J. Huggard and L.L. Kremsater. 2003. Learning to sustain biological diversity on Weyerhaeuser's coastal tenure. The Forest Project, Weyerhaeuser, Nanaimo, BC.
2 Bunnell, F.L. 2003. Monitoring to Sustain Biological Diversity in British Columbia. Report to BC Ministry of Water, Land and Air Protection,Victoria, BC.

d) What to measure?

Deciding on what to measure is critical. Measures and sampling units are selected based on the monitoring questions, derived from the indicators of biodiversity (Step 1). For example, if the indicator is provision of habitat structure, snag density per hectare may be a measure that helps evaluate the question of snag provision among stand types. Two questions are fundamental to all data**:**

- ***"What would we do with such data if we had them?"***
- ***"Will the data and design be sufficient to answer the question?"***

Selecting measurables is a difficult task. Useful measurables have these characteristics:

- Relevant to the management activities
- Practical and easy to measure in a cost effective manner
- Sensitive to stresses on the system
- Respond to stresses in a predictable way
- Predict changes that can be averted by management actions
- Reflect known or suspected cause-effect relations between system components and reflect underlying ecosystem processes
- Have a high signal to noise ratio (information can be differentiated from background variation).

There is a wide array of measures to choose from but the tendency is to monitor forest structural components rather than species because that is more cost-effective. Measuring only habitat may fail to indicate if the provision of habitat structure retained can maintain productive populations of species over time. Species should be monitored as well.

Table 2. Relative advantages and disadvantages of measuring habitat components and measuring species.

Forest structural components		Species	
Advantages [3,7]	**Disadvantages** [3]	**Advantages** [3]	**Disadvantages** [1,2,3,6,8,9,10,11]
Cost-effective	Alone, it may fail to indicate if the provision of habitat structure retained (in harvestable and protected areas) can maintain productive populations of species over time.	Species indicate if the provision of habitat retained is sufficient to maintain populations of species over time.	Costly. Difficult to select informative species.
Already established inventory programs (e.g. forest cover).		Permits comparisons to habitat benchmarks. Trends in population provide an early warning system.	Its application may be unsuccessful if inappropriate species are selected.
Forest management is focused on vegetative communities.		Helps refine relationships with habitat to allow modelling over long time periods and large areas.	Limited resources and logistic issues do not allow the monitoring of all species. Informative taxa must be selected.
		Helps identify problems with population persistence where fine-scale monitoring needs to be focused	Selection of species is controversial.
		The public sees maintaining species as the ultimate measure of success or failure at maintaining biodiversity.	Misleading tendency to use single species (often rare or vulnerable) or groups of species as direct indicators of biodiversity throughout the whole landscape.

Limited resources and logistic issues do not allow monitoring all species, and monitoring too few species is misleading.[3] Selected species or groups of species (e.g., focal species, guilds) should be chosen for their ability to answer important monitoring questions. An extended list of example sub-indicators for all three generic indicators is offered under Adaptive management step 1 when indicators are discussed. Species accounting systems attempt to combine the advantages of species and habitat monitoring, and provide focus to the species selection process.[12]

[1] Lindenmayer, D.B., C.R. Margules and D.B. Botkin. 2000. Indicators of biodiversity for ecologically sustainable forest management. Conservation Biology 14(4): 941-950.
[2] Lindenmayer, D.B. 1999. Future directions for biodiversity conservation in managed forests: Indicator species, impact studies and monitoring programs. Forest Ecology and Management 115: 277-287.
[3] Bunnell F.L., B.G. Dunsworth, D,J, Huggard, and L.L. Kremsater. 2003. Learning to sustain biological diversity on Weyerhaeuser's coastal tenure. The Forest Project, Weyerhaeuser, Nanaimo, BC.
[4] Ferris, R. and J.W. Humphrey. 1999. A review of potential biodiversity indicators for application in British forests. Forestry 72(4): 313-328.
[5] Bunnell, F.L. 2000. Report to the Arrow IFPA on criteria and indicators of sustainable forest management. Centre for Applied Conservation Biology, University of British Columbia, Vancouver, BC. Prepared for Arrow Innovative Forest Practices Agreement, Slocan, BC.
[6] Kneeshaw, D.D., A. Leduc, P.Drapeau, S. Gauthier, D.Pare, R.Carignan, R. Doucet, L. Bouthillier and C. Messier. 2000. Development of integrated ecological standards of sustainable forest management at an operational scale. The Forestry Chronicle 76(3): 481-493.
[7] Mulder, B.S., B.R.Noon, T.A.Spies, M.G.Raphael, C.J.Palmer, A.R.Olsen, G.H.Reeves and H.H. Welsh. 1999. The strategy and design of the effectiveness monitoring program for the northwest forest plan. USDA Forest Service, Pacific Northwest Station. PNW-GTR-437
[8] Lindenmayer, F.B. and J.F. Franklin. 2002. Conserving forest biodiversity: A comprehensive multiscale approach. Island press, Washington, DC. 351pp.
[9] Noss, R.F. 1990. Indicators for monitoring biodiversity: A hierarchical approach. Conservation Biology 4(4):356-364.
[10] Landres, P.B., J. Verner, and J.W. Thomas. 1988. Ecological use of vertebrate indicator specie: a critique. Conservation Biology 2: 316-328.
[11] Lambeck, R.J. 1997. Focal species: A multi-species umbrella for nature conservation. Conservation biology 11(4): 849-856.
[12] Bunnell, F.L. 2005. A species accounting system for northeastern British Columbia. Report to Canadian Forest Products.

e) The statistical design

The objective in monitoring is to attain credible guidance from statistical inference. Ecological experiments and monitoring present many statistical challenges because of the large scale of the questions, noise in data (e.g., influence of weather), difficulties in finding replicates, and low efficiencies of some sampling techniques. As a result, many monitoring programs are poorly designed, or use inappropriate measurements or observations.[1] Statistically valid forest monitoring programs are currently very rare.[2] The challenge is to develop monitoring programs that are statistically sound to collect unbiased measurements of operational performance over time.[3] The monitoring program implemented must have sufficient statistical power to detect meaningful changes in the values of the indicators. The statistical design for a monitoring program should be planned by consulting with a statistician.

To be robust, a statistical design must:[4,5,6]

- Compare management options using 2 or more treatments.
- Have a sufficient number of replicates 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 measures are normally distributed), or adjust the analyses.
- Consider statistical power when determining sample size.

A more complete treatment of statistical design for monitoring biodiversity, including when pre-treatment measures are appropriate is found in [3.]

[1] Noss, R.F. and A.Y. Cooperrider. 1994. Saving natures legacy: Protecting and restoring biodiversity. Island Press, Washington, D.C. 416pp.
[2] Lindenmayer, D.B. and J.F. Franklin.2002. Conserving forest biodiversity: A comprehensive multiscale approach. Island Press, Washington, DC. 351pp.
[3] Bunnell F.L., B.G. Dunsworth, D,J, Huggard, and L.L. Kremsater. 2003. Learning to sustain biological diversity on Weyerhaeuser's coastal tenure. The Forest Project, Weyerhaeuser, Nanaimo, BC.
[4] Scheiner, S.M. and J. Gurevitch (eds.) 1993. Design and analysis of ecological experiments. Chapman & Hall Publishing, New York, NY. 445pp.
[5] [In Lindenmayer et al. 2000]: margules, C.R., G.A. Milkovits and G.T. Smith. 1994. Contrasting effects of habitat fragmentation on the scorpion *Cerphonius squama* and an amphipod. Ecology 75: 2033-2042.
[6] Lindenmayer, D.B., C.R. Margules and D.B. Botkin. 2000. Indicators of biodiversity for ecologically sustainable forest management. Conservation Biology 14(4): 941-950.
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f) Sampling methods

Given the breadth of issues and entities encompassed by the term "biological diversity", a wide range of sampling methods are potentially relevant. The appropriate method thus *begins with the question* (see Monitoring objectives, under Adaptive Management step 1 – Where do we want to go?). The question,determines the appropriate temporal and spatial scales and appropriate measurables. In some instances, choice between methods may be influenced by their relative cost and relative reliability. To select the best sampling methods available, it is best to consult with experts when choosing methods to monitor specific questions and variables. The government of British Columbia provides, through the Resource Information Standard Committee (RISC), a series of guidelines to sample and inventory various habitat attributes and taxa in the Province. These standards are useful, but most were created to address a single species or habitat attribute. As a result, they can become unmanageable and too costly when many are combined. Unfortunately, most efforts to monitor biodiversity must address many variables and thus cannot expect to consistently meet RISC standards. The 'monitoring standard' describes ways of varying RISC standards based on the needs of monitoring, including increased reliance on professional accountability.

g) How often should we monitor?

Ideally monitoring is continued until the question is answered or a reliable trend has been established. Some monitoring may be short term but it often is continual (though intermittent) – because human activities and demographics lead to ongoing environmental changes that bring unexpected ecological events.[1] The frequency of monitoring depends on the rates at which the measurables change. Slowly changing variables are monitored less frequently. Within an adaptive management program, sampling frequencies will be revised periodically based on the information collected.

[1] Mulder, B.S., B.R.Noon, T.A.Spies, M.G.Raphael, C.J.Palmer, A.R.Olsen, G.H.Reeves and H.H. Welsh. 1999. The strategy and design of the effectiveness monitoring program for the northwest forest plan. USDA Forest Service, Pacific Northwest Station. PNW-GTR-437.

Adaptive management step 4 – How do we change when the direction is wrong?

Feedback to Management

Approaches to management are often linear, without serious checks on their effectiveness, implying that managers are either confident about the outcome, or have little concern.[1] Conservation biology is theoretical and the effectiveness of most conservation policies and programs is largely unproven.[2] To improve the effectiveness of management decisions and policies, a framework of adaptive management integrates a continual learning process through a management loop (Figure 3). In this iterative approach, management interventions are treated as "experiments" and are monitored.

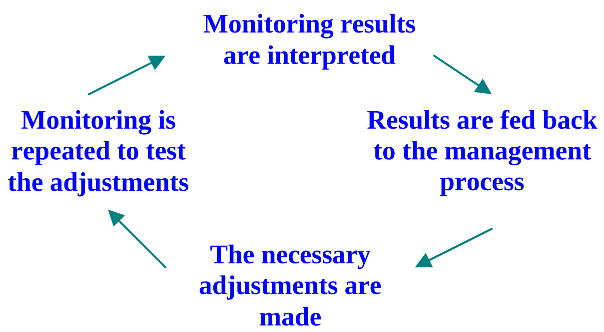

Figure 3 The adaptive management loop.

The ongoing collection of new information 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. If the management loop is not closed the management process limits both learning and adjustments to meet the goals and targets.

Planning must ensure that the management loop will be closed.

- Monitoring programs tend to focus on the technical aspects of design, with little consideration given to the specifics of how that information will be maintained and used.[3]
- Feedback to management can reveal areas of relative weakness where improvements to management will be most effective, inform decisions about appropriate mixes of practices, or determine how close we are to thresholds and targets.[4]
- The management system must formally incorporate ways of receiving information and adjusting planning and practice. Details such as "who" will analyze and interpret the data, and "how" the information will be maintained and transmitted to managers must be integrated in the monitoring plan.
- Monitoring results must be presented simply, point out relative weaknesses, monitor improvement, and the decision-making groups must assess what the best options are, or if current ones are satisfactory.[4,5]

- Any decisions on best options are based on values, especially tolerance of ecological risk and assumptions about the relative values of the managed land base. For example, there are potentially competing values around sapsuckers, timber loss, and worker safety. The decisions do not rest solely with scientists.[4]
- Sufficient funding must be provided to analyze, interpret, maintain, and transmit the data or results to managers.

For example:
Useful corrective feedback to management and monitoring actions were provided by the initial ecological representation analyses (Indicator 1) performed in 2001 on the Weyerhaeuser coastal tenure.[6] Indicator 1 was applied tenure-wide. Indicator 1 is about knowing which ecosystem types are not represented or are poorly represented in the non-harvestable land base, and which are represented by only small or poorly-distributed areas or low-productivity sites. Feedback was:

- Old Growth zones initially were delineated in a few, large contiguous areas. A few were reallocated to improve ecological representation and increase alignment with areas of public concern.
- The main weakness within non-harvestable areas (under-representation of drier/warmer variants) stimulated two actions: a pilot restoration program to develop old-growth characteristics in riparian zones on the east side of Vancouver Island, and an economic analysis of the costs of applying the program elsewhere (e.g., southeastern Vancouver Island).
- Under-represented areas have been identified [6] as areas where future fine-scale monitoring can be focused.
- Representative, larger areas than can serve as benchmark controls have been identified and are being used for long-term monitoring.

In the short term, changes in representation levels from management actions—like moving Old Growth zones—were far overshadowed by changes resulting from redefinition of the non-harvestable land base during timber supply analysis and the 20% “take back”. Over the longer term, change in representation can be tracked and management actions in response to representation tracked and assessed for effectiveness.

Examples of Feedback to Management for representation*:*
Management feedback from the monitoring of ecological representation typically focuses 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 less-intensively managed areas, enhanced stand-level retention practices in poorly-represented ecosystems, moving discretionary reserves, developing alternative strategies such as 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. Bunnell et al [4] note actions that can help reduce the risk of omitting biologically significant habitats from the analyses for indicator 1.

Examples of Feedback to Management for Habitat and Landscape Structures:
Feedback to management from monitoring stand-level retention focuses on identification of 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 show 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 can contribute to refining our definitions of “ecologically distinct ecosystem types” used in monitoring Indicator 1.

Example Feedback to Management for Organisms:
Information on species feeds back to management in several ways: 1) Occurrence of species can be used to examine reductions or expansions in ranges to indicate potential problems or successes. 2) Trends in populations can trigger closer scrutiny to discover mechanisms. 3) 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. 4) 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.

[1] Noss, R.F. and A.Y. Cooperrider. 1994. Saving natures legacy: Protecting and restoring biodiversity. Island Press, Washington, D.C. 416pp.
[2] Lindenmayer, F.B. and J.F. Franklin. 2002. Conserving forest biodiversity: A comprehensive multiscale approach. Island press, Washington, DC. 351pp.
[3] Mulder, B.S., B.R.Noon, T.A.Spies, M.G.Raphael, C.J.Palmer, A.R.Olsen, G.H.Reeves and H.H. Welsh. 1999. The strategy and design of the effectiveness monitoring program for the northwest forest plan. USDA Forest Service, Pacific Northwest Station. PNW-GTR-437
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[5] Bunnell, F.L., and B.G. Dunsworth. 2004. Making adaptive management for biodiversity work - the example of Weyerhaeuser in coastal British Columbia. Forestry Chronicle 80: 27-43.
[6] Huggard, D. 2001. Ecological representation in Weyerhaeuser’s non-timber landbase. Report to Weyerhaeuser Adaptive Management Working Group.