71 Recommended features of protocols for long-term ecological monitoring

KAREN L. OAKLEY, U.S. Geological Survey Biological Resources Division, Alaska Biological Science Center, 1011 East Tudor Road, Anchorage, Alaska 99503; karen_oakley@usgs.gov

SUSAN L. BOUDREAU, Denali National Park and Preserve, P.O. Box 9, Denali Park, Alaska 99755; susan_boudreau@nps.gov

SIOUX-Z HUMPHREY, Strides, Inc., 1815 Bunker Street, Anchorage, Alaska 99503; siouxz@strides-net

In 1991, the National Park Service (NPS) selected seven parks to serve as prototypes for development of a long-term ecological monitoring program. Denali National Park and Preserve was one of the prototype parks selected. The principal focus of this national program was to detect and document resource changes and to understand the forces driving those changes. One of the major tasks of each prototype park was to develop monitoring protocols. In this paper, we discuss some lessons learned and what we believe to be the most important features of protocols.

One of the many lessons we have learned is that monitoring protocols vary greatly in content and format. This variation leads to confusion about what information protocols should contain and how they should be formatted. Problems we have observed in existing protocols include (1) not providing enough detail, (2) omitting critical topics (such as data management), and (3) mixing explanation with instructions. Once written, protocols often sit on the shelf to collect dust, allowing methods changes to occur without being adequately considered, tested, or documented. Because a lengthy and costly research effort is often needed to develop protocols, a vision of what the final product should look like is helpful. Based on our involvement with the prototype monitoring program for Denali (Oakley and Boudreau 2000), we recommend key features of protocols, including a scheme for linking protocols to data in the data management system and for tracking protocol revisions. A protocol system is crucial for producing long-term data sets of known quality that meet program objectives.

What is a protocol?

According to the American Heritage dictionary, a protocol is "the plan for a medical or scientific experiment." Often, the term "protocol" is used in a narrower sense to refer to specific field or laboratory methods for data collection or measurement. We prefer the broader definition that a protocol is a complete study plan—not just a description of field or laboratory methods. A study plan explains what will be done and why. As a complete study plan, a protocol should demonstrate that the proposed monitoring has worthwhile objectives achievable for the given ecosystem within the limits of time, money, and personnel available for the project.

Why are protocols so important in long-term monitoring?

Long-term monitoring faces challenges not evident in the typical 2- to 5-year research project. Measurement error and consistency are of much greater concern. To be confident that any change detected is the result of an actual change, and that changes are not masked by inconsistent methods, one must know the data were collected with repeatable and documented methods. The quality of the data must be

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known. The many subtleties in the collection, handling, and analysis of data may affect their future use. These subtleties need to be documented to provide future data users with the information they need to evaluate data quality.

Sources of measurement inconsistency include:

1. Changes in measurement techniques, often due to improvements in technology;
2. Changes in personnel (a given in any long-term monitoring program);
3. Changes in what is being measured (e.g., dropping one attribute in favor of another);
4. Changes in the location where measurements are taken (e.g., the National Weather Service station at Denali park headquarters has been moved several times in its 75-year history, each move resulting in a recognizable change in the data); and
5. Changes in the frequency and timing of measurement (Beard et al. 1999).

Measurement errors are much easier and less costly to prevent than to correct (Geoghegan et al. 1990; Beard et al. 1999). The key to preventing such errors is to have a quality assurance and quality control plan (Shampine 1993). The heart of any such plan is a detailed statement of the methods to be used, and a documentation of the methods actually used (Geoghegan 1996).

Protocols written in the context of long-term ecological monitoring need more background information and greater attention to detail than is the case for the typical research project (Geoghegan 1996). Moreover, monitoring protocols need to be stored in a manner that keeps track of changes, and allows the exact methods used in any given year to be easily reconstructed.

Who are protocols written for?

In writing any document, one must consider the audience: the needs of the audience determine content, format, and style. Audiences for monitoring protocols are diverse, and include both current and future:

- Monitoring program managers;
- Peer reviewers;
- Monitoring personnel—the people who do the work; and
- Scientists who are hoping to use the data.

We want to emphasize that the audience includes people in the future. The success of the monitoring program depends on our ability to communicate exactly what must be done so that measurements taken by different observers at different and widely separated points in time prove consistent and comparable. We must also communicate why it is important to continue such measurements, or the opportunity costs of monitoring may exceed its perceived value, resulting in program disruption or termination (Caughlan and Oakley, in prep.). The diversity of the audience for monitoring protocols, including managers, scientists, and technical workers, creates a challenging situation for the protocol writer.

Recommended features of protocols

To meet the specific requirements of protocols for long-term monitoring, we recommend that they be divided into three distinct parts: (1) a narrative, (2) standard operating procedures (SOPs), and (3) a revision tracking system. The narrative explains in general terms what will be done, and why. Attached to the narrative will be any number of SOPs. SOPs are instructions written for the personnel doing the monitoring work; formatting—to optimize readability—is advised (Wieringa et al. 1998). The revision tracking system consists of a process for approving methods

changes, a log to record and easily retrieve information about any changes made, and use of the monitoring database to link protocols and data.

What goes in the narrative?

The narrative provides contextual information and is a clarifying document for all protocol audiences. The narrative is especially helpful to the program manager concerned with overall program relevancy and logistical coordination. The narrative should describe:

- Objectives, including explicit information on how they relate to overall program goals. Objectives should be measurable (e.g., What magnitude and direction of change in a given attribute is of interest? At what scales of space and time? What degree of confidence is required?).
- The sampling design and rationale for its selection.
- The measurements to be taken. The details, however, will be provided in the SOPs.
- Data quality objectives and quality controls required to meet those objectives.
- How data will be organized, documented, analyzed and reported.
- Budget information and an indication of what measurements will be taken and what methods would be used under varying budget scenarios.
- A schedule.
- Documentation of required compliance measures (e.g., Animal Use and Welfare Committee approval).
- The history of the protocol's development.

The narrative concludes with a list or flow chart referencing all the SOPs written to describe the monitoring work. The narrative should also explain assumptions about who will use each procedure. Procedures should be written at a level of detail appropriate for the intended users. The relationship between staffing decisions, the level of detail in the procedures, and the depth of training is important, and should also be explained in the narrative.

Standard operating procedures

Every protocol can be expected to include several SOPs. One step in protocol development will be to decide how to divide the work into logical units that cover all aspects. As an example, the protocol for small-mammal population monitoring at Denali is broken into 13 SOPs:

- SOP 1—Before the field season;
- SOP 2—Field season schedule;
- SOP 3—Field crew training;
- SOP 4—Setting up a small-mammal sampling grid;
- SOP 5—Catching and processing small mammals;
- SOP 6—Data management;
- SOP 7—Data analysis;
- SOP 8—Reporting;
- SOP 9—Working in the backcountry;
- SOP 10—Processing of incidental mortalities;
- SOP 11—Documenting vegetative and site characteristics of sampling grids;
- SOP 12—End of field season; and
- SOP 13—Procedure for changing the procedures.

Procedures are instructions, and they must be geared specifically to the intended user. Wieringa et al. (1998) provide a thorough overview of procedure writing. They note that the attention of the person who will use the instructions is divided: he or

she is trying to perform a task while following the written guidance. Thus, formatting the SOP to improve readability under the worst conditions of expected use is helpful. The instructions should be written as steps with appropriate use of placeholders, emphasis, and organization. A benefit of writing procedures as steps is that it becomes clearer where missteps are most likely, and where quality control checks should therefore be inserted. Numbering of steps helps by providing a convenient way to track revisions.

The publication format of procedures will vary depending on the type of work to be performed. If the procedures will be used outdoors, a conveniently sized handbook with waterproof pages might be appropriate. For lab procedures, a more standard publication format could be used. To ensure that the publication format helps the intended user operate in a consistent manner, testing under actual conditions of use is essential.

While the primary audience of the SOPs is monitoring personnel, the SOPs will also be used by peer reviewers and future scientists interested in the data. These audiences will be concerned with the fine details of how data were collected.

Revision tracking system

In any long-term monitoring program, methods will change over the years. New technologies may appear, allowing data to be collected more efficiently. Reconstructing the exact methods used in any one year can be difficult or impossible. Yet, without knowing what methods were used in a given year, we diminish or lose the use of that data for comparisons. Although stability in methods is desired, it is wiser to plan in advance for changes by using a procedure for approving changes (changes should not be made lightly) and keeping track of changes. In some cases, data will need to be collected under both the old and new methods for a period of time to allow calibration and build confidence that the data will not be compromised by the change in methods (Newell and Morrison 1993; Beard et al. 1999).

We recommend that three features be included in a revision tracking system. The first is to have a procedure that addresses how procedural changes will be made and approved (e.g., SOP 13 in the Denali small-mammal protocol). The second is to keep a revision history log that tracks changes as they occur. The log provides an index to the changes, including when they were made, why they were made, and what the exact change was. The third is to use the monitoring database to connect the data collected via a protocol to the protocol itself. To do this, each version of the protocol receives a code. The code is entered into a "protocol" field in the database with the data collected as per the protocol. The protocol codes can also be linked to a digital copy of the protocol, which is also stored in the database. This system for documenting the methods used will allow future users of the data to readily ascertain whether comparable methods were used. This system of tracking protocol changes and which protocols were used in a given year will need to be planned for and kept in mind as the protocols are written, and as the database management system for a monitoring program is developed.

Discussion

The monitoring program development process focuses on producing protocols that, when properly used, allow data to be collected, analyzed, and reported in a way that meets the program's goal. Protocols represent the end product of what may have been a lengthy, convoluted, and expensive development and testing process. Capturing this protocol development history within the protocol itself is important. The appropriate place for this is the narrative. Peer review of the protocol is critical before they are officially sanctioned. For peer reviewers to evaluate whether the draft protocol will meet the objectives, they will need to see the results of pilot studies, any sensitivity modeling that occurred, and other background information. Thus, while the SOPs, as instructions, would not include data, the narrative needs to include, or re-

fer to, data collected and analyzed in the process of protocol development. These data need to be available for peer reviewers looking at the adequacy of the protocol for meeting the stated objectives.

The protocol development history should also include information about methods that were considered or tested but rejected. The reasons such methods were rejected are important to understanding what methods eventually were adopted. A promising technique may have been overlooked or rejected based on faulty reasoning. Peer reviewers and future monitoring program managers will need to evaluate these contingencies. In addition, problems that prevented use of a certain technique at one point in time may later be overcome, perhaps by technological developments or increased funding, leading to a change in methods. As noted, such changes need to be carefully evaluated prior to adoption. Understanding the full history of the protocol's development will be critical to such evaluations.

Conclusion

Writing protocols as full study plans to the level of detail we recommend will require more effort than is typically devoted to such activities in short-term research. However, without clear statements of methods and the rationale for using them, or records of what methods were actually used, the quality of the data will be unknown, and the ability of a monitoring program to achieve its goal diminished. Substantial work is required to develop and test monitoring methods to ensure they will be consistent and comparable over periods ranging from decades to centuries. To fully realize the investment in the monitoring program, protocols must meet this higher standard.

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