The Design of Forest Inventories and Monitoring for Biological Conservation

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Abstract

Within large forested landscapes, inventories provide the cornerstone for effectiveness monitoring of biological conservation. Systems of classification are needed to characterize the varieties of expression of large number of habitat elements as well as their distributions in terms of their geographic locations. These systems of classification must underwrite reasonably reliable forecasts of future forest conditions. To be effective at conservation requires that we anticipate future forest conditions, first in the absence of our interventions, and then in the presence of them so that we may pursue our biological conservation goals in acknowledgement of the cumulative effects of our interventions on species and their habitats.

Stand structure classification is particularly important in forestry because it can be used to forecast local and long-term changes in the distributions of the numbers of trees per hectare by species, diameter and whether or not they are alive or dead. To a considerable extent changes in these distributions affects changes in non-tree vegetation both directly and indirectly through interactions with broader scale natural disturbance processes. Therefore they affect the occurrences of species and their habitats.

It is suggested that to do an acceptable job of effectiveness monitoring, much more attention needs to be paid to the details of how inventories are designed, maintained and used to develop forest management practices and guidelines in anticipation of future forest conditions. Practicing biological conservation in relation to the current state of the forest, with little regard for the future is not likely to be effective in the same way that driving down the road while only concentrating on what is in the rear view mirror is unlikely to succeed.

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Citation: Moss, I.S. 2007. The Design of Forest Inventories and Monitoring for Biological Conservation. Paper presented at the “Monitoring the Effectiveness of Biological Conservation” conference, 2-4 November 2004, Richmond, BC. Available at: **http://www.forrex.org/events/mebc/papers.html**

Notes: This paper has been peer reviewed prior to posting.

Introduction

Johnson and O'Niel (1984) defined conservation biology as the body of knowledge that deals with the careful protection, utilization, and planned management of living organisms and their vital processes to prevent their depletion, exploitation, destruction or waste. They also defined monitoring as a process of collecting information to evaluate whether objectives of a management plan are being realized. The term "effectiveness monitoring" refers to the process of collecting information for the purpose of determining whether policies and practices have actually produced the desired consequences. This requires that such policies and practices be linked to consequences in terms of cause and effect. If no such link can be made then the decision as to whether a policy or practice is effective is left in doubt. Alternatively, if a link can be made and shown to produce adverse consequences, then it can be concluded that the policies and practices employed are counterproductive. Avoiding these two outcomes means that success has been achieved, at least to some degree.

In this discussion we are primarily concerned about assessing the consequences of forest management on species habitats and as it relates to the influences of harvesting, silviculture and forest protection. Many forests encompass large areas (e.g., > 100,000 hectares), and change slowly with time, notwithstanding large-scale catastrophic events often caused by fire, wind and insects or disease. How do we go about making ground-level observations of species occurrences and/or requirements in relation to habitat elements in a way that enables reasonable assessments of the size and health of habitats within broad landscapes? After having done so, how do we use this information to improve management plans and practices? We need a system for the monitoring, planning and management of inventories. The system must be affordable to implement. What are the basic elements of an inventory needed to support such a system?

The Design of Forest Inventories

Forest inventories provide the basis for monitoring the kinds and distributions of structural attributes on the landscape. The act of maintaining, protecting or (re) creating species habitats involves making reliable estimates of the current state of the inventory, as well as of future states of the inventory under different scenario's that reflect those things we have control over (e.g., where to harvest next), and those that we may hope to influence (e.g., the probability of occurrence of wildfire), and those that we may need to respond to (e.g., climatic warming). From a monitoring perspective we must also be able to reflect on the past, and whether or not the decisions we imposed at those times, produced the desired outcomes in terms of what we observe in the present. Within this context and with reference to forest management, Kremsater et al. (2003) identified three dominant mechanisms for the protection of biodiversity:

- Ensure representation of habitat types in a relatively unmanaged state to ensure that little-known species are retained (some aspects of natural disturbances can be mimicked in managed stands, others cannot).

- Identify the structure of stands and landscapes to ensure that the key elements are present through time (intermediate filter: Diverse structures lead to diverse habitats).

- Identify indicator organisms to track whether retaining structures and patterns, while addressing representation, will maintain species and populations whose life needs are well understood (fine-filter: This aims at species that are not accommodated in 1 and 2).

The goal in maintaining an inventory is to describe the spatial variation in the occurrences of a large list of attributes or habitat elements. It is generally not possible to measure all of the elements in every location. Nor is it possible to sample or even reasonably estimate the degree of elemental expression in every location. As a result, the inventory must be characterized through a series of classifications designed to capture the natural variation within a necessary but sufficient number of categories. Such classifications typically contain the following kinds of information:

- Land cover (MSRM, 2002; e.g., Forested, grassland, wetland, stream, rock)
- Terrain (Howes and Kenk 1988) or soils (e.g., Jungen 1985) classification.
- Biogeoclimatic zones and ecosystem types (Meidinger and Pojar 1991), or climatic zones and "habitat" types (Pfister et al. 1977), or wildlife habitat types (Chappell et al. 2001).

These systems of classification are seen as being central to the definition of habitats insofar as they broadly characterize features related to distinct geographic regions with a relatively consistent (but not necessarily narrow) range of climates, elevations, and patterns and distributions of vegetation types (Chappell et al. 2001). These classifications are effective at characterizing relatively static features of the landscape; they are much less effective at capturing the more dynamic features over which we have some control and seek to manage in order to achieve conservation goals and objectives.

For the purposes of conservation, many forest inventories start to break down when it comes to describing the structure of vegetation at the stand or smaller scale ecosystem-level of observation. In forested ecosystems the stand-level distributions of trees with respect to size and species composition is critical not just for characterizing species habitats, but also for forecasting changes in these same characteristics with time. Try as we might to protect unique species and their habitats, we must recognize that change is inevitable and that we must learn to cope with it. Similarly a wide variety of habitat elements will change with time and accordingly, indicator organisms will move from one location to another, and there may well be a need to update indicators from time-to-time. Conservation biology can only be effective if to the extent possible such change is anticipated and as a result habitats may be moved around the landscape by design or are expected to move in response to natural disturbances. Some kinds of habitats may also be managed in a way that ensures they are more or less self-perpetuating at stand and landscape levels of resolution.

One example of stand structure classification used for habitat assessment is provided by O'Neil et al. (1984). They point out that the habitat concept does not address demographic (survival and reproduction), environmental (food supply, predators, weather), natural catastrophe (flood, drought, fire) or genetic (genetic drift or inbreeding) uncertainties. They rationalize this statement on the basis that these uncertainties, though important, are difficult to determine, predict, and manage. In the final analyses, they refer to structure as being something that resource manager's can manipulate to achieve various objectives, consistent with the discussion above. As a result, their structural classification is simply a tool for characterizing habitats from a static rather than a dynamic point of view. This is a significant weakness as discussed above, and it is a weakness associated with many systems of stand structure classification (see O'Hara et al. 1996).

As an alternative, the Cumulative Distribution Approach (CDA) was developed (Moss 2003) for the purpose of designing systems of stand structure classification that readily enable field identification of differences in structure (Farnden et al. 2003), and provide for broad characterization of differences in habitats while at the same time containing descriptions of a large number of habitat elements. The CDA systems of classification can be used as a basis for establishing stand and stock table kinds of information for each stand in an inventory, even though plots may not have been established in all of the stands. Stand and stock tables summarize stand conditions in terms of the numbers of trees, basal areas and volumes on a per hectare basis by species and diameter class. These kinds of data can be input into standard individual tree growth and mortality models (e.g., see Stage 1973 or Arney 1984) for the purposes of forecasting stand and landscape dynamics. Such data and models may also be used as a better basis for describing the probable occurrences and patterns of natural disturbances such as fire, wind, and insects. For example, it is generally known that fire suppression over a long period of time, can lead to a buildup of fuels in over-dense stands, ultimately resulting in large scale fires (Whelan 1995); such phenomena can be reasonably forecast using stand and stock tables derived in association with stand structure classification, and using growth and mortality models in conjunction with landscape-level fire dynamic models.

Effectiveness Monitoring

Effectiveness monitoring for biological conservation in large areas of forest require that a formal inventory be maintained. A series of classifications are necessary for describing inventories in a way that can be easily understood, in a way that conveys a wealth of habitat attributes, and in a way that supports the reasonably reliable forecasting of future forest habitat conditions in response to natural disturbances and with or without the direct intervention by forest managers. Managers need these tools so as to act in timely sort of way, preventing or mitigating the potential for species and/or habitat losses and producing more favourable conditions for those species that are threatened or endangered.

Inventory classifications are important because we rely on them to infer presence, absence and abundance of a large number of habitat elements that are difficult, if not impossible to monitor on every piece of land. A system of monitoring plots and transects is required to be established such that the broad classes of information described in the inventory are represented according to proper statistical sampling procedures. Within monitoring plots a large list of habitat attributes may be assessed. Within plots and along transects the occurrences of indicator species may be assessed. Based on the locations of plots and transects, and their juxtaposition with stands and associated classification attributes, detailed descriptions of habitat elements may be extrapolated to stands with similar classification attributes throughout the rest of the inventory. Monitoring plots are also needed to verify and update forecasts of ecosystem development with time, since the consequences of our management actions are best designed in anticipation of those developments rather than simply as a means to modify current landscapes based on their current conditions. It is the cumulative effects of decisions that have the greatest impacts; our ability to meet biological conservation goals is severely limited in the short term so that we must be much more anticipatory in our approach to biological conservation.

Conclusion

Most large area (> 100,000 ha.) forest inventories are currently lacking in the details necessary to support effective habitat conservation. Systems of classification must be designed for the purpose of describing where, what kinds of attributes occur and to what degree. While this is necessary, it is not sufficient. Habitats change with time. As a result, systems of classification must also underwrite reasonably reliable forecasting of future forest and stand conditions in response to natural processes, with or without management intervention. Stand structure classification is particularly important in this regard because it refers to the within stand distributions of trees as it relates to species and sizes. Such distributions can be seen to drive many of the changes that take place at the stand scale of observation, including changes in vegetation community composition, and they interact with landscape level processes to manifest change in response to natural disturbances. Such distributions are also one of the primary levers that accessible to forest managers for the purpose of manipulating structural elements in pursuit of conservation goals.

Lastly, the systems of classification must be linked to a system of plots established to be statistically representative of the array of the population of stands and landscapes as a whole. This is needed to evaluate whether or no the forecast changes did indeed take place and to subsequently adjust the forecasts to date to account for errors, and where necessary to address the inadequacy of the forecasts themselves. Emphasis is placed on forecasting because we must learn to be more effective in anticipation of change, rather than in response to it. The tools exist to make this leap. What is needed is a collective will and organization to deploy them.

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