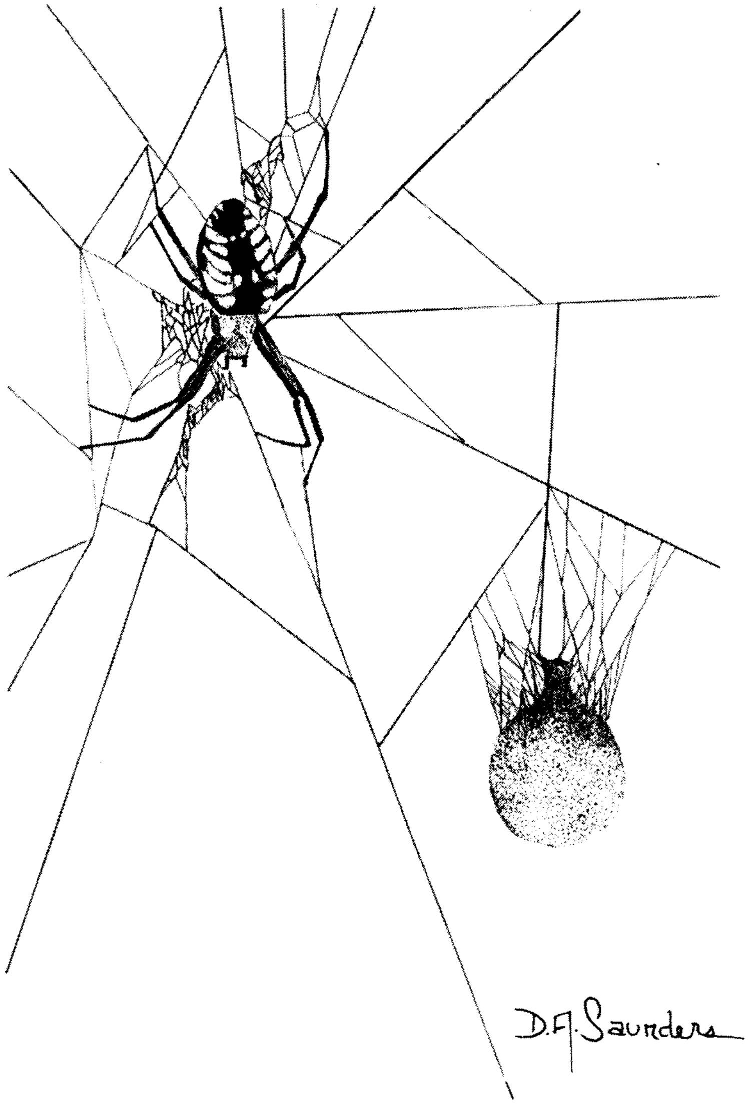
CHAPTER 14
Objectives



Argiope aurantia
Black and yellow argiope
Artist: D. Andrew Saunders

In this handbook we are promoting objective-based monitoring within an adaptive-management framework (see Chapter 1). We believe successful monitoring depends on developing specific management objectives. Objectives are clearly articulated descriptions of a measurable standard, desired state, threshold value, amount of change, or trend that you are striving to achieve for a particular population or indicator. Objectives may also set a limit on the extent of an undesirable change.

In this chapter, we describe a process for developing clear management objectives. We also describe a process for writing sampling objectives, which are companion objectives to be included whenever monitoring involves sampling procedures. The sampling objectives include information on desired levels of precision, minimum detectable change, and acceptable false-change and missed-change error rates. The information contained within the sampling objectives is essential for completing the sampling design.

As part of the adaptive-management cycle, management objectives accomplish the following:

- Focus and sharpen thinking about the desired state or condition of the resource.
- Describe to others the desired condition of the resource.
- Determine the management that will be implemented, and set the stage for alternative management if the objectives are not met.
- Provide direction for the appropriate type of monitoring.
- Provide a measure of management success.

As the foundation for all of the management and monitoring activity that follows, developing good management objectives is probably the most critical stage in the monitoring process (MacDonald et al. 1991). Objectives must be realistic, specific, and measurable. Objectives should be written clearly, without any ambiguity.

COMPONENTS OF AN OBJECTIVE

Six components are required for a complete management objective:

- Species or Indicator: identifies what will be monitored
- Location: geographic area
- Attribute: aspect of the species or indicator (e.g., size, density, cover)
- Action: the verb of your objective (e.g., increase, decrease, maintain)
- Quantity/Status: measurable state or degree of change for the attribute
- Time frame: the time needed for the management strategy to prove effective

Management objectives lacking one or more of these components are unclear. Box 14.1 gives examples of typical incomplete objectives and identifies their missing components.

Species or Indicator

Monitoring may involve measuring the change or condition of some aspect of the species itself. If you are monitoring the species, the objective should include its scientific name. If the objective will address a subset of the species (e.g., only flowering individuals, only females), this should be specified.

Monitoring may also measure indicators that function as surrogate measures of species success. We described four general classes of indicators in the first chapter: 1) indicator species that correlate with the success of the target species and are easier to measure; 2) habitat characteristics; 3) threats; 4) indices of abundance such as tracks and sign.

Box 14.1. *EXAMPLES OF OBJECTIVES MISSING ONE OF THE SIX COMPONENTS OF A MANAGEMENT OBJECTIVE: SPECIES OR INDICATOR, LOCATION, ATTRIBUTE, ACTION, QUANTITY/STATUS, AND TIME*

Most of these objectives are missing a component. What's missing?

1. *Decrease cowbirds (*Molothrus ater*) at the Three Creeks Wildlife Management Area by 2005.*
2. *Exclude livestock from the Summit Creek* Primula alcalina *population.*
3. *Exclude livestock from the Summit Creek if cattle are impacting* Primula alcalina.
4. *Increase percent cover of living hard corals on the Scott's Head Bay reef by 50%.*
5. *Decrease the percent of* Astragalus aquilonius *individuals trampled by livestock at the Grandview site by the 2003 grazing season.*
6. *Maintain a population of at least 500 breeding giant tortoises on Isla Pinzon between 2000 and 2025.*
7. *Allow no more than 30% herbivory of inflorescences in any two years in a row between 2000 and 2008.*
8. *Increase the white-tailed deer population at the Huntington Wildlife Forest by 25% between 2000 and 2005.*
9. *Increase the habitat occupied by* Gymnosteris nudicaulis *by 300 hectares.*
10. *Increase the viability of the onion.*
11. *Maintain, at a minimum, 300* Happlopappus radiatus.
12. *Increase the number of waterfalls with viable populations of Chittenango ovate amber snail (*Succinea chittenangoensis*) under protective management by 3 by 2010.*

Missing component:

1. *Decrease what attribute of cowbirds? Decrease from what level or from which time?*
2. *This is a management response, not an objective.*
3. *Not an objective, more similar to a management response. The term "impacting" is ambiguous. Need to identify some measurable parameters.*
4. *Increase by 50% over current value? By when?*
5. *How large a decrease in percent? From when?*
6. *Looks OK.*

(Continued)

Box 14.1. *EXAMPLES OF OBJECTIVES MISSING ONE OF THE SIX COMPONENTS OF A MANAGEMENT OBJECTIVE: SPECIES OR INDICATOR, LOCATION, ATTRIBUTE, ACTION, QUANTITY/STATUS, AND TIME (Continued)*

7. *What plant? What site or population? Is an inflorescence included in the 30% if it is only partially eaten, or does it have to be completely consumed?*
8. *What attribute of deer populations? Total numbers? Numbers of reproductive females? Number of antlered males? Something else?*
9. *Where? In a certain population or watershed or throughout the resource area? By when should this increase occur?*
10. *What is viability? How much increase? What onion? What population? By when?*
11. *Where? Time frame? Maintain 300 of what attribute (individuals, stems, flowering plants)?*
12. *What is protective management? What is a viable population? Where should these sites occur?*

Monitoring indicators may be less expensive, provide more immediate monitoring feedback to management, and focus on the aspect of the species that you actually have management control over (habitat quality or intensity of threat). Monitoring indicators may also be problematic because the relationship between an indicator and a particular species is usually hypothetical, or at best only partially understood. Monitoring an indicator may thus result in false conclusions about the condition of a species population. The benefits and potential problems with using indicators is discussed at length in Chapter 1.

Location

Clear delineation of the specific entity or geographic area of management concern allows all interested parties to know the limits to which management and monitoring results will be applied. The spatial bounds of interest defined in a management objective will vary depending on land management responsibilities (e.g., you may only have access to a portion of a particular population because of land ownership patterns) and particular management activities (e.g., you may only be interested in individuals located within recently logged forests). The location is related to the selected scale of monitoring (see Chapters 3 and 8), which is affected by conservation goals and responsibilities, the biology of the species, and the realities of limited monitoring resources.

Attribute

The best attribute to use in monitoring depends on the management situation, the species, and the monitoring resources available. Population size is a common attribute when monitoring rare species. Population size of plants and some animal species may be counted directly in a census (if you can count them all) or estimated by making counts in plots within an area of known size.

For some species, monitoring population size may be difficult. Animals that are secretive and hard to count may be estimated by the techniques described in Chapter 13, but another attribute may be easier to monitor and just as effective for assessing management (e.g., indices of population size, habitat characteristics, threats—see Chapter 1). Box 14.2 describes some examples of these. For plants, population size is sometimes difficult to measure when individuals (or some other counting unit) are difficult to distinguish (e.g., rhizomatous plants). For these plants another measure such as cover may be a better attribute to monitor (Box 14.3). Chapter 12 describes several vegetation measures suitable for use as monitored attributes. Qualitative estimates of abundance, presence/absence and aerial extent are all useful attributes to consider (described in Chapter 4). Attributes of habitat indicators or threats may be similar to quantitative measures for species (e.g., density of tire tracks or cover of woody species) or may be particular to the indicator chosen (e.g., level of a trace contaminant expressed in parts per million).

When selecting an attribute, first narrow the list of potential attributes given constraints of species morphology and site characteristics (e.g., density is not an option if your species lacks a recognizable counting unit). Then narrow the list further by considering the following criteria:

- The measure should be sensitive to change (preferably the measure should differentiate between human-caused change and "natural" fluctuation).
- Biologically meaningful interpretations of the changes exist that will lead to a logical management response.
- The cost of measurement is reasonable.
- The technical capabilities for measuring the attribute are available.
- The potential for error among observers is acceptable.

Box 14.2. *ATTRIBUTES THAT CAN BE MONITORED FOR ANIMAL POPULATIONS*

- *Age and sex composition (based on differences in plumage, pelage, or other external characteristics often visible to the eye during counts)*
- *Size of individuals (antler beam in deer, snout-vent length in amphibians and reptiles, tarsus or wing length in birds)*
- *Mass*
- *Condition (often some combination of mass divided by length, or, in birds, overall electrical conductance or visual inspection of subcutaneous fat deposits as a measure of lipid reserves, or presence of deformities in amphibians)*
- *Reproductive status (often based on evidence of lactation in mammals or swellings of the reproductive organs in birds and amphibians, x-rays of reptiles to detect eggs)*
- *Parasite loads (e.g., tick-loads in mammals, mite-loads in birds)*
- *Reproductive rates (for example, number of offspring accompanying their mother—ungulates, whales, young per nest in birds, or egg masses deposited by frogs and some salamanders)*
- *Survival rates and immigration/emigration (require intensive studies)*
- *Area occupied*

Box 14.3. *PLANT ATTRIBUTES SUITABLE FOR MONITORING*

- *Density*
- *Cover (canopy cover or basal cover for trees, matted plants, and some bunchgrasses)*
- *Frequency*
- *Biomass (on a plot basis rather than an individual plant basis)*
- *Condition (vigor, color, percentage of damaged or dead parts)*
- *Size of individuals (height, basal diameter, biomass)*
- *Reproductive output (number of flowers, percentage flowering success, number of fruits, seed production)*
- *Seedlings (survival, density)*
- *Flowering plants (density or percentage of the plants that are reproductive)*
- *Density or percentage of plants exhibiting herbivory or injury*
- *Mortality (density or percentage of dead plants)*
- *Population area*

Action

There are three basic actions: increase, decrease, and maintain. There is a tendency when managing rare things to want to have them increase. Some populations, however, may already be at the maximum potential for their habitat or suffer from no apparent threats. For these, a more realistic objective would be to maintain current condition. For other populations you may wish to set a threshold that will trigger a management action if the population falls below the threshold. The following are some questions to consider:

- Are current populations viable or have recovery needs such as increased population size, improved vigor, or change in demographic distribution been identified? Species with potential for rapid declines or existing significant degradation of habitat may deserve a more aggressive approach than simply maintaining the current condition.
- Are management options available that you believe will increase the abundance or improve the condition of the species?
- Will increases occur with removal of threats, or will more active management efforts be necessary (e.g., prescribed fire, augmentation by transplants, control of competing exotics).

The following is a list of common action verbs used in management objectives and guidelines describing when each is appropriate:

- **Maintain.** Use when you believe the current condition is acceptable or when you want to set a threshold desired condition (e.g., maintain a population of 200 individuals).

- **Limit.** Use when you wish to set a threshold on an undesirable condition or state of the species or habitat (e.g., limit Noxious Weed A cover to 10%; limit mortality to 10% per year).
- **Increase.** Use when you want to improve some aspect of the species or indicator (e.g., increase the average density by 20%; increase the number of populations to 16).
- **Decrease.** Use when you want to reduce some negative aspect of the species or indicator (e.g., decrease livestock utilization of inflorescences to 40% or less; decrease cover of Noxious Weed A by 20%).

Quantity/State

The condition or change must be described with a measurable value. This can be a quantity (e.g., 500 individuals, 20% cover, 30% change), or a qualitative state (e.g., all life stages present at the site, cover class 4).

Determining these quantities or states requires consideration of a number of factors:

- How much can the species respond? Populations of long-lived species (such as tortoises or trees) may be very slow to respond to management changes. Changes may be small and difficult to detect, or take many years to express. (Consider using an indicator as an alternative).
- What is necessary to ensure species or population viability (e.g., how much change, what population size, what qualitative state)?
- How much change is biologically meaningful? Some species (such as annual plants) can have tremendous annual variability, and an objective that specifies, for example, a 10% increase in density is meaningless.
- What is the intensity of management? Will you continue existing management, remove current threats, or implement a radical alternative?
- What is the implementation schedule of management? If the monitoring project is scheduled to last 5 years, but new management will not be implemented until the second year of the study, the change results from only 3 years of management.
- What are the costs and problems associated with measuring the amount of change specified? Small changes are often difficult and expensive to detect (see Chapters 7 and 8).

The task of specifying a measurable quantity or state is usually a challenging one. The ecology of many species, especially rare ones, is poorly understood. Predicting the response of a population to particular management activities is often difficult. Many populations undergo natural fluctuations as they respond to varying climatic conditions or to the fluctuating populations of pollinators, herbivores, predators, or prey. Most populations have been subject to impacts from human activities; thus, historic conditions or natural population levels are unknown. Few species have been studied in enough detail to reliably determine minimum viable population levels, and theoretical problems with the concept of minimum viable populations remain even in species that have been intensively studied. These challenges should not serve as obstacles to articulating measurable objectives. Use the tools described below and do the best that can be done. If you do not articulate a measurable management objective, you have no means to assess if current management is beneficial or deleterious to the species of interest.

Time Frame

The time required to meet a management objective is affected by the biology of the species, the intensity of management, and the amount of change desired. Populations of short-lived species that reproduce annually may respond quickly, but long-lived species and those with episodic reproduction may require more time. Intense management will result in more rapid changes than low intensity or no special management. Large changes will require more time than smaller ones, unless a management action will have immediate, large impacts (e.g., timber harvest).

Objectives with time frames as short as a few months to a year may be appropriate in some situations. We recommend that time frames be as short as possible for several reasons:

- Changes in management budgets and personnel often doom long-term monitoring projects.
- Short-term objectives promote regular reassessment of management and implementation of management changes.
- Monitoring often uncovers unexpected information; short-term objectives encourage modification of objectives and monitoring based on this information.
- Short-term objectives circumvent the trap of monitoring ad infinitum while avoiding difficult decisions.
- The adaptive-management cycle must occur within a short enough period that opportunities for species recovery or alternative management are not lost.

TYPES OF MANAGEMENT OBJECTIVES

Objectives can be described in one of two ways:

- A **condition** (e.g., increase the population size of Species A to 5000 individuals; maintain a population of Species B with at least 2500 individuals; maintain Site B free of noxious weeds X and Y). We will call these target/threshold management objectives.
- A **change** relative to the existing situation (e.g., increase mean density of Species A by 20%; decrease the frequency of noxious weed Z by 30%). We will call these change/trend management objectives.

For target/threshold objectives, you assess your success in meeting your objective by comparing the current state of the measurement attribute to the desired state or to an undesirable state that operates as a red flag or threshold. With a change/trend objective you measure the trend over time. The two types of objectives are appropriate for different situations. You may choose a change/trend objective when you have insufficient information to describe a realistic future condition but you can describe a realistic rate of change. You would also use a change/trend objective when you believe the current state is less important than the trend over time. For example, whether a population has 8000 individuals or 6000 individuals may not matter; a decline from 8000 individuals to 6000 individuals (a 25% decline) may be very important to detect. Usually change objectives are more appropriate than target/threshold types of objectives when management has changed and you want to monitor the response (trend) of the selected attribute.

The two types of objectives also require different considerations in designing the monitoring methodology and analyzing the results, especially when the monitoring of the objective requires sampling. Chapters 8 and 9 describe these issues in detail.

Management objectives can be written to describe either desirable or undesirable conditions and trends. You would frame your objective in desirable terms if you believe improvement of the population or indicator is necessary and if you have implemented management that you believe will result in improvement. These objectives are sometimes referred to as "desired condition objectives" because they describe the target condition or trend of the resources (e.g., increase to 2000 individuals, decrease cover of a noxious weed by 40%).

If you believe the current condition is acceptable, and that a continuation of current management will likely maintain that condition, you could frame your objective using undesirable thresholds of condition or trend. These are sometimes termed "red flag objectives" because they state the level of an undesirable condition or change that will be tolerated (e.g., no fewer than 200 individuals; no more than 20% cover of the noxious weed; no more than a 20% decrease in density). These objectives act as a warning signal that management must change when the threshold is exceeded. Red flag objectives can be written to identify an unacceptable decline in a rare species or a surrogate habitat variable, or an unacceptable increase in a negative factor (e.g., an exotic species, encroaching shrub cover, the percentage of habitat disturbed by recreational vehicle traffic, etc.).

Different types of management objectives require varying intensities of monitoring (see Chapter 3). Qualitative objectives can be monitored using techniques that assess condition or state without using quantitative estimators. Simply finding if the species still occurs at a site is a type of monitoring that can be very effective for some situations. Another approach is to use estimates of abundance such as "rare," "occasional," "common," and "abundant," or to map the aerial extent of the population. Objectives may also be written so they can be monitored by complete counts. Other populations may require monitoring by sampling. If so, the management objective is paired with a sampling objective (see below). We give you examples of plant and animal management objectives (paired where needed with sampling objectives, described later in this chapter), arranged in order approximating increasing intensity and including desired condition and red flag types (Box 14.4 for plants and 14.5 for animals).

Box 14.4. *THESE EXAMPLES OF OBJECTIVES FOR PLANTS ARE DIVIDED INTO TWO MAIN CATEGORIES: TARGET/THRESHOLD AND CHANGE/TREND. WITHIN EACH CATEGORY, OBJECTIVES ARE ARRANGED IN ORDER THAT ROUGHLY CORRESPONDS TO INCREASING MONITORING INTENSITY. EXAMPLES OF DESIRED CONDITION AND RED FLAG TYPES OF OBJECTIVES ARE INCLUDED.*

Many of the following management objectives illustrate examples where sampling is not occurring and therefore no sampling objective needs to be articulated. For management objectives where sampling is likely to occur, an example sampling objective is included.

TARGET/THRESHOLD OBJECTIVES

Management Objective	*Increase the estimated total cover (plotless visual estimate) of* Astragalus leptaleus *in Macroplot A at Birch Creek from Class 1 (1–10%) to Class 3 (21% to 30%) by 2010.*
Management Response	*Grazing will be changed to fall use only if an increase is not observed.*
Management Objective	*Eliminate OHV (off-highway vehicle) tracks in* Xanthoparmelia idahoensis *habitat (illustrated on habitat areas Map 1) beginning in 2002.*
Management Response	*If OHV evidence is found, implement educational efforts to reduce OHV traffic in habitat areas. If these are unsuccessful, area closures will be identified and fences constructed.*

(Continued)

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Management Objective	*Increase the number of population areas of* Penstemon lemhiensis *within the Iron Creek Drainage from 8 to 15 by 2010.*
Management Response	*If new populations fail to establish under current management, a transplant reintroduction program will be considered and, if approved, implemented by the year 2011.*
Management Objective	*Maintain a minimum cover of 30%* Xanthoparmelia idahoensis *(plotless visual estimate) in at least 7 of the 10 macroplots established in the Bent Hills population area between 2003 and 2009.*
Management Response	*If, in any year, cover decreases below this threshold, reduce OHV use by area closures and erecting fences.*
Management Objective	*Maintain an estimated cover of at least 20% (plotless visual estimate) of* Xanthoparmelia idahoensis *in Macroplot A in the Warm Springs drainage between now and 2003.*
Management Response	*If cover declines below an estimated 20%, institute a more extensive, quantitative monitoring project that assesses the trend of the entire population in the Warm Springs drainage.*
Management Objective	*Increase the number of individuals of* Penstemon lemhiensis *in the Iron Creek population to 160 individuals by the year 2005.*
Management Response	*Failure to detect an increase to 160 individuals will result in more intensive monitoring to determine if the current population of 122 is stable and viable (demographic analysis), and the implementation of alternative management by 2010 if it is not.*
Management Objective	*Maintain at least 50 reproductive individuals of* Thelypodium repandum *at the Lime Creek population during mining operations.*
Management Response	*Collect seed the first year the population falls below 50 individuals, and for 3 years following.*
Management Objective	*Maintain a population of at least 200 individuals of* Thelypodium repandum *at the Malm Gulch site between 2003 and 2010.*
Management Response	*Failure to maintain a population of the minimum size will trigger additional monitoring and study to determine the reason for failure. Alternative management will be implemented by 2012.*

Management Objective	*Increase the mean density of* Viola adunca *in Macroplot A at the Clatsop Plains Preserves to 1.0 plants/m²* *by 2005.*
Sampling Objective	*Be 95% confident that estimates of density are within ±30% of the estimated mean density.*
Management Response	*If the desired increase does not occur, additional monitoring of the population will be implemented, and alternative management implemented by 2008. If the mean density is equal to or greater than the target density, current management will continue and the population will be monitored again in 2008.*
Management Objective	*Allow herbivory of inflorescences on no more than 20% of the individuals of* Primula alcalina *at the Birch Creek population in any year.*
Sampling Objective	*Be 90% confident that estimates of inflorescence herbivory are within ± 8% of the estimated percent grazed.*
Management Response	*Exclude cattle use from the Birch Creek* Primula alcalina *site by constructing a buck and pole fence within 6 months of the time the threshold is exceeded.*
Management Objective	*Maintain a frequency of 20% (0.10-m² square quadrats) or less of the noxious weed* Taeniatherum caput-medusae *in Macroplot A at the Agate Desert Preserve in any year between 2002 and 2007.*
Sampling Objective	*Be 95% confident that frequency estimates are within ±5% of the estimated frequency values.*
Management Response	*Initiate chemical weed control the following field season if the frequency of* Taeniatherum caput-medusae *exceeds 20% in Macroplot A.*
Management Objective	*Allow no more than 30% of the population of* Silene scaposa *var.* lobata *to be killed by logging operations at the Wood Creek site.*
Sampling Objective	*Obtain estimates of percent mortality with 95% confidence intervals that are no wider than ± 10% of the estimated percent mortality.*
Management Response	*Logging will not be allowed in other population areas of* Silene scaposa *var.* lobata *if the mortality at this site exceeds the threshold.*
Management Objective	*Maintain a minimum population of 1000 clumps of* Sarracenia oreophila *at the Eller Seep Preserve between 2003 and 2010.*
Sampling Objective	*Estimate the number of* Sarracenia orephila *clumps with 95% confidence intervals no wider than ±10% of the estimated number of total clumps.*
Management Response	*Additional monitoring will be initiated if the population falls below the threshold of 1000 clumps.*

(Continued)

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CHANGE/TREND OBJECTIVES

Management Objective	*Increase the density of* Lomatium cookii *at the Agate Desert Preserve by 20% between 2003 and 2008.*
Sampling Objective	*Be 90% sure of detecting a 20% change in density with a false-change error rate of 0.20.*
Management Response	*If the density fails to increase, additional research of potential management options will be initiated and alternate management implemented by 2012.*
Management Objective	*Allow a decline in the mean density of* Primula alcalina *at the Summit Creek site of no more than 20% between 2002 and 2010.*
Sampling Objective	*Be 95% sure of detecting a 20% change in density with a false-change error rate of 0.10.*
Management Response	*A decline of 20% will trigger a more intensive study of the interaction of livestock grazing and* Primula alcalina, *with the implementation of alternative management within 4 years after the first year an unacceptable level of decline is measured.*
Management Objective	*Allow a decrease of no more than 20% of the 2001 cover of* Astragalus diversifolius *at the Texas Creek population between 2001 and 2008.*
Sampling Objective	*Be 90% certain of detecting a 20% decrease in the percent cover with a false-change error rate of 0.10.*
Management Response	*Exceeding the decrease will trigger a change in grazing management to a fall-use only system, implemented the season after a 20% decrease is exceeded.*
Management Objective	*Allow a decrease of no more than 30% in the number of individuals of* Conradia glabra *at Apalachicola Bluffs and Ravines Preserve over a 2-year period after implementing prescribed fire.*
Sampling Objective	*Be 80% certain of detecting a 30% decrease in the total number of individuals with a false-change error rate of 0.20.*
Management Response	*If the reduction exceeds 30%, populations will be protected from subsequent burns at the Apalachicola Bluffs and Ravines Preserve. Prescribed fire in population areas of* Conradia glabra *at other preserves will be designed to affect 20% or less of the population and implemented only if resources are available to monitor the response of the species to fire.*

Box 14.5. *EXAMPLES OF OBJECTIVES FOR ANIMALS.*

TARGET/THRESHOLD OBJECTIVES

Management Objective	*Allow harvest of no more than 100 capybara (*Hydorchaeris hydrochaeris*) adults per year between 2000 and 2005 at Hato Cedral.*
Management Response	*Assuming all harvest is accurately and completely reported, maintain current harvest program as long as reported kills each year are < 100.*
Management Objective	*Maintain the current low population level of the yellow-footed rock-wallaby (*Petrogale xanthopus*) population at the Melville Hall property from 2000 to 2005. Currently 95% of permanent plots show no evidence of rock-wallaby sign (pellets or browse).*
Management Response	*No rock-wallaby control measures will be undertaken unless a sign occurs in more than 10% of the permanent plots.*
Management Objective	*Increase local recruitment of young into the aging population of Galapagos giant tortoises (*Geochelone elephantopus*) on Isla Pinzon so that >25% of the population is in the immature age class by 2050.*
Sampling Objective	*Obtain estimates of the proportion of the population in the immature age class with a 90% confidence interval no wider than ± 5%.*
Management Response	*Continue efforts to control introduced rat populations on the island until local recruitment target has been achieved.*
Management Objective	*Increase the Sandy Point Marsh's population of territorial least bitterns (*Ixobrychus exilis*) to 25 males by 2010.*
Sampling Objective	*Be 90% confident that numbers of calling bitterns are estimated to within ±5 individuals.*
Management Response	*Continue efforts to increase cattail growth in the marsh to create favorable habitat for least bitterns until 25 males are detected, by 2010 at the latest.*

CHANGE/TREND OBJECTIVES

Management Objective	*Double the number of beaches occupied by populations of Puritan tiger beetles (*Cicindela puritana*) on the lower Connecticut River by 2010.*
Management Response	*Cease population translocation efforts after beetle populations are thriving on twice the current number of occupied beaches*
Management Objective	*Allow a decrease of no more than 10 in the population of eastern spadefoot toads (*Scaphiopus holbrookii*) attempting to breed in the Sand Plains Pond between 2005 and 2006.*
Management Response	*If numbers of toads captured (and censused) in drift fences surrounding the pond drop by more than 10 individuals between years, the stricter protective measures outlined in the management plan will be implemented.*

RESOURCES AND TOOLS FOR SETTING OBJECTIVES

Existing Plans

General goals for a particular species may be described in other planning documents such as conservation plans, watershed plans, regional or local land use plans, forest plans, or activity plans. Linking a monitoring project to these higher-level planning documents may increase management support and funding for the project. The goals in these plans may also serve as a useful starting point for developing more complete and specific objectives.

Ecological Models

Ecological models are simply conceptual visual or narrative summaries that describe important ecological components and their relationships. Constructing a model stimulates thinking about the ecology and biology of the target species. You do not have to be mathematically inclined to develop and use a model; the type of model described here rarely involves complicated formulas or difficult mathematics.

Ecological models have three important benefits. First, they provide a summary of your knowledge of the species, helping you to see the complete picture of the ecology of the species. For example, because livestock grazing affects a plant species negatively by direct herbivory, you may consider that relationship first. Grazing may, however, also affect the species positively through indirect effects on community composition by reducing competition. Trampling by livestock may positively affect the population by exhuming seeds from the seed bank and increasing germination. During the development of an ecological model, you will have to think about these indirect and sometimes hidden relationships. The model will often identify several factors that can cause the change you hope to detect by monitoring, and perhaps help isolate the most important mechanism.

Second, ecological models identify the gaps in your knowledge and understanding of the species. Your model may suggest that these gaps are not important, in which case you may choose to ignore these unknowns. Conversely, the model may suggest that an unknown relationship is extremely important for understanding the total ecological and management scenario. You may need additional studies before effective monitoring can begin.

Third, ecological models help identify mechanisms and potential management options. If the ecological model suggests, for example, that seedling establishment appears rare, that successional processes of canopy closure may be occurring, and that litter buildup on the ground provides few germination sites, you may be inclined to think about prescribed fire, or some other management strategy that induces germination or reverses succession. Lacking an ecological model, you may have focused on only a single attribute such as the lack of seedling establishment, which can result from a multitude of causes.

An ecological model can be as simple or complex as you wish. You can focus on a single management activity, as shown in Figure 14.1, or you can attempt to summarize all the interactions, as shown in Figure 14.2.

Reference Sites

Reference sites can serve as comparison areas to help set quantitative targets in objectives. These are areas with minimal human impact such as designated natural areas or reserves, parks, or wilderness areas. Undesignated areas with populations that appear thriving and healthy may also function as reference sites.

Reference sites can be valuable, but use them with caution. Simply because a population is located in a protected area does not ensure that it is viable or healthy. Lack of management activities within protected areas may be allowing natural processes to occur that are detrimental to a species. In addition, populations that appear "healthy and thriving" to casual observation may actually be declining.

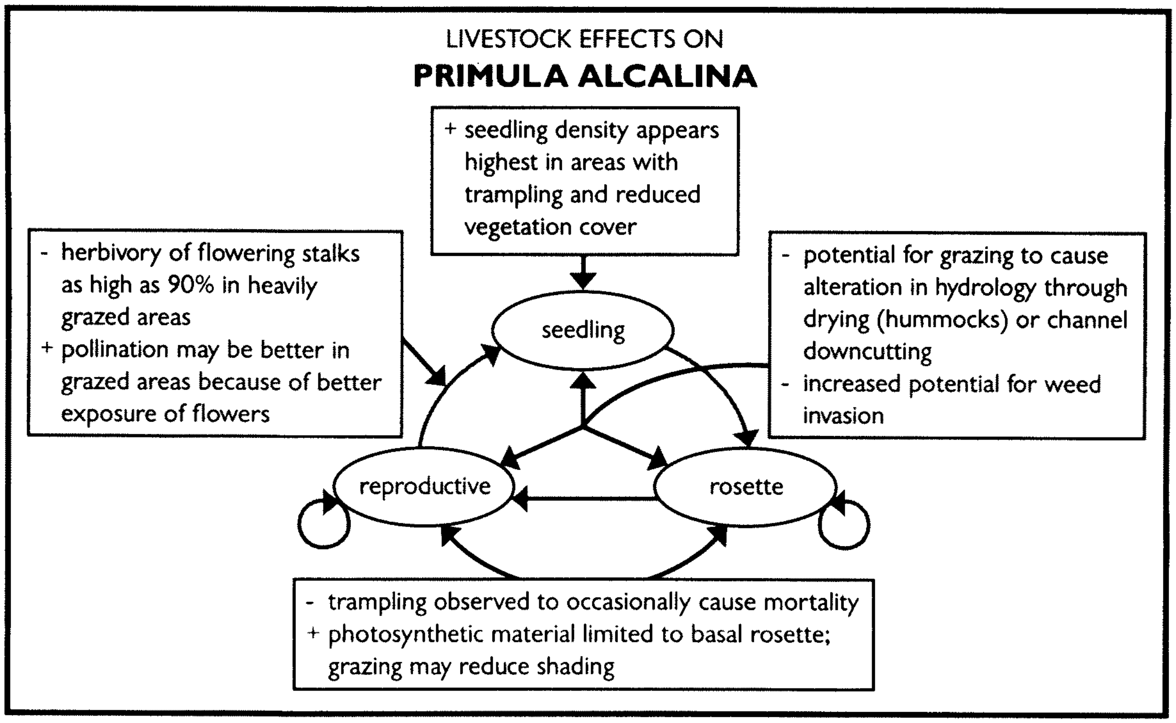

Figure 14.1. An ecological model showing positive and negative effects of grazing on an Idaho (United States) endemic plant species, *Primula alcalina*.

The protected status of these sites may actually limit their usefulness for setting objectives for some species. While the behavior of a species in the absence of human activity may provide useful information, in many cases we are managing populations in areas where human activity is occurring. Populations may respond differently than in pristine conditions, but still be "healthy." Look at the *Penstemon* modeled in Figure 14.2. Populations in disturbed open habitats (whether caused by fire or human disturbance) contain a higher percentage of reproductive plants and exhibit increased germination compared with populations in protected areas. One could argue in this example that the population dynamics exhibited in areas disturbed by human activities may actually function as the target for introducing disturbance (e.g., prescribed fire) in natural areas.

Related or Similar Species

Comparisons with more "successful" related species or with species that appear ecologically similar may help set objective quantities that are biologically reasonable (Pavlik 1993). For example, Pavlik (1988) compared nutlet production in an endangered borage, *Amsinckia grandiflora*, with a weedy *Amsinckia*. In another series of studies, the demography of the rare *Plantago cordata*, which grows in freshwater tidal wetlands along the East Coast and along nontidal streams in Indiana and Illinois, was compared with the widespread *P. major* (Meagher et al. 1978). A comparable approach has been used to examine causes of endangerment in animals, for example, primates (Jernvall and Wright 1998) and neotropical migratory songbirds (Whitcomb et al. 1981). This approach has obvious limitations. Rare species are often rare because they do not have the reproductive capacity, dispersal potential, or growth potential of more common species.

Experts

Experts can provide additional information and opinions on the assumptions within the ecological model. Within the agency or organization, experts include regional and national ecologists, biologists and botanists, as well as specialists in other disciplines such as forestry, range management, and riparian management. External specialists include academic, professional, and amateur

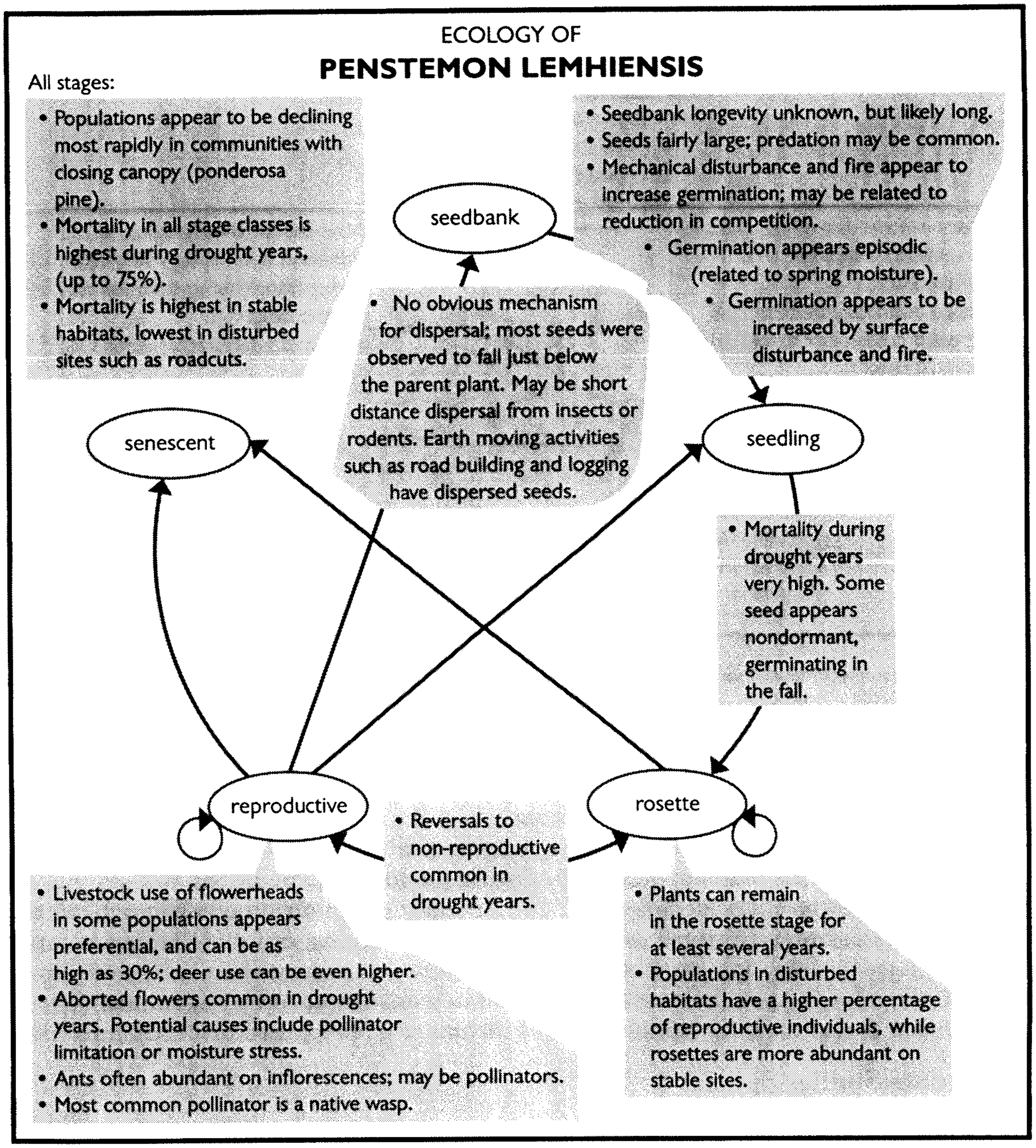

Figure 14.2. An ecological model of all known or suspected interactions for a rare *Penstemon* species.

ecologists, biologists and botanists who may know about the species of interest, or a closely related one, or may be knowledgeable about the ecological system in which the species resides. These people can help set realistic, achievable objectives.

Historical Records and Photos

Historical conditions at a site may have been captured in old aerial photos or in historic photos or other historical records housed in museums or maintained by local historical societies. Human disturbances such as roads, trails, and buildings may be visible. Woody species density and/or cover may also be visible. Early survey records often contained descriptions of general vegetation and habitat characteristics. Long-term elderly residents can be a fascinating source of information on local historical conditions.

DEVELOPING MANAGEMENT OBJECTIVES—AN EXAMPLE

The following provides an example of developing a management objective for a rare plant. This is intended as a generic demonstration of setting objectives. Please note that all the steps and concepts elaborated on are equally applicable to other plants or animals.

Our position is botanist with the United States Forest Service. *Collomia debilis* var. *camporum* is a long-lived, mat-forming perennial that occurs in 12 discrete locations (occurrences) along a 7-mile stretch of the North Fork of the Salmon River. Occurrences occupy stable slopes of blocky talus. Plants grow in soil pockets among the talus. Size of each occurrence ranges from 0.5 to 3 acres, each with 50 to 500+ pockets of plants. The number of plants cannot be determined because mats grow into each other and are difficult to separate into individuals. A two-lane highway runs along the base of the slope for the entire 7 miles. Any expansion of the highway (wider shoulders or more lanes) would severely impact all *Collomia* occurrences. Expansion is unlikely, however, given the status of the North Fork as a Wild and Scenic River and the controversial nature of any major road reconstruction. Two noxious weed species, cheatgrass (*Bromus tectorum*) and knapweed (*Centaurea repens*), occur along the highway right-of-way and are controlled annually. Some *Collomia* occurrences have sparse knapweed and cheatgrass. The effects of these weeds on the rare species are not known.

Review Upper-Level Direction

We first evaluate goals and objectives pertinent to *Collomia* in upper-level plans. The existing Forest Plan does not even recognize the occurrence of *Collomia* on USFS lands because the populations were discovered after the Forest Plan was finalized. The only direction provided by the Forest Plan is a standard operating procedure that states the effects of all projects on sensitive plant species will be evaluated through a field examination. An Allotment Management Plan (AMP) that describes cattle grazing management is in place for the area containing *Collomia*. It contains no references to sensitive plants nor is cattle grazing an issue on *Colomia* sites because the steep and rocky nature of its habitat precludes livestock use. The AMP is scheduled for evaluation and revision in 2010, and is the appropriate vehicle for describing management for all resources on that management unit (not just cattle management).

Identify the Species or Habitat Factor

An objective could focus on some aspect of *Collomia* or on the most immediate threat, weed infestation. You select the species itself for the following reasons:

- Although weeds are a concern, they currently are quite sparse in population areas, and current weed control efforts in the highway right of way appear fairly effective. You also have no information of the effects of weeds on *Collomia*, so monitoring weed density would not serve as a reliable indicator for population health.
- You have no data on trends or current condition of the *Collomia* occurrences except estimates of aerial extent and number of clumps of plants for each of the 12 occurrences. Although plants appear to be long-lived (many mat-forming species are), you noted in your field surveys that there seemed to be many dead individuals and no seedlings. You are concerned that some unknown factor may be causing these undesirable demographic dynamics. Because of the lack of information on trend or health of the occurrences you prefer to monitor the species directly.

In this situation, monitoring only the *Collomia* population and ignoring the potentially serious threat of weed infestation places the population at risk. If resources are available to monitor both the species and the weeds, you should develop a separate objective addressing the weed problem, rather than trying to combine the species and weeds into a single complex objective.

Draft objective: *Collomia debilis* var. *camporum*

Specify the Location

You decide to address all 12 occurrences because of the following reasons:

- All of the occurrences are administered by the Forest Service.
- You believe all 12 occurrences are important to the viability of the *Collomia* because this variety is so rare, and limited to such a small total area.
- This species is your top priority for monitoring, and will receive about half of your monitoring resources.

Draft objective: all 12 occurrences of *Collomia debilis* var. *camporum* along the North Fork

Describe the Attribute

Because of the high conservation priority of *Collomia*, you plan to quantitatively monitor this species at each occurrence. You select cover as an appropriate attribute for mat-forming perennials that cannot be separated into individuals.

Draft objective: Cover of all 12 occurrences *Collomia debilis* var. *camporum* along the North Fork.

Specify Action

Because you know so little about the species, you are unable to design management actions that would increase any aspect of this species. The current habitat exhibits no obvious impacts from humans (except for sparse weeds); thus, you assume that current levels are "natural." You decide that maintaining the current population would be acceptable.

Draft objective: Maintain cover of all 12 occurrences *Collomia debilis* var. *camporum* along the North Fork.

Specify Quantity

You want to maintain the current cover of *Collomia*, but you expect some natural fluctuation around a mean cover value even if *Collomia* populations are healthy and stable. You must specify the level of change that you will allow before you implement alternative management. You have no data suggesting an acceptable level of fluctuation. Because the species is so rare, you do not want to specify an allowable level of fluctuation so large that real and worrisome changes are not detected, but you also do not want your allowable limits of fluctuation so narrow that you are implementing new management unnecessarily. You decide to allow a decrease of 15% from current cover before you will implement alternative management. You base this value on your knowledge of natural fluctuations in unrelated perennial mat-forming species measured in a nearby range monitoring study.

Draft objective: At each of the 12 occurrences along the North Fork, limit any decrease in cover of *Collomia debilis* var. *camporum* to no more than 15%.

Specify Time Frame

Your objective is still unclear. As currently written, it suggests that an annual decrease of 10% from the previous year would be acceptable. You must identify the starting point from which you will measure the threshold decline of 15%. You also need to specify the period for which your objective is effective. Most objectives should include a final date that triggers a complete evaluation and final report.

You decide you want to measure the population for several years before writing a final report. You select the year 2005 because the AMP is scheduled for reevaluation in 2010 and because you are concerned about the percentage of dead plants in the population and the lack of seedlings. If you see a worrisome decline by 2005, you will have a few years for further study or implementing trial management (such as weed control if weeds appear to be increasing) before the AMP is rewritten in 2010. You also decide that the baseline cover will be the cover measured in 2001, and that a decrease of more than 15% from that level would be unacceptable.

Final objective: At each of the 12 occurrences along the North Fork, limit any decrease from current (2001) cover of *Collomia debilis* var. *camporum* to no more than 15% between 2001 and 2005.

MANAGEMENT RESPONSE

The response of management to the outcome of monitoring must be identified before monitoring begins. If there are no management alternatives or options, monitoring resources are better spent on another species or population. Usually, however, there are options, but some of them may be expensive, or politically difficult to implement. There is a tendency in resource management agencies to continue monitoring, even when objectives are not met, rather than make the difficult decisions associated with changes in management. Because of this inertia, we recommend that management responses be an integral part of premonitoring planning. Management alternatives are more likely to be applied if they are identified before the monitoring begins, and if all parties agree to the objectives, monitoring methods, and response to monitoring data (see more on this in Chapter 15).

Identifying alternative management is difficult because in many situations the needed management changes are unknown. At a minimum, a management commitment can be made before monitoring begins that additional, more intensive investigation into the management needs of the species will begin if objectives are not achieved. For examples of management objectives paired with management responses, see Box 14.4 for plants and 14.5 for animals.

SAMPLING OBJECTIVES

Sampling objectives should be written as companion objectives to management objectives whenever monitoring includes sampling procedures. As described in Chapter 7, sampling involves assessing a portion of a population with the intent of making inferences to the sampled population as a whole. If you are weak on basic principles of sampling and have not yet read Chapter 7, please do so before reading this section on sampling objectives.

Sampling objectives specify information such as target levels of precision, power, acceptable false-change error rate, and the magnitude of change you are hoping to detect. Unlike a management objective, which sets a specific goal for attaining some ecological condition or change value, a sampling objective sets a specific goal for the measurement of that value. For example, consider the following management objectives, with corresponding sampling objectives:

> **Management objective:** We want to maintain a population of *Lomatium bradshawii* at the Willow Creek Preserve with at least 2000 individuals from 2002 to 2010 (target/threshold objective).
>
> **Sampling objective:** We want to be 95% confident that estimates are within ± 25% of the estimated true value.
>
> **Management objective:** We want to see a 20% increase in the average density of *Lomatium bradshawii* at the Willow Creek Preserve between 2002 and 2005 (change/trend objective).
>
> **Sampling objective:** We want to be 90% sure of detecting a 20% change in the density and we are willing to accept a 1 in 10 chance that we will say a change took place when it really did not.

The principal reason to add sampling objectives to management objectives is to ensure that you end up with useful monitoring information. If this additional information is not specified, you risk ending up with an inadequate sampling design that makes it difficult or almost impossible to assess whether you have achieved your management objective. For example, without setting sampling targets, you may end up with an estimate of population size with confidence intervals nearly as wide as the estimate itself (e.g., 1000 plants ± 950 plants) or you may find that you have low power to detect some biologically meaningful change (e.g., only a 15% chance of detecting the change you were hoping to achieve). The information specified in a sampling objective is also necessary to determine adequate sample sizes using the procedures described in Chapter 8 and Appendix II.

For monitoring that does not involve sampling, your ability to assess success at meeting your management objective should be obvious from the management objective itself without the need to specify additional information. Consider the following management objectives that involve monitoring without sampling:

- Maintain the current knapweed-free condition of the *Penstemon lemhiensis* population in the Iron Creek drainage for the next 10 years.
- Maintain at least 100 individuals of *Penstemon lemhiensis* in the Iron Creek drainage over the life of the Iron Creek Allotment Management Plan.

To determine success at meeting the first objective, you simply need to visit the site at some specified interval and search for the presence of knapweed. To assess success for the second objective, you will likely be able to count all the plants in the population (or at least the first 100 that you find). Thus, the management objectives for these nonsampling types of monitoring do not require the additional components that are discussed in this chapter.

Sampling objectives are classified into two types that correspond to the two major categories of management objectives: 1) target/threshold management objectives and 2) change/trend management objectives.

Target/Threshold Management Objectives

The sampling objective in this case is to estimate some parameter in the population (e.g., mean density per unit area, mean percent cover, or mean height or weight), to estimate a proportion (e.g., the frequency of a particular species within a set of quadrats placed within a sampled area), or to estimate total population size (total number of individuals within a sampled area). These estimates are then compared with the target/threshold value to determine if the management objective is met. Sampling objectives for this type of management objective need to include two components related to the precision of the estimate:

- **The confidence level.** How confident do you want to be that your confidence interval will include the true value? Is 80% confidence high enough or do you want 90%, 95%, or even 99% confidence?
- **The confidence interval width.** How wide a range are you willing to accept around your estimated value? For example, is ± 20% of the estimated mean or total value adequate or do you want to be within ± 10%?

The following is an example of a target/threshold management objective with a corresponding sampling objective:

Management objective: Increase the number of individuals of *Penstemon lemhiensis* in the Iron Creek Population to 1000 individuals by the year 2010.

Sampling objective: We want to be 95% confident that population estimates are within 20% of the estimated true value.

This sampling objective specifies a relative confidence interval width (± 20% of the estimated true value) so the targeted confidence interval width in absolute units will depend on the estimated population size. For example, if the first year of monitoring yields a population estimate of 500 plants, the targeted confidence interval half-width is 500 plants × 20% = ± 100 plants. Information from pilot sampling can be used to determine how many sampling units need to be sampled to achieve a confidence interval width of ± 100 plants.

Why should you set sampling objectives for target/threshold management objectives? Most importantly, it helps you avoid designing monitoring studies that provide unreliable estimates that are of little value for making management decisions (e.g., a population estimate of 1200 ± 950). The values set in your sampling objective will be used after the pilot study to determine the sample size needed to meet the sampling objective. Sampling objectives set a quantitative measure of the quality of your monitoring design.

See Box 14.4 (plants) and 14.5 (animals) for additional examples of sampling objectives paired with target/threshold management objectives.

Change/Trend Management Objectives

The sampling objective in this case is to determine whether there has been a change in some population parameter such as a mean value (e.g., mean density per unit area of a particular species, mean percent cover, mean weight), a proportion (e.g., the frequency of a particular species within a set of quadrats placed within the sampled area), or the total population (total number of individuals within a sampled area) between two or more periods. This category of sampling objective must include the following three components:

- **The acceptable level of power (or the acceptable level of the missed-change error [Type II error] rate).** How certain do you want to be that, if a particular change does occur, you will be able to detect it? If you want to be 90% certain of detecting a particular magnitude of change, then you are specifying a desired power of "90%" (power and missed-change error rates are complementary, so in this example, the missed-change error rate is 0.10).
- **The acceptable false-change error (Type I error) rate.** What is the acceptable threshold value for determining whether an observed difference actually occurred or if the observed difference resulted from a chance event? This represents the chance of concluding that a change took place when it really did not. While the $\alpha = 0.05$ level is frequently used, you should carefully consider the impact of this decision on the probability of making missed-change errors before selecting a false-change error rate. In many monitoring studies, a higher false-change error rate (e.g., $\alpha = 0.10$ or $\alpha = 0.20$) is appropriate.
- **The desired MDC (minimum detectable change).** The MDC specifies the smallest change that you are hoping to detect with your sampling effort. The MDC should represent a biologically meaningful quantity given the likely degree of natural variation in the attribute being measured.

The following is an example of a change/trend type of management objective with a corresponding sampling objective:

Management objective: I want to see a 20% increase in the density of *Lomatium cookii* at the Agate Desert Preserve between 2002 and 2010.

Sampling objective: I want to be 90% certain of detecting a 20% increase in density between 2002 and 2010 and I am willing to accept a 10% chance that I will make a false-change error.

This sampling objective specifies a power of 90%, a false-change error rate of 10%, and an MDC of 20%. The MDC is specified in relative terms, so the targeted MDC in absolute units will depend on the estimated density in 2002. For example, if the mean density in 2002 is 10 plants/quadrat, the desired MDC is an increase of two plants/quadrat.

Why bother specifying false-change error rates, power, and some desired MDC when you are writing a sampling objective designed to detect change over time? The main advantage is that it helps you avoid designing monitoring studies with low power. The sample size determination procedures discussed in Chapter 8 require the specification of false-change error rate, power, and the size of the change you are interested in detecting before you can determine how many sampling units to sample. If your pilot data indicate that you have low power to detect a biologically important change (high probability of a missed-change error), you can then correct your sampling design before you have gathered many years of monitoring data.

See Box 14.4 (plants) and 14.5 (animals) for additional examples of sampling objectives paired with change/trend management objectives.

Setting Realistic Sampling Objectives

Sampling objectives should be written during the planning phase of a monitoring study. Targeted levels of precision, power, false-change error, and MDC should be based on the following:

- The biology of the species. How much can it change? How fast? How much does it fluctuate from year to year?
- The risk of being wrong. You are not required to use the 5% level, so common in research studies. Evaluate the relative risks of false-change and missed-changed errors. Remember false-change and missed-change error rates are inversely related to each other, although not proportionately (see Chapter 7). Remember too that a smaller MDC is more difficult to detect. Consult with decision-makers and stakeholders interested in the monitoring results to ensure that they are comfortable with the targeted levels of precision, power, etcetera, specified in the sampling objectives.
- The resources available for monitoring. Higher levels of precision and lower acceptable miss-change and false-change errors require more resources for monitoring (usually more sampling units because you have already done your best to develop an efficient design—see Chapter 8).

Writing sampling objectives for target/threshold management objectives is fairly straightforward. You must decide the width of the confidence interval, and the risk you are willing to take that your estimate is not actually within that interval (that risk equals one minus the confidence level).

Setting error rates in sampling objectives for change/trend management objectives is more complicated. Both false-change and missed-change error rates can be reduced by sampling design changes that increase sample size or decrease sample standard deviations, but missed-change and false-change error rates are inversely related, which means that reducing one will increase the other (but not proportionately) if no other changes are made. The decision of which type of error is more important should be based on the nature of the changes you are trying to determine, and the consequences of making either kind of mistake. Because these errors have different consequences to different interest groups, there are different opinions as to what the "acceptable" error rates should be: The following examples demonstrate the conflict between false-change and missed-change errors.

- Testing for a lethal disease. When screening a patient for some disease that is lethal without treatment, a physician is less concerned about making a false diagnosis error (analogous to a false-change error) of concluding that the person has the disease when he does not than failing to detect the disease (analogous to a missed-change error) and concluding that the person does not have the disease when in fact he does.

- Testing for guilt in our judicial system. In the United States, the null hypothesis is that the accused person is innocent. Different standards for making judgment errors are used depending on whether the case is a criminal or a civil case. In criminal cases, proof must be "beyond a reasonable doubt." In these situations it is less likely that an innocent person will be convicted (analogous to a false-change error), but it is more likely that a guilty person will go free (analogous to a missed-change error). In civil cases, proof only needs to be "on the balance of probabilities." In these situations, there is a greater likelihood of making a false conviction (analogous to a false-change error), but a lower likelihood of making a missed conviction (analogous to a missed-change) error when compared to criminal cases.
- Testing for pollution problems. In pollution monitoring situations, the industry has an interest in minimizing false-change errors and may desire a very low false-change error rate (e.g., $\alpha = 0.01$ or 0.001). Companies do not want to be shut down or implement expensive pollution control procedures if a real impact has not occurred. In contrast, an organization concerned solely with the environmental impacts of some pollution activity will likely want to have high power (low missed-change error rate) so that they do not miss any real changes that take place. They may not be as concerned about occasional false-change errors (which would result in additional pollution control efforts even though real changes did not take place).

Missed-change errors may be as costly or more costly than false-change errors in environmental monitoring studies (Toft and Shea 1983; Peterman 1990; Fairweather 1991). A false-change error may lead to the commitment of more time, energy, and people, but probably only for a short time until the mistake is discovered (Simberloff 1990). In contrast, a missed-change error, as a result of a poor study design, may lead to a false sense of security until the extent of the damages are so extreme that they show up in spite of a poor study design (Fairweather 1991). In this case, rectifying the situation and returning the system to its preimpact condition could be costly. For this reason, you may want to set equal false-change and missed-change error rates or even consider setting the missed-change error rate lower than the false-change error rate (Peterman 1990; Fairweather 1991).

There are many historic examples of costly missed-change errors in environmental monitoring. For example, many fish population monitoring studies have had low power to detect biologically meaningful declines so that declines were not detected until it was too late and entire populations crashed (Peterman 1990). Some authors advocate the use of something they call the "precautionary principle" (Peterman and M'Gognigle 1992). They argue that, in situations where there is low power to detect biologically meaningful declines in some environmental parameter, management actions should be prescribed as if the parameter had actually declined. Similarly, some authors recommend shifting the burden of proof in situations where there might be an environmental impact from environmental protection interests to industry/development interests (Peterman 1990; Fairweather 1991). They argue that a conservative management strategy of "assume the worst until proven otherwise" should be adopted. Under this strategy, developments that may negatively impact the environment should not proceed until the proponents can demonstrate, with high power, a lack of impact on the environment.

The sampling objectives serve as a critical aid during the preliminary or pilot field sampling phase. Once pilot sampling data are available, information on the variability of the data can be plugged into sample size equations (see Chapter 8 and Appendix II) along with the information specified in the sampling objectives to determine how many sampling units should be sampled. If you are faced with a monitoring situation with high variability between sampling units (despite all of your sampling design efforts to lower this variability) and the components of your sampling objective lead to a recommended sample size of more sampling units than you can afford to sample, then you need to reassess the monitoring study. Is it reasonable to make changes to some components of the sampling objective? For target/threshold types of management objectives, this may mean lowering the level of confidence or decreasing the precision of the estimate (i.e., increasing the confidence interval width) or both. For objectives directed towards tracking change over time, this may mean increasing the acceptable false–change error rate, decreasing the targeted power level, or settling on a larger specified MDC. Will these changes be acceptable to managers and other stakeholders? If you feel that making these modifications to the sampling objective is unreasonable, then you should take an alternative monitoring approach rather than proceed knowing that your monitoring project is unlikely to meet the stated objectives.

MANAGEMENT IMPLICATIONS

Management objectives are the foundation of a monitoring study. As measurable descriptions of desired state or condition of the resource, objectives promote communication, give direction for management actions and monitoring approaches, and provide a means to measure management success. Objectives should include the following components: species or indicator, location of management, attribute of species or indicator expected to respond to management, amount of change or desired condition or the species or indicator, and the time frame during which management will be applied and results expected. Objectives can be generally classified into two types. Target/threshold management objectives state the desired condition or state of the species or indicator. Change/trend management objectives describe the amount and direction of desired change.

Management objectives should be paired with a clearly defined management response that will be implemented if the objective is not met. Management objectives must also be paired with sampling objectives when the monitoring study involves sampling. Sampling objectives ensure that the monitoring design will provide useful and meaningful data when using sampling. These describe the target level of precision (confidence level and confidence interval width) for target/threshold management objectives, and the desired power, acceptable false-change error rate, and minimum change that should be detected by a study that monitors a change/trend management objective.