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A Primer on Selecting Biodiversity Indicators for Forest Sustainability: Simplifying Complexity

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Summary

Maintaining biodiversity is a primary goal of sustainable forestry. However, maintaining "life in all its forms" can be a seemingly impossible task. 'Biodiversity,' as commonly defined, is simply too complex to measure or monitor. The only practical solution is to use indicators. In theory, good indicators are relatively simple to measure and correlate with many other elements of biodiversity so that they too do not have to be measured. All sustainable forestry programs use indicators as the measures of success, yet there is tremendous confusion and frustration among forest managers and forest stakeholders about the usefulness of indicators. Here we explain why indicators can cause such confusion and propose a new framework for selecting biodiversity indictors that will better inform decision makers and stakeholders. What has been lacking for biodiversity indicators in sustainable forestry is not science, but a structured, transparent, inclusive process for selecting indicators.

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All major sustainable forestry efforts explicitly state that conserving biodiversity is a fundamental goal (e.g., SFI, FSC, CSA). However, the biodiversity element of sustainable forestry has been especially challenging to forestland owners, states, countries, and other policy making bodies. The challenge can seem overwhelming because biodiversity typically is defined as life in all its forms, from the level of the gene, to species, to whole ecosystems, including all the processes that maintain these various levels. In most forests there are thousands, if not tens of thousands, of plant and animal species. The number of species and all their potential interactions simply cannot be quantified. Yet something that is not being measured cannot be managed. The only practical approach to assessing "life in all its forms" is to measure a relatively few components of the forest system (e.g., species, processes, stressors) that are correlated with as many other components of the system as possible (i.e., indicators). What should these few components be?

Indicators tell us whether we are meeting the goals of sustainability. Choose them carefully.

Despite the inherent appeal, practical necessity, and a prolific scientific community on the subject, the utility of indicators remains constrained by confusion and misunderstanding in sustainable forestry. This confusion often has resulted in the selection and application of indicators that are not instructive. Or, users do not understand *why* they are instructive for assessing biodiversity for sustainable forestry. Some key reasons indicators have been confusing include:

- Different decision makers make decisions at different spatial and temporal scales. An indicator that might be appropriate at a large spatial scale may not be appropriate for use at small spatial scales.
- Different decision makers work in different biological, cultural, and social settings. Indicators that work in one place may not be appropriate for another.
- Often an indicator is selected without careful consideration of what value(s) it is intended to indicate.
- Once an indicator is measured, it is often not clear what action needs to be taken, or if *any* action is needed. Benchmarks, or target levels are almost always lacking for indicators, so indicators have no frame of reference.
- Inherent conflicts often exist between indicators. Positive change in one indicator (timber growth rate) can result in a negative change in another indicator (e.g., late-successional forest). Which indicator should the

manager favor?

- Many indicators respond to multiple stressors. As a result, when these indicators have a negative change, suggesting a loss in a biodiversity value, it can be difficult for managers to determine which stressor is the cause of the change.
- The selection of indicators has not always relied on a socially inclusive, or transparent, process. It can therefore be frustrating to landowners and managers when efforts to achieve sustainable forestry are met with skepticism and suspicion.

There is a remarkable volume of recent literature on ecological indicators (e.g., National Research Council 2000) and sustainable forestry indicators (e.g., Franc et al. 2001 and papers therein, Raison et al. 2001 and papers therein; Wright 2002). Unfortunately, many good ideas are still relatively unorganized and an effective framework for selecting biodiversity indicators in sustainable forestry situations does not yet exist, perhaps because of the still-young age of sustainable forestry as a social concept. Many mistakes are made in the selection of indicators, sometimes to the point that the indicators are even counterproductive (Failing and Gregory 2003).

Our goal here is to bring a minimum of structure and organization to the selection of biodiversity indicators in sustainable forestry so that the indicators can become more useful in decision making and in maintaining biodiversity.

Three types of indicators

One of the first indicator frameworks to be widely adapted and used was the Pressure-State-Response system (Friend and Rapport 1979, Adriannse 1993). This fundamental system has been modified in many ways for environmental assessment. Environmental indicator systems typically distinguish 3 types of indicators: **condition** (or 'state') indicators describe the current condition (or level) of a value to be sustained. **Pressure** indicators report on the level of a pressure that can cause the condition to change. **Policy response** indicators provide information about the level of human action being taken to reduce the pressure (Box 1).

An example illustrates how these different types of indicators convey different information to a decision maker. Large-diameter snags are well known to be important for biodiversity in many forest types. A 'condition' indicator for large snags might be the density of large snags in the landscape. This metric tells us about the status, or condition, or the resource at present, and has units of measure (snags/ha). A 'pressure' indicator would tell us something about where this resource is headed in the future. A good pressure indicator might be harvest rotation length. If the present-day rotation length is too short to allow large diameter snags to develop, then we can predict there will be fewer large-diameter snags in the future, regardless of the current density as indicated by the condition indicator. In this respect, condition indicators alone can be misleading—evidence of change in a condition indicator may come too late, whereas pressure indicators can provide an early warning to future change in condition. Finally, a 'policy response' indicator might be the presence of an internal policy for snag management. Condition and Pressure indicators usually are expressed with units of measure (e.g., snags/acre, rotation length [yrs]). Often policy response indicators have no units of measure.

It is easy to see why condition, pressure, and policy response indicators all would be useful to making management decisions. Many sustainable forestry certification programs only contain policy response indicators. The actual current condition of biodiversity (with units of measure) is not often reported as an indicator. Rather than reporting the amount of forest by forest type and age class (e.g., in hectares), a condition indicator, landowners typically must demonstrate that they have a *plan or policy* to manage for forest types and age classes (a policy response indicator). By contrast, the Montreal Process indicators that came out of the Santiago Declaration in Chile in 1995 are all condition indicators (all have units of measure), and contain no policy response indicators.

Policy response indicators, however, play an essential role in bringing biodiversity concepts into forest planning and decision making. They do not, however, inform us about whether we are maintaining the value of concern.

Evaluation criteria for indicators

Any given indicator can have strengths and weaknesses. To choose effective indicators, candidate indicators should be evaluated for 5 traits (Box 2). First, the **relevance** of the indicator to a stressor of concern should be evaluated. A good indicator will increase or decrease only in relation to one specific stressor of interest and not to unknown stressors. For example, if timber harvesting is the stressor of

Box 1

Different types of indicators are designed to provide decision makers with different kinds of information. If indicators are chosen from each the 3 types listed, decision makers will be much better able to track performance for sustainability.

Type	***Purpose***
Condition	*To indicate the level, or **condition**, of a specific value to be sustained (e.g., indicator: density of large-diameter snags).*
Pressure	*To indicate the **level of a stressor** affecting the **condition** of a value of interest (e.g., indicator: rotation length [a pressure that affects density of large-diameter snags]).*
Policy Response	*To indicate the level of **policy action** taken to maintain the **condition** or reduce the **pressure** (e.g., indicator: existence of a management strategy for maintaining large-diameter snags).*

interest to the user then the indicator should respond to cutting trees, not global warming. If the indicator is not linked to a known stressor then it will not be possible to identify corrective actions.

Good indicators will have strong **scientific merit** (i.e., there is a well-established scientific relationship between the indicator and the value(s) of concern. An indicator has good **ecological breadth** when it is correlated to a large number of other values that are not being measured. For example, the density of large living trees (e.g., density of trees ≥18" dbh) can be a good indicator of mature forest epiphytes (e.g., sensitive mosses and lichens), nesting habitat for raptors, and future large-diameter snag density.

Two important characteristics to forest managers are **practicality** and **utility**. Indicators are practical if they are not expensive to measure, do not require special skills to measure (e.g., a plant taxonomist, or bryologist), and do not require complicated analysis. Finally, **utility** refers to the ability of the forest manager to make a decision with the indicator. If once measured, the indicator metric does not provide any guidance to the manager, then the indicator has low utility (e.g., the indicator cannot be used to make a decision).

If indicators have not been evaluated for these 5 characteristics it is likely that the indicators will not be good ones. They will fail to inform decision makers and leave them wondering about the purpose of the indicator. Indicators are supposed to be a means to achieving a goal—simply *having* indicators is not the end point of sustainable forestry.

In reality, practicality (e.g., affordability) has been the dominant characteristic influencing the selection of indicators. Indicators must be affordable or they will not be used. But if the other four evaluation criteria are not included in the selection process, policy makers run a high risk of selecting poorly performing indicators.

Box 2

Before specific indicators are selected for use in any sustainable forestry situation, each indicator should be evaluated for each of the 5 categories of evaluation criteria. Indicators that are not evaluated for these criteria are unlikely to serve decision makers or forest stakeholders well.

Evaluation Category	Description
1. Relevance	Degree to which the indicator responds to the stressor of concern; e.g. timber harvesting as opposed to air pollution.
2. Scientific merit	Extent to which the indicator is supported by science.
3. Ecological breadth	Number of other ecosystem components (species, structures, and/or processes) that the indicator indicates.
4. Practicality	Feasibility, including cost, time, and skill required, of measuring the indicator.
5. Utility	Ability to inform decision makers of needed actions.

A structured process for selecting indicators is needed

We have reviewed hundreds of indicators in use and potential indicators for biodiversity in sustainable forestry (Whitman and Hagan 2003). The primary impediment to selecting effective indicators is not a limitation of science, but rather the lack of a transparent procedure to select indicators. The single most critical aspect of selecting good indicators is having a socially-inclusive process for their selection. If the indicators are not viewed by stakeholders as being legitimately selected, then even the best, most scientifically rigorous efforts to document sustainability will fail (Box 3).

To address this problem we have developed a structured, socially-inclusive, stepwise, transparent process for selecting biodiversity indicators. This process requires the participation of forest managers, scientists, and forest stakeholders, each having separate and precise roles to play in the selection process. The process incorporates the selection criteria outlined in this report, and can be used to select indicators for any spatial scale. A forthcoming report in this series will outline this procedure.

The primary challenge to selecting good indicators is procedural, not technical or scientific.

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Box 3

Essential Elements for Selecting Good Indicators

1. ***First divide "biodiversity" into practical subcomponents***. *"Biodiversity" as a whole is too all-encompassing to be helpful in selecting indicators. Examples of subcomponents are: aquatic/riparian values, late-successional and/or old-growth values, hunting values, charismatic species, non-charismatic species, natural plant communities, etc.*
2. ***Establish goals for each biodiversity subcomponent***. *If there are no clear goals, the indicator will not have context. There will be no way of knowing whether the indicator is too high or too low, and therefore no decisions can be made in response to the indicator. Keep in mind that 'a goal' might be a lower threshold, below which you do not want the indicator to fall.*
3. ***Be specific about the spatial and temporal scale at which the goals apply***. *Use indicators appropriate for the scale at which you will be working: (usually local management unit, county, state, province, nation, or planet).*
4. ***Include scientists, forest stakeholders, and forest managers in the selection process***, *and clearly partition the roles of each group. Forest stakeholders must participate in the process to identify specific biodiversity values of interest or concern. The scientists' role (e.g., ecologists, conservation biologists, wildlife biologists) is to identify possible threats to those specific values and to identify science-based indicators that are linked to those threats and values. Forest managers are needed to select indicators that are practical and affordable to implement.*
5. ***The selection process should be socially transparent and inclusive***. *Regardless of whether sustainable forestry is being applied on private or public lands, one purpose of sustainable forestry is to earn a social license to cut wood. Any indicator selection process that is either exclusive of stakeholders or concealed in method will not win legitimacy.*
6. ***Select condition, pressure, and policy response indicators*** *to provide different types of information that can be useful for making decisions.*
7. ***Critically evaluate each indicator*** *for relevance, scientific merit, ecological breadth, practicality, and utility. Each indicator should be evaluated by scientists and forest managers for these 5 criteria. Only then can strengths and weaknesses of different indicators be evaluated.*
8. ***Determine how each indicator can be used to make a real decision***. *Ask the following question of each indicator before making a final selection: "If I [the forest manager] had this number, specifically how would I use it in making harvest or forest planning decisions?" If the answer is unclear, then utility is low and the indicator should be rejected.*
9. ***Keep the indicator set as small as possible*** *to cover the values of concern. Look for single indicators that can inform decision making about multiple biodiversity values.*

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