Setting Monitoring Objectives for Landscape-size Areas

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The setting of objectives for monitoring schemes for landscape-size areas should be a complex task in today's regulatory and sociopolitical atmosphere. The technology available today, the regulatory environment, and the sociopolitical considerations require multiresource inventory and monitoring schemes, whether the ownership is industrial or for preservation. Monitoring is essential so that we know if we are meeting our management objectives.

Monitoring is the basis of adaptive management. In consideration of the pressures to know if we are headed in the right direction with our land management, monitoring becomes an integral part of a land plan. Regulatory agencies consider a plan to be a contract based on adaptive management. It allows us to move forward in the face of uncertainty.

Human influences are great everywhere on earth. Action or no action, both have a significant effect on some, most, or all resources. So even preservation areas need management plans and monitoring schemes.

So, the crux of this presentation is "What do I need to know to set up an effective monitoring program?" or "How do I set up a useful monitoring program?"

Key in this effort is to avoid collecting a lot of useless information. That should be one of the main objectives along with collecting enough information to be meaningful. What's meaningful and what's useful should be well thought out well in advance. We can certainly collect mounds of data.

And, of course, we all know what we want to measure and how we think we ought to measure it, but careful consideration of the appropriate analytic approach, be it statistical or otherwise, may change our priority for measurement.

There are some things that we would like to know, but getting that information or enough of the information to be worthwhile is so expensive that we must postpone measurement until the technology or collective desire permits us to get the information.

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First, we need to identify what needs to be collected, that is, who needs what information. We must provide for:

- Management Needs
- Regulatory Needs
- Sociopolitical Needs

What's meaningful and what's useful depends on one's needs. Management or planning needs necessitate a certain approach. Private timberland owners often want to know how much timber they have and what kind of growth they have to supply their mills. These same timberland owners now must often meet regulatory requirements of sustainability with respect to timber yields and also sustainability of habitat. And government regulators push to err on the conservative side, calling into question habitat models and growth and yield models. Sociopolitical pressures are also calling for conservative planning approaches.

A monitoring program may have many components. For example, a monitoring scheme might include:

- Plot data for vegetation
- Camera stations for wildlife occurrence
- Trapping grids for wildlife
- Stream temperature probes
- Transect of woody debris in the uplands or streams
- Fish trap counts
- Remotely sensed resources

And there are many, many, many more. Each type of organism or physical condition could and probably should be tracked at some level. But we can't measure everything.

Next, we want to define why we are collecting information. It may be for:

- Point Estimation
- Change Detection
- Resource Modeling
- Model Validation

Each of these can necessitate a different statistical or sampling approach.

Setting priorities and defining the overall objectives can be the most tedious part of the whole inventory and

monitoring program. We say this because in today's regulatory and political environment there are pressures to measure or monitor everything as well as pressures to improve or validate existing models for resource projections or to develop new models. This can be very costly. In no way could we begin to help resource managers weigh and balance demands for information. What we can do is help develop a process for implementing the highest priorities for monitoring and integrating them into an efficient system.

Today's land management requirements necessitate monitoring for multiple objectives. Of course, we monitor for multiple objectives; we've always wanted to get information on a number of variables when we monitor. If it's timber, we want to know volume, growth, defect, and size distribution. If it's wildlife, we want to know number, age distribution, sex distribution, and condition.

But in the past, monitoring schemes focused on one or maybe two variables to achieve target precision. We can assign a target precision for every variable or at least know what kind of precision to expect. Once we know what information we can get and what information we want to get, we can choose and adjust.

Each component may require a different statistical or analytical approach. But these approaches can be integrated together. Point estimation and change detection involve collecting data in an unbiased fashion. Often we want to use stratified sampling that can minimize effort where there is low occurrence of the population. On the other hand, model development and validation requires data collection across the range of conditions, even targeting the extreme conditions to "nail down" the extremes in the model so that the model will behave well through the range of conditions in which it is intended to be used.

First, we want to define the all populations to be monitored. Defining the populations to be monitored usually begins by prioritizing information needs, that is, sensitive species or resources, etc. This might be a population of stream temperatures, a population of timber volumes, a population of slime molds, or a population of migrating fish. The information may be count data (number of organisms) and/or measure data (weight of organisms).

We need to choose one or many analytic approaches. They may be different for different components in the monitoring scheme. For example, we might choose:

- Multiple Comparisons
- Trend Analysis
- Regression Analysis including ANOVA/ MANOVA, linear and non-linear models
- Change Detection (Remote Sensing)

It is imperative that the analytic approach be well thought out before going into the field, whatever the approach. Without clearly defined analyses detailed ahead of time, we'll get a lot of useless data.

We need to consider the timing of measurement or remeasurement for each component. How often should we measure a particular component to be monitored? Not all resources need to be measured equally often. Great savings might be made if we can forego measuring some components each time we want to measure.

And, of course, we want to maximize our monitoring dollars. A well-coordinated approach, well thought out in advance, will ultimately cost less.

We need to incorporate all available information into our design.

- For each measure to be tracked, compute variance/standard error
- Use different sampling unit sizes, if possible
- Use a pilot study to determine appropriate sampling unit size and shape

For each variable to be measured, we want to be able to achieve a certain precision, be it for a point estimate or for a model. Varying the sampling unit size can help economize to achieve the best precision for the least cost. If we don't have good information about a certain resource to be tracked, then a pilot study, investigating variance with respect to sample size, sampling unit size, travel time, and plot location, can save time and effort later.

Again, we want to assign a target precision for each component to be monitored. Whether we can achieve all the targets or not, it's best to know what the tradeoffs are in advance and at least make informed decisions. What is the appropriate confidence interval for each measure? Confidence limits could, and may very well likely, be different for each component.

Assign a measurable difference to detect. How much of a change do you want to be able to detect, statistically, that is? With forest inventory, we would often target a certain confidence interval for a given probability. And if we measured an ownership once, we would get one answer. And if, at some time in the future, we measured the ownership again we would get another answer, both within the specified target precision. Was there a significant change? The precision targets for a single point

estimate will unlikely provide sufficient power for finding if the two estimates are statistically different. This may not be important for timber resources, but it might be very important for rare resources that might be impacted by management.

The sampling strategy should consider:

- Sample Size
- Sample Unit Location (Travel time versus variance)
- Sample Unit Size and Shape

As we move towards developing a monitoring strategy, we must look at, and juggle, the various components of sampling. Before we decide on a final scheme, it is probably best to develop several sampling scenarios for each resource to be monitored, so that a strategy can be adjusted when we make our final plan of action.

And now we'll want to integrate the various sampling approaches. Integrating the monitoring scheme means that once we have identified all the things we want to measure and once we have calculated the sampling unit size, sample size, sample allocation method, and sampling frequency for each of these things, we must integrate them into an efficient system, minimizing cost and effort. The overall available budget for monitoring will dictate the level of priorities that can be met. This will usually involve tradeoffs, but of course we begin by including the highest priority things and the requisite sampling approach for them first.

And finally, monitoring schemes can be adaptive. That is, in the future we can modify the scheme as better information becomes available. We'll want to maintain the statistical validity of our scheme, but there are opportunities to reduce the sample size or reduce the frequency of measure. How we set the criteria for modification should be spelled out at the outset, so that we have some understanding of where we are going.

So, as we set objectives for monitoring, we should keep in mind that these priorities can and do change as we know more about the sensitivity of resources and as the technology for measurement improves.

As we stated at the outset, the setting of objectives for monitoring schemes for landscape-size areas can and should be complex. The technology available today, the regulatory environment, and the sociopolitical considerations all require the use of multiresource inventory and monitoring schemes. Such monitoring is essential so that we know if we are meeting our management objectives. A carefully conceived monitoring plan will help minimize data collection costs and provide the information needed for land management decisionmaking.