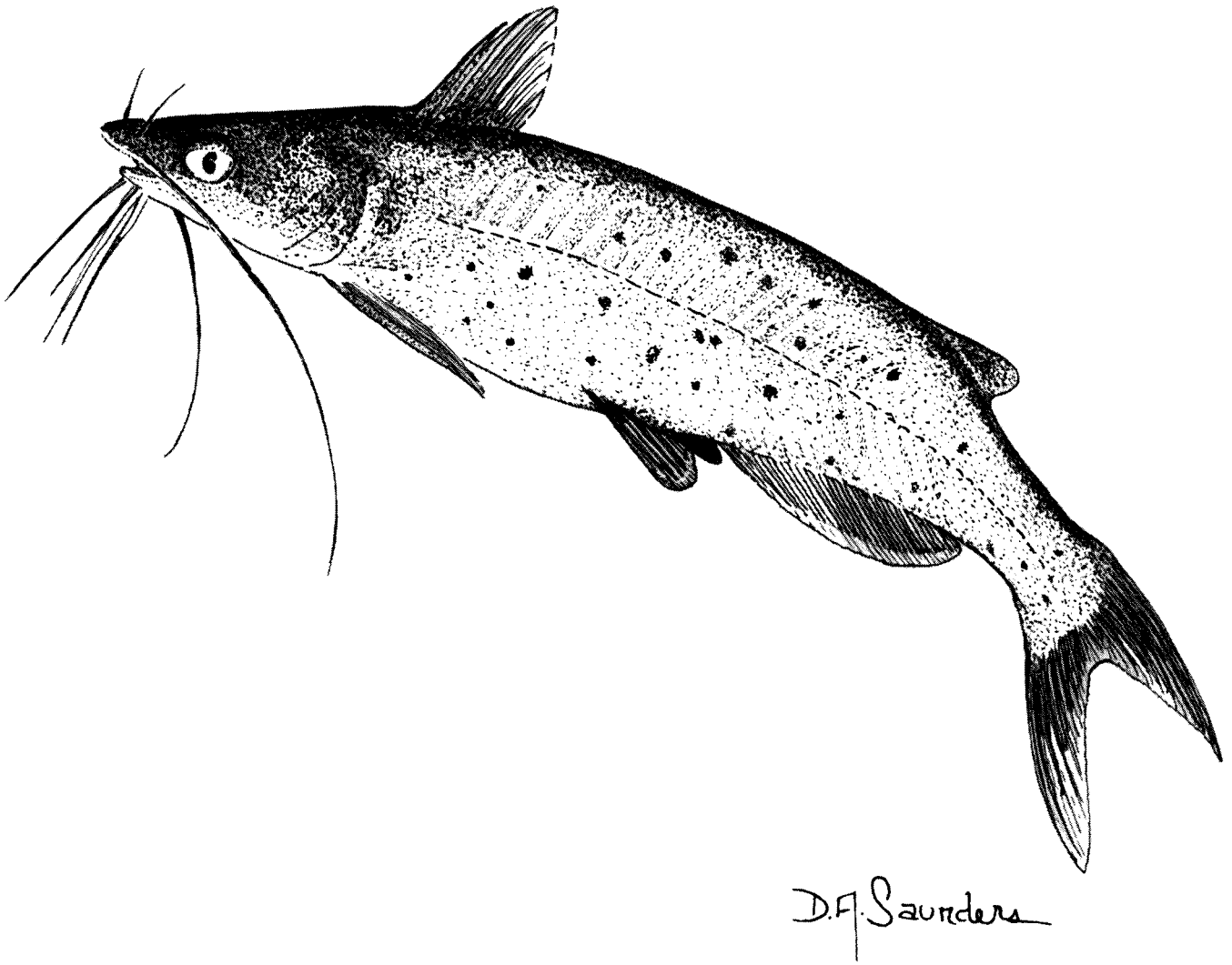
CHAPTER 2
Monitoring Overview



Ictalurus punctatus
Channel catfish
Artist: D. Andrew Saunders

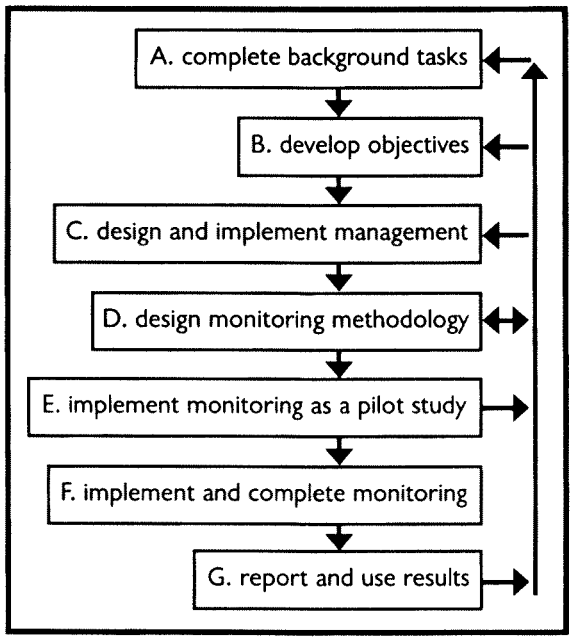


Figure 2.1. These seven major steps are broken into sub-steps and illustrated in Figures 2.2–2.5.

This chapter provides an overview of the development of objectives and monitoring methods and briefly addresses the development of management strategies. The steps described below and illustrated in the flow diagrams in Figures 2.1 through 2.5 provide an overview of the development of an adaptive management cycle (Fig. 1.1).

The major steps from completing background tasks to reporting and using results are shown in Figure 2.1. Each of these seven steps is broken down into its components and is described and illustrated. Steps are shown roughly in the order in which they occur in developing an adaptive management project, but recognize that feedback loops and reviews are many, as shown by the multidirectional arrows in the flow diagrams. At nearly any point in the process of developing a project, earlier decisions may have to be revisited and changes made.

COMPLETE BACKGROUND TASKS (FIG. 2.2)

Compile and Review Existing Information

Compile relevant information on the species and/or populations. For those monitoring projects where the target species and/or population are predetermined, you will only need the information specific to the species. For management programs that are just beginning, you will likely want to assemble the information needed to set priorities among all the target species occurring in your conservation/management area. If you manage many species, you may wish to start with a short list of species that are high priority, perhaps because of legal reasons such as nationally listed rare species and species of concern (see Chapter 3).

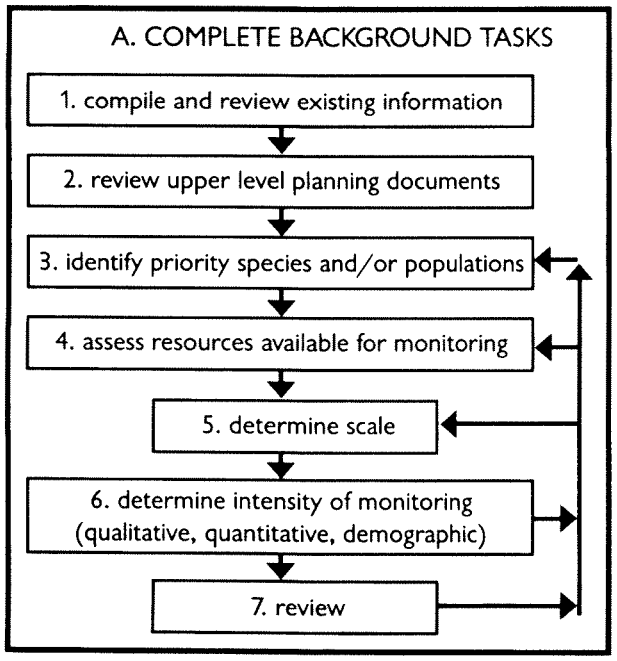


Figure 2.2. Flow diagram of the monitoring process, continued. Steps associated with completing background tasks are illustrated in detail.

Review Upper-Level Planning Documents

Consistent, local, land management depends on following upper-level planning documents, especially in management of State and Federal lands. These documents describe to the public the agency's planned activities. Because managers are accountable for implementing these plans, specific management activities for rare or target species should demonstrate progress toward meeting the goals and objectives described in them. Even if you believe your agency's land use plan provides little specific direction for management of a particular species (many of the older ones do not), you will increase support for your specific project if you can show a clear relationship between it and the general directives outlined in the planning documents (see Chapter 3). Stewards of private conservation areas may also wish to consider upper-level government planning documents to increase consistency of their conservation actions with those on adjacent or nearby Federal or State lands.

Identify Priority Species and/or Populations

Prioritize the species for monitoring, and document the process. This documentation will be immediately useful for review by the other parties that are involved in setting priorities, and it will also be useful to you and your successor if managers and other parties question the priority ranking at a later date. For priority species, select priority populations. These priorities may periodically require reassessment because of changes in threats, management, conflicts, and the interest of outside parties (see Chapter 3).

Assess the Resources Available for Monitoring

Resources for monitoring depend on management support, priorities, and the people and equipment available. Has management placed a priority on this monitoring project, or is support and funding limited? You may need to promote the importance of the project before you begin working on it. Are qualified personnel available to do the work? Do you have the necessary field equipment such as vehicles and measuring tapes? Is any high-tech equipment available (e.g., geographic information systems, global positioning systems, survey or forestry equipment)? Are people willing to give reviews and help sharpen your thinking? Do you have access to people with specialized skills? The types and amounts of resources will limit the extent and complexity of a monitoring project (see Chapter 3).

Determine Scale

Identify the scale of interest for monitoring (e.g., the range of the species, the populations within a certain watershed, populations in certain types of management units, a single population, a portion of a single population such as a key area or macroplot). Decide the scale of interest early in the monitoring process because it will influence later decisions and design. If, for example, the scale of interest is the species across its entire range, you will need to coordinate with various administrative units to develop a network of monitoring studies (see Chapter 3).

Determine Intensity of Monitoring

Will qualitative monitoring be adequate? Do you need quantitative data? Does the rarity of the species, the degree of threats, the uncertainty of management effects, or the political sensitivity of potential decisions warrant the use of an intensive monitoring approach? You may need to reevaluate the selected intensity of monitoring as you work through the remaining monitoring decisions (see Chapter 3).

Review

At this point, management should be briefed, and opinions and review should be solicited. For small projects, you could complete these steps on your own and then solicit internal and possibly external review. For larger programs or highly controversial species and populations, you may need to assemble a team (see Chapter 15).

DEVELOP OBJECTIVES (FIG. 2.3)

Develop an Ecological Model

In this handbook we promote the use of narrative or diagrammatic summaries (models) of the ecological and management interrelationships of the species of interest (Chapter 14 gives examples). Completing a model will help develop objectives, focus your monitoring, and improve interpretation and application of the data.

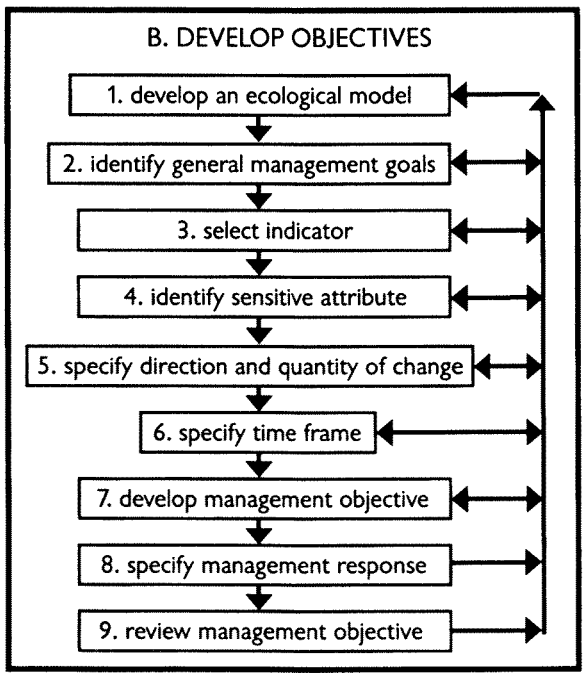


Figure 2.3. Flow diagram of the monitoring process, continued. Tasks associated with developing objectives are illustrated in detail.

Identify General Management Goals

Using your ecological model, try to refine conservation goals. Should the population size of the species be increased? Maintained? Recruitment increased? Mortality decreased? Describing these general management goals is the first step toward developing specific objectives.

Select Indicator

You may choose to monitor some aspect of the species itself or some indicator of species success. Effective indicators include other species, threats, habitat characteristics, or an indirect index of population abundance or success (such as animal track density). Other species that respond to management in a way similar to the target species but are easier to measure may be a cost-effective indicator. Monitoring threats can form an effective basis for management changes. Habitat indicators are especially useful for species that are difficult to measure or monitor directly (e.g., secretive or highly mobile animals, annual plants, long-lived species). For animals that are difficult to count, indirect indices of abundance may be the only way to assess population dynamics.

Identify Sensitive Attribute

Attributes may be measured values, such as population size, density, height, or age. Attributes also include qualitative and semiquantitative measures, such as presence or absence of the species, estimates of cover by cover class, and visual estimates of population size. Attributes for habitat characteristics or threat may also be measured variables or qualitative or semiquantitative. The attribute most sensitive and useful for monitoring depends on the management situation, the life history and morphology of the species, and the resources available to measure the attribute. Some species are so poorly known that you may have difficulty identifying a sensitive parameter. Make the best choice you can, or postpone monitoring until you know more about the natural history of the species.

Specify Direction and Quantity of Change

Will you monitor for a percentage change or an absolute change, a target value or a threshold value (see Chapter 14)? What amount of increase do you want to see, or what decrease will you tolerate? Can you specify a target population size? The quantity has to be measurable (confidently measuring a 1% change in average density is extremely difficult) and biologically meaningful (a 10% change in density of an annual plant species or some insect species is probably not important). Again, you may be limited by lack of information. You may also be limited by the amount of change you can detect in a sampling situation (see Chapters 7, 8, 9, and 10).

Specify Time Frame

How soon will management be implemented? How quickly do you expect the species to respond? How long do you want this monitoring program to continue if some threshold is not reached? The time frame should be biologically meaningful for the change you are anticipating. A 50% increase in the density of a long-lived woody plant, for example, is unlikely to occur over the next 3 years (although a decline of that magnitude may be possible and alarming).

Develop Management Objective

The priority species or population, the selected scale (location), the sensitive attribute, the quantity and direction of change, and the time frame of change are the critical components of the objective. Combine them into a simple, measurable, understandable objective (see Chapter 14).

Specify Management Response

Given the potential alternative results of monitoring, what management changes would be implemented in response to each alternative (see Chapter 14)? These management responses should be clarified before monitoring begins so all parties know the implications of monitoring results.

Review Management Objective

Preferably, a team of specialists and management would complete many or all of these steps, but sometimes the biologist will work alone through these steps. Before proceeding to the design of monitoring, solicit internal and external review, especially from parties that may be affected by management changes made in response to monitoring data (see Chapter 15). Do others have information about the biology or ecology of the species that you should incorporate into the model? Do all agree on the management objective? Do all agree with the proposed management response?

DESIGN AND IMPLEMENT MANAGEMENT

Depending on the situation, current management may be continued or new management proposed. Often current management is continued and monitored because little is known about the ecology and management requirements of a particular rare species. In some cases, however, previous monitoring data or natural history observations may suggest a need for management change. The ecological model may provide insight on needed changes as well. If new management is required, it must be completely described so it can be implemented effectively.

The design of conservation management strategies involves consideration of the ecology of the species, funding, management options, conflicting uses and activities, and communication and coordination with public and user groups. This complex and difficult step is unique to each situation and is a subject beyond the scope of this handbook.

DESIGN THE MONITORING METHODOLOGY (FIG. 2.4)

Qualitative Monitoring

Design General Methodology

Methods for qualitative monitoring include estimating quantity (e.g., ranked abundance, cover class) and quality (e.g., population stage class distribution, habitat condition) and using a permanent recording method such as a photopoint or a video sequence (see Chapter 4).

Design Methods to Reduce Variability Among Observers

The biggest drawback of using qualitative techniques is that estimates among observers can vary significantly. Between-observer variability can be reduced by several strategies described in Chapter 4.

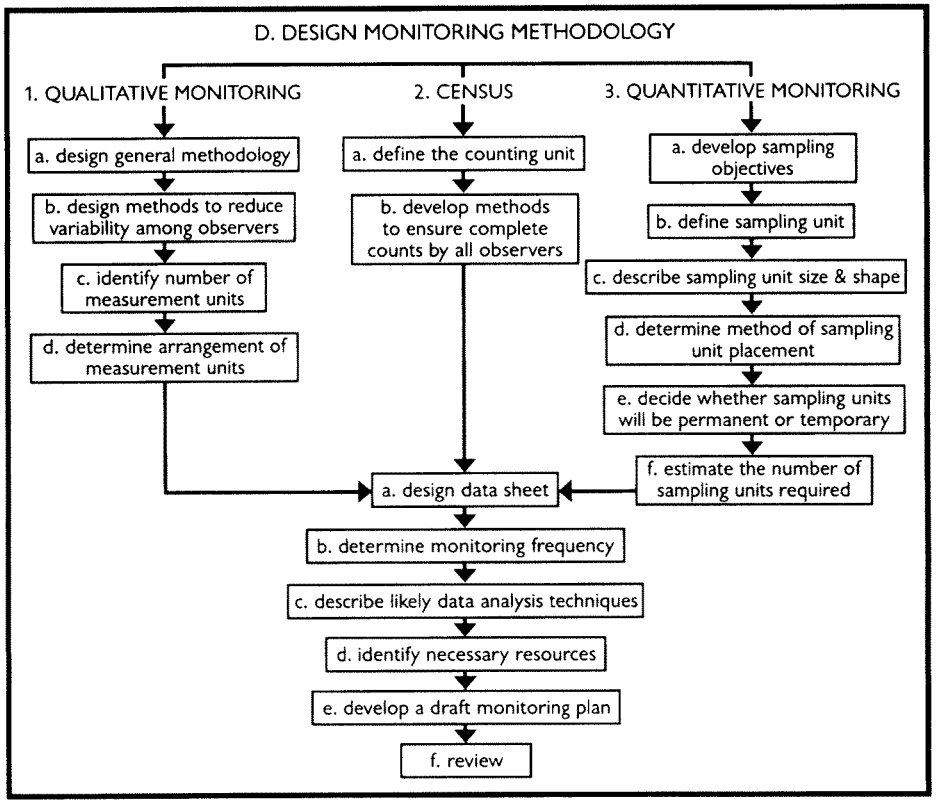


Figure 2.4. Flow diagram of monitoring process. The decisions required for each of the three types of monitoring—qualitative, census, and quantitative (sampling)—are summarized.

Identify Number of Measurement Units

Some qualitative monitoring situations may require several to many measurement units such as macroplots or photoplots. These are not sampling units, since they will not be combined and analyzed as a sample. Many design decisions, however, are similar to those required for sampling units and include selecting size, shape, and permanence.

Determine Arrangement of the Measurement Units

How will these measuring units be distributed in the population or across the landscape? Will you selectively place them based on some criteria such as threat or ease of access? Will you distribute these units evenly across the population to enhance dispersion and avoid bias?

Census

Define the Counting Unit

For plants you must decide if you will count individuals (genets), stems, clumps, or some other unit. For all species you must decide if you will count all individuals or only certain classes (such as juveniles)? If all individuals are not completely detectable and easily counted (usually the situation with animals), then a census will not be possible and some sampling protocol that adjusts for incomplete detectability will be required (see Chapter 13). These questions must be clearly addressed in the design to ensure that different observers conduct counts using the same criteria.

Develop Methods to Ensure Complete Counts

Will you have standardized methods (transects, plots, or grids)? Counts that are intended to be a complete census are often incomplete. What strategies will you use to ensure that small or cryptic individuals are not overlooked? For many animal species, counts are incomplete because of cryptic or elusive individuals.

Quantitative Studies with Sampling

Develop Sampling Objectives

If you are using sampling to estimate population sizes or mean values (such as density, cover, or frequency), you must also identify an acceptable level of precision of the estimate. If you are sampling and determining the statistical significance of changes over time, you must identify the size of the minimum detectable change (previously specified in your management objective), the acceptable false-change error rate, and the missed-change error rate (or statistical power level). What is the risk to the species if your monitoring fails to detect a real change (missed-change error), and how confident must you be of detecting a change over time (statistical power)? What is the risk to alternative uses/activities if your monitoring detects a change that is not real (false-change error)? (See Chapters 7, 8, and 9.)

Define the Sampling Unit

Will sampling units be plots, line transects, a collection of plots or points placed along a line or in a cluster, individuals, or parts of individuals (in plants such as number of seedpods)? Will all individuals be equally detectable? If not, adapt sampling techniques to adjust for incomplete detectability (see Chapter 13 for specialized sampling methods for animals). The sampling unit must be explicitly identified to ensure that the selected units are random and independent (see Chapter 8).

Describe Unit Size and Shape

The most efficient size and shape of the sampling unit depend on the spatial distribution of the species you are sampling. Most plants and animals are spatially arranged in clumps (i.e., individuals are not randomly dispersed across the landscape). Unless careful consideration is made of sampling-unit size and shape, many units may fail to intersect clumps of the target species. Many sampling units will be required in such a design to meet the specified precision and power of the sampling objective. Efficient sampling design using sampling units of appropriate size and shape can dramatically reduce the number of sampling units that must be measured, thus reducing the time and resources required for the field work and data entry. The size and shape of the sampling unit may be the most important decision affecting the success of projects where sampling is used (see Chapter 8).

Determine Sampling-Unit Placement

Sampling units must be positioned without bias. There are several methods described in Chapter 8.

Decide Whether Sampling Units Will Be Permanent or Temporary

Permanent sampling units are suitable for some situations, while temporary ones are more suitable for others (see Chapter 8). If the sampling units are permanent, monumentation or another method of relocation becomes critical and will require additional field time for plot establishment during the first year of the monitoring project (see Chapter 5).

Estimate the Number of Sampling Units Required

Data from a pilot study are the most reliable means to estimate the number of sampling units required to meet the targets of precision and power established in the sampling objective (see below). Chapter 8 and Appendix II describe estimation of sample size based on pilot data, as well as some alternative methods.

Design Issues Common to All Three Types

Design Data Sheet

While some studies may use electronic tools to record data, in most studies the researcher will record measurements on a data sheet. A well-designed data sheet can simplify rapid and accurate data recording and later computer data entry (see Chapter 6).

Determine Monitoring Frequency

How often should the parameter be measured? Will you be monitoring annually? Every 3 years? The frequency varies with the life-form of the species and the expected rate of change (e.g., long-lived plants or animals may require infrequent measurement), the rarity and trend of the species (the risk of loss for very rare or very threatened species is higher), and the resources available for monitoring.

Describe the Likely Data-Analysis Techniques

For all projects, describe how the data will be evaluated and analyzed. If you are using quantitative sampling, identify the statistical tests appropriate for the data you are planning to collect so the assumptions of the tests can be considered in the design stage (see Chapter 9). Do not assume that you can collect data, give it to an "expert," and expect meaningful results. Useful data analysis starts with good field design and data collection. This is also a good point to check whether the data will actually address the objective, given the analyses you plan to use.

Identify Necessary Resources

Now that you have specifically designed the monitoring project, estimate the projected annual and total costs and compare needed versus available resources. Reevaluate equipment and personnel required to successfully implement your project, and ensure that they are available. Document the individual or team responsible for implementation of the monitoring, the source and amount of the funding for monitoring (annually and over the life of the project), and the necessary equipment and personnel.

Develop a Draft Monitoring Plan

If all of these steps have been documented and reviewed, many components of your monitoring plan have been completed. The draft monitoring plan provides four important benefits: 1) it focuses the thinking of the author by forcing articulation, 2) it provides a vehicle for communication and review, 3) it documents approval and acceptance when finalized, and 4) it provides a history of the project and guards against the untimely end of the monitoring project if the primary advocate leaves (see Chapter 15). For those monitoring projects requiring minimal review from people outside the organization, the monitoring plan may be postponed until after data from the pilot stage have been analyzed.

Review Plan

Use the monitoring plan to solicit review of your proposed project (see Chapter 15). Do all reviewers agree with the methodology? Does the proposed methodology really monitor the objective? It may be necessary to revise the methodology, the objective, or both. For example, your objective may involve increasing cover of the target plant species; however, as you design the monitoring, you may realize that measuring cover of this particular species will be difficult. Treat the development of objectives and design as an interactive process. The objective drives the design of the monitoring, but the practical constraints of the morphology or biology of the species, the characteristics of the site, or the availability of monitoring resources may require reevaluation of the objective.

IMPLEMENT MONITORING AS A PILOT STUDY (FIG. 2.5)

Collect Field Data and Evaluate Field Methods

The first trial of a monitoring method in the field often exposes problems with the methodology (e.g., plots cannot be positioned because of dense vegetation; the proposed counting unit cannot be applied consistently; lacy vegetation proves a problem for measuring shrubs along a line intercept). This is why the pilot period is important for testing the feasibility of the proposed moni-

toring approach and for identifying improvements. You may find at this stage that the project cannot be implemented as planned and requires substantial revision, or even abandonment, in spite of all the work done to this point.

Analyze Pilot-Study Data

Analyze data from the pilot study. Do assumptions of the ecological model still appear correct? Are sampling objectives of precision and power met? If not, you may need to alter your monitoring design (add more sampling units or improve the efficiency) or the sampling objective (accept lower precision and/or power) or perhaps abandon the entire project. Does the level of change or difference you have specified seem realistic? Do changes caused by weather seem larger than you anticipated, thus swamping the quantity specified in your objective, or do the plants appear so slow growing that the proposed change is unrealistic? You may need to reassess the quantity or time-frame component of your objective.

Reassess Time/Resource Requirements

The pilot project should provide a better estimate of the resources required for monitoring. Your estimate of costs should include the amount of time it has taken to develop the monitoring to this point, as well as how much time it will take to continue the monitoring annually and to complete final data analysis and reporting.

Review

Solicit review of the results of the pilot period. Do all parties still agree to continue the monitoring and abide by the results? Are there resources available to implement monitoring throughout its life span? Make necessary changes to the monitoring design and the monitoring plan, and solicit final review.

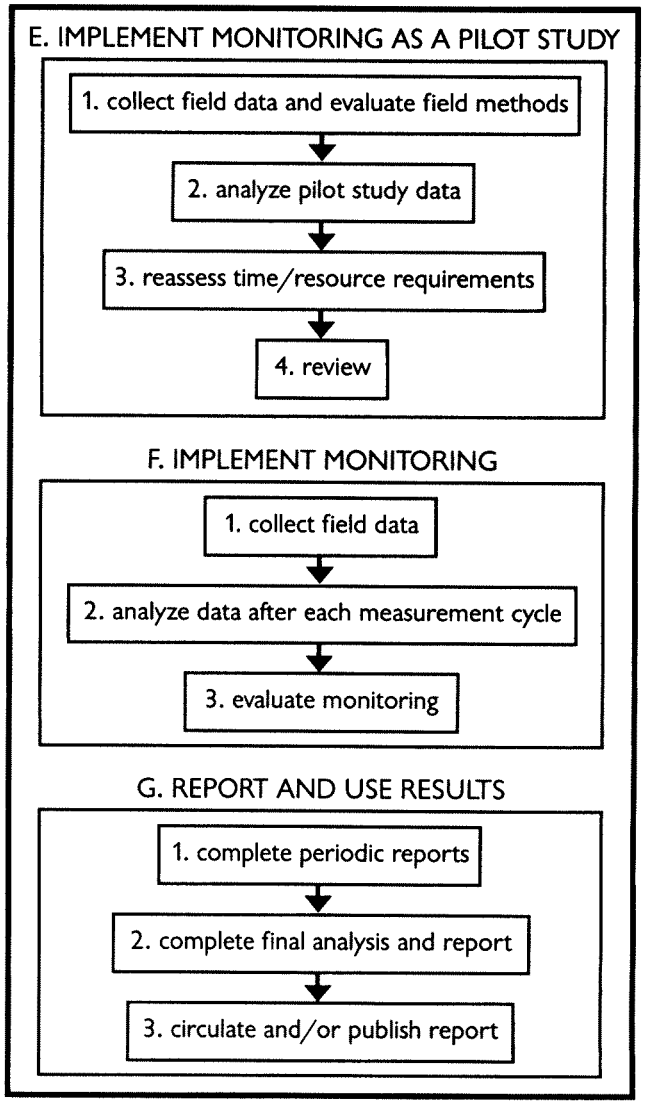


Figure 2.5. Flow diagram of the monitoring process, continued. Tasks associated with implementing monitoring as a pilot study, continuing monitoring, reporting and using results are illustrated.

IMPLEMENT MONITORING (SEE FIG. 2.5)

Collect Field Data

Complete data collection at specified intervals. Ensure that data sheets are completely filled out, duplicated, and stored in a safe place.

Analyze Data after Each Measurement Cycle

Complete data analysis soon after data collection. Data should not be stored over several years before analysis for a final report. Timely analysis identifies problems early, reduces the work associated with the final report, and ensures that questions requiring additional field visits can be addressed. In addition, questions that occur when field data sheets are entered into the computer can often be answered because the field work is still fresh in your memory.

Evaluate Monitoring

Evaluate field methods, costs, sample size, and relevancy of the monitoring project after each data collection. Recognize that at any time in the process a problem may arise that causes you to change or abandon your monitoring effort. All the steps preceding this one reduce that risk, but do not eliminate it.

REPORT AND USE RESULTS (SEE FIG. 2.5)

Complete Periodic Reports

Completing a summary report each time data are collected will yield the following benefits: 1) display the importance and usefulness of the monitoring to management, thus increasing continued support; 2) provide a summary for successors in the event of your departure; and 3) provide a document that can be circulated to other interested parties.

Complete Final Analysis and Report

At the end of the specified time frame (or earlier if objectives are achieved), prepare a final monitoring report and distribute to all interested parties (see Chapter 15). This final report presents and summarizes the data, analyses, and results and provides recommendations. If the monitoring project has been designed and documented as described above and data have been analyzed periodically, completion of this final report should not be onerous nor contain major surprises.

Circulate and/or Publish Report

Sharing the results of your monitoring increases the credibility of the organization, assists others in the design of their monitoring projects, enhances partnerships, contributes to the scientific enterprise, and reduces redundancy. Sharing the results in a technical forum such as a symposium or a journal article is also a good opportunity for professional development for you.