Guidelines for long-term monitoring protocols

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Abstract Monitoring protocols are detailed study plans that explain how data are to be collected, managed, analyzed, and reported, and are a key component of quality assurance for natural resource monitoring programs. Protocols are necessary to ensure that changes detected by monitoring actually are occurring in nature and not simply a result of measurements taken by different people or in slightly different ways. We developed and present here guidelines for the recommended content and format of monitoring protocols. The National Park Service and United States Geological Survey have adopted these guidelines to assist scientists developing protocols for more than 270 national park units.

Key words format, guidelines, monitoring, national park, natural resources, policy, protocol, sampling

Natural resource monitoring is "the collection and analysis of repeated observations or measurements to evaluate changes in condition and progress toward meeting a management objective" (Elzinga et al. 1998:1). To be certain that changes detected by monitoring are actually occurring in nature and not simply a result of measurements taken by different people or in slightly different ways, detailed and exacting monitoring protocols should be developed and implemented as part of all long-term monitoring programs (Geoghegan et al. 1990, Shampine 1993, Geoghegan 1996, Beard et al. 1999). Monitoring protocols are 1) a key component of quality assurance for monitoring programs to ensure that data meet defined standards of quality with a known level of confidence, 2) necessary for the program to be credible so that data stand up to external review, 3) necessary to detect changes over time and with changes in personnel, and 4) necessary to allow comparisons of data among places and agencies.

As part of planning and designing a long-term natural resource monitoring program for more than 270 national parks in the United States, scientists from the Inventory and Monitoring Program of the National Park Service (NPS) and the Status and Trends Program of the United States Geological Survey (USGS) have been working together to develop protocols for sampling natural resources in national parks. We developed these guidelines for protocol content and format to help overcome the unique challenges posed by long-term monitoring. The 2 agencies have adopted the following guidelines to assist scientists in developing protocols for the national parks. Ultimately, improving the quality of protocols is required for the program to meet its goal of detecting changes in the status and trends of ecosystems under the protection and management of the NPS.

Recommended content and format for monitoring protocols

Designing a monitoring project is like getting a tattoo: you want to get it right the first time because making major changes later can be messy and painful. Monitoring projects that incorporate a large up-front investment in defining objectives, optimizing sampling designs, and determining how monitoring results will be used are more likely to succeed over the long term. Consequently, an effective monitoring protocol will provide more than a

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detailed description of field methodology. Careful documentation of the questions being asked; the sampling framework and survey design; step-by-step procedures for collecting, managing, and analyzing the data; and expectations on how the data will be presented and used are all part of "getting it right the first time." A good monitoring protocol will include extensive testing and evaluation of the effectiveness of the procedures before they are accepted for long-term monitoring. Peer review of protocols and revisions are essential for their credibility. The documentation should include reviewers' comments and authors' responses.

No matter how much advanced planning goes into protocol development, some changes and improvements in such things as field methodology and approaches to data analysis and reporting are to be expected. To accommodate and plan for periodic review and revision, we propose a modular protocol organization consisting of a protocol narrative, a series of Standard Operating Procedures (SOPs), and a supplementary section of supporting materials. In this way, changes to specific protocol components are more easily documented and tracked through time. A modular organization also facilitates export and adaptation of protocols across ecological regions or agencies.

We recommend that a monitoring protocol include the following three sections:

1. *Narrative*. The Protocol Narrative provides the rationale for why a particular resource or resource issue was selected for monitoring, gives background information concerning the resource or resource issue of interest, describes how monitoring results will inform management decisions, and discusses the linkages between this and other monitoring projects. The narrative gives an overview of the various components of the protocol, including measurable objectives, sampling design, field methodology, data analysis and reporting, personnel requirements, training procedures, and operational requirements. The narrative also summarizes testing and evaluation procedures involved in protocol design, and documents the history of decision-making that accompanied protocol development. This may be accomplished directly in the protocol narrative or by referencing related reports. Providing a history of protocol development and refinement will help ensure that periodic review and revision result in continued protocol improvement, rather than mere repetition of previous trials and comparisons. The recommended content of the protocol narrative is outlined in Table 1.

2. *Standard Operating Procedures*. A series of SOPs present the details on how all aspects of the components described in the narrative will be carried out. The SOPs are likely to be updated more often than the protocol narrative. The SOPs should be written in the form of instructions, with step-by-step details of how to carry out each procedure (Wieringa at al. 1998). One of the SOPs should explain the procedure for making revisions to the protocol, and each protocol should include a log of its revision history and archives of previous versions. The revision procedure should also specify the need for and appropriate duration of an overlap period before new methods are adopted (Newell and Morrison 1993). Data sets should indicate which version of the protocol was being used when the data were collected, perhaps by including a field in the database to describe protocol version number.

3. *Supplementary Materials*. Supplementary Materials include example databases, supporting data and reports (e.g., digital maps of soil strata, guild assignments of bird species), custom data management, data analysis or decision support tools (e.g., link to software programs), as well as materials that cannot easily be formatted and included as part of the digital protocol document (e.g., paper maps, photographs, binders of peer reviewers' comments and authors' responses).

Example of a monitoring protocol

A protocol for monitoring land birds at 2 national parks in Nebraska and Kansas (Peitz et al. 2003) follows these guidelines and is in the process of being tested and evaluated for these prairie parks. The protocol consists of the protocol narrative, 11 SOPs, and supplementary materials including a relational database developed in Microsoft Access© (Redmond, Wash.). The database includes a field for which version of the protocol was being followed when the data were collected; all versions of the protocol are archived. The full text of the protocol is available on the internet through the protocol metadatabase developed by the NPS at http://science.nature.nps.gov/im/monitor. The 11 SOPs for this particular example are as follows:

SOP 1: Preparations and Equipment Setup Prior to the Field Season

SOP 2: Training Observers
SOP 3: Using the Global Positioning System
SOP 4: Establishing and Marking Sampling Plots
SOP 5: Conducting the Variable Circular Plot Count
SOP 6: Documenting Habitat Variables
SOP 7: Data Management
SOP 8: Data Analysis
SOP 9: Reporting
SOP10: Procedures and Equipment Storage After the Field Season
SOP11: Revising the Protocol

Is it worth the extra effort?

Writing protocols to the level of detail we recommend will require more effort than is devoted to such activities in the typical 2–5-year research project. However, to be certain that changes detected by long-term monitoring are actually occurring in nature, and not simply a result of measurements taken by different people or in slightly different ways, the methods used must be carefully documented. Substantial work is required to develop and test monitoring methods to ensure they will be consistent and comparable over periods from decades to centuries. To fully realize the investment in the monitoring program, protocols must meet a higher standard.

Improving the comparability of data from different locations is critical to much-needed integration of our nation's environmental monitoring efforts (Committee on Environment and Natural Resources 1997). Improving the quality of protocols, as we recommend, will facilitate data comparability and integrated assessments of the status and trends of our ecosystems.

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Table 1. Guidelines for long-term monitoring protocols: recommended content of the protocol narrative.

1. Background and objectives
   a. Background and history; describe resource issue being addressed
   b. Rationale for selecting this resource to monitor
   c. Measurable objectives
2. Sampling design
   a. Rationale for selecting this sampling design over others
   b. Site selection
      i. Criteria for site selection; define the boundaries or "population" being sampled
      ii. Procedures for selecting sampling locations; stratification, spatial design
   c. Sampling frequency and replication
   d. Recommended number and location of sampling sites
   e. Recommended frequency and timing of sampling
   f. Level of change that can be detected for the amount/type of sampling being instituted.
3. Field methods
   a. Field season preparations and equipment setup (including permitting and compliance procedures)
   b. Sequence of events during field season
   c. Details of taking measurements, with example field forms
   d. Post-collection processing of samples (e.g., lab analysis, preparing voucher specimens)
   e. End-of-season procedures
4. Data handling, analysis, and reporting
   a. Metadata procedures
   b. Overview of database design
   c. Data entry, verification, and editing
   d. Recommendations for routine data summaries and statistical analyses to detect change
   e. Recommended reporting schedule
   f. Recommended report format with examples of summary tables and figures
   g. Recommended methods for long-term trend analysis (e.g., every 5 or 10 years)
   h. Data archival procedures
5. Personnel requirements and training
   a. Roles and responsibilities
   b. Qualifications
   c. Training procedures
6. Operational requirements
   a. Annual workload and field schedule
   b. Facility and equipment needs
   c. Startup costs and budget considerations
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