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Monitoring for Adaptive Management in Conservation Biology

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Monitoring for Adaptive Management in Conservation Biology

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Source: E. Sterling and K. Frey

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Introduction

As conservationists, we devote a great deal of effort and resources to preserving biological diversity. While we pour a lot of energy into developing and implementing management plans, we rarely assess whether our labors have helped us to achieve our goals. In recent years, however, many of us have taken a growing interest in measuring the outcome of our conservation projects and in defining conservation success. Donor agencies and non-governmental organizations have also recognized the need to make conservation and development projects more effective and accountable (World Bank, 1998; Margoluis and Salafsky, 1998; Kleiman et al., 2000). Monitoring, if carefully executed, can provide these kinds of insights.

Elzinga et al. (2001) define *monitoring* as "the collection and analysis of repeated observations or measurements to evaluate changes in condition and progress toward meeting a management objective." Margoluis and Salafsky (1998) broadened this definition to include the periodic collection of data relative to stated project goals, objectives and activities. Monitoring is critical, for example, in managing harvested and endangered species, measuring the effects of management activities and natural perturbations, and documenting compliance with regulatory requirements or contractual agreements. Through monitoring, we can determine whether management was a success and should be continued or whether it was a failure and should be abandoned or altered. In most situations, significant amounts of funding are applied to conserve the biological diversity of particular areas. An effective monitoring program is a vital part of determining if those resources are well spent.

According to Salafsky and Margoluis (1998), the three components that comprise any conservation project can be monitored: the state of the target condition (species, ecosystems, protected areas etc.), the success in mitigating threats to the target condition, and the process of implementing interventions. These three types of monitoring are as follows:

(i) *Monitoring the status of the target condition*: Monitoring efforts that are focused on the biological state of the target condition have been referred to as ecological or biological monitoring. Many of these approaches measure conservation outcome using biological indicators of success (e.g. Noss, 1990; Spellerberg, 1991; Sparrow et al., 1994). This is best known as "*biological monitoring*."

(ii) *Monitoring the status of threats to the target condition*: A second approach to monitoring involves focusing on threats to the target condition. Are the most critical threats that affect the target condition changing in their severity or geographic scope as a result of conservation strategies (or lack thereof)? Monitoring threat status has recently gained increasing attention (e.g. Salafsky and Margoluis, 1999; Hockings et al., 2000; Margoluis and Salafsky, 2001; Ervin, 2003). This topic has been addressed in detail in an accompanying module ("Threat Assessment in Conservation Planning and Management") and is very briefly reviewed in the latter section of this overview. This is best known as "*threats monitoring*."

(iii) *Monitoring the process of implementing interventions*: This type of monitoring involves tracking progress in accomplishing project activities to ensure that project activities are getting done. Assessing whether an activity has been completed could involve developing a checklist for recording when activities are completed (Margoluis and Salafsky, 1998). This is best known as "*implementation* *monitoring*."

In most contexts, "*adaptive management*" (Holling, 1978; Ringold et al., 1996) provides a useful framework for monitoring conservation effectiveness. Within an adaptive management milieu, monitoring measures progress toward or success at meeting an objective, providing the evidence necessary for deciding whether to change or continue a specific management practice. More succinctly, adaptive management in conjunction with monitoring is a "learning by doing" process. It is a way of thinking about and implementing natural resource management that states that we should view any management we impose on a system as an experiment from which we can learn (Walters and Holling, 1990; Grumbine, 1994, Gunderson, 1999, Meffe et al., 2002).

Adaptive management is about systematically implementing management in order to achieve a desired outcome. It involves several specific steps as outlined below:

1. Establishment of a clear management goal to describe the desired condition of a species, ecosystem, protected area or other conservation interest.
2. Development of a management plan to clearly identify both threats to the target condition and activities that will reduce these threats, thus achieving the project goal. Threats might include invasive species or poaching, for example.
3. Development of a monitoring plan, to focus (assess) on these target conditions, threats and activities.
4. Implementation of the management and monitoring plans.
5. Data analysis and communication of results.
6. Iterative use of results to adapt and learn. Only by carefully tracking a system in response to management actions can we learn how our actions affect it. Management is adapted (changed) if objectives are not reached or if the new knowledge from monitoring suggests a better course of action.

This overview will primarily focus on monitoring the state of the target condition, which could be a particular species, a suite of species, a protected area, an ecosystem type or a landscape comprising all of these components. Specifically, it describes: (1) how to articulate clear management goals; (2) how to convert these into explicit monitoring goals; (3) how to estimate sampling necessary to meet those monitoring goals; (4) how to analyze monitoring data to determine if change has occurred; and (5) how to report results to stakeholders in a timely and effective fashion.

Monitoring the Status of the Target Condition in Biodiversity Conservation

Conservationists must meet several criteria in order to successfully monitor their work within an adaptive management context. From the outset, conservationists must translate general aims into clear management goals, which they must then further refine into precise and measurable monitoring objectives. This process may seem obvious, but often managers fail to address it! If useful targets are not identified and progress toward them tracked, it cannot be known if management succeeded, nor can management practices evolve and improve.

Determining whether or not we have met monitoring objectives depends on sampling the resource before and after the management has been completed. Proper sampling involves deciding on the amount of data collection necessary to track a resource. Because sampling always includes some uncertainty, estimation is also required of the precise number of samples needed to confidently conclude that management did or did not work. A common problem in monitoring is either undersampling or oversampling the conservation target. Undersampling (taking too few samples) prevents one from detecting a change even if a change has occurred. Oversampling will let one identify a change in response to management but results in an unnecessary waste of effort. Because monitoring in the field is often very expensive and time consuming, it is important to optimize sampling. This can only be done if monitoring objectives are clear.

Keep in mind that the concepts introduced here can be applied to any conservation context. Perhaps you wish to determine if an incentive program actually changed people's behavior, or whether recovery efforts actually increased a population of a rare species. Or perhaps you are concerned with whether or not a law or prohibition is working in terms of the resource it was designed to protect. All of these issues can be assessed by following variations of the basic steps outlined below.

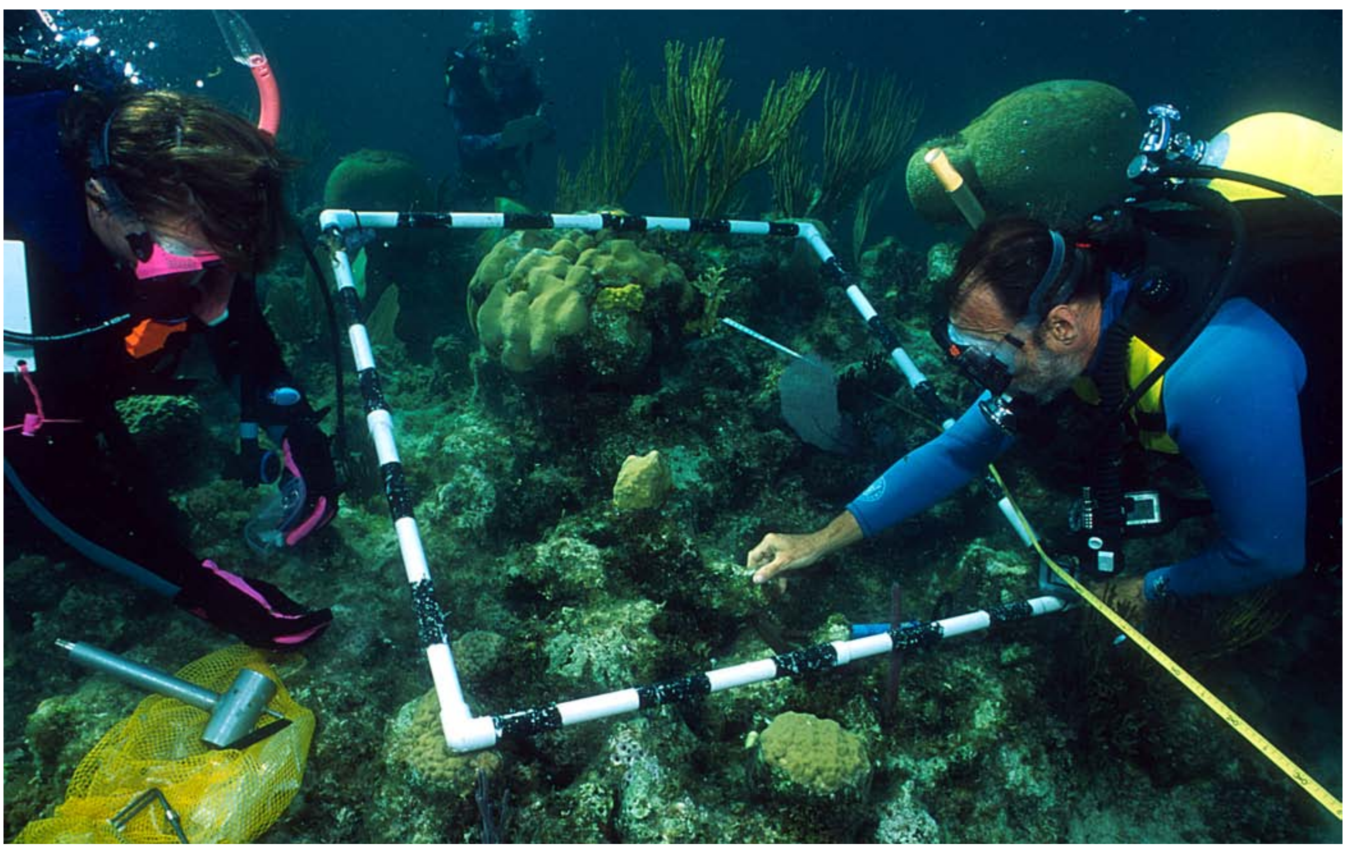
Translating General Management Goals into Specific Management Objectives

Components

Before you can set up a robust monitoring program, you first need to be clear about your general *management goals*. These goals guide resource management by specifying the types of conditions or trends desired in resource conditions. These goals might come from existing management plans and environmental regulations, ecological models of how a system should best function, reference sites or comparison areas, expert opinion, or perhaps even historic records and photographs. Management objectives can take many forms but a complete one has the following components:

The Entity to be Measured

This might be a direct measurement of species/community or an indirect measure of a habitat 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 also be specified. Monitoring may also measure indicators that function as surrogate measures of species success. There are four classes of indicators: 1) indicator species that correlate with the success of the target species and are easier to measure; 2) characteristics of the ecosystem



Taxonomists Paula Mikkelsen and Gordon Hendler survey a patch reef in the Bahamas (Source: D. Brumbaugh) the species inhabits; 3) threats; and 4) indices of abundance. Monitoring indicators may be less expensive, provide more immediate monitoring feedback to management, and focus on the aspect of the species or community over which you actually have management control, such as habitat quality or intensity of threat. Monitoring indicators may also be problematic, however, 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 biological resource.

Attribute to be Measured
This is the specific attribute of the entity to be measured. Often this will be a parameter such as size, density, cover, or frequency. It might also be condition or a qualitative measure (e.g., many, few, none). The best attribute to use in monitoring depends on the management situation, the species, and the monitoring resources available.

Action is the Desired Change in the Entity's Attribute, Usually to:

1. **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).
2. **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 50%; limit mortality to 50% per year).
3. **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).
4. **Decrease.** Use when you want to reduce some negative aspect of the species or indicator (e.g., decrease livestock utilization of inflorescences (the buddings and flowerings of plants) to 50% or less; decrease cover of Noxious Weed A by 20%).

Managers working to recover rare species usually seek to increase the population. Some populations, however, may already be at the maximum potential for their habitat, or they suffer from no apparent threats. For these, a more realistic objective would be to maintain current conditions. For other populations you may wish to set a threshold that will trigger a management action if the population falls below it.

Quantity/ Status
This is the measurable status or degree of change for the entity's attribute. For example, you might want to specify not only that numbers of an endangered species increase, but also by what degree. Determining these quantities or states requires consideration of a number of factors:

1. How much can the species respond? Populations of long-lived species (like tortoises or trees) may be very slow to respond to management changes. Responses may be small and difficult to detect, or take many years to express. In this situation, consider using an indicator as an alternative.
2. What is necessary to ensure species or population viability? How much change, what population size, what qualitative state is required to ensure the survival of a species or population?
3. How much change is biologically meaningful? Populations of annual plant species, for example, can vary dramatically from year to year. An objective that specifies increase or decrease in density for such populations is meaningless.
4. What is the intensity of management? Will you continue existing management, remove current threats, or implement a radical alternative?
5. 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.
6. What are the economic costs or other associated considerations associated with measuring the mount of change specified? Small changes are often difficult and expensive

to detect.

Location of Interest
This defines the geographic area to which management and monitoring pertains. 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 and particular management activities. For example, you may only have access to a portion of a particular population due to multiple land ownership patterns, or you may only be interested in individuals located within recently logged forests. Location will also vary in relation to the scale at which monitoring will occur. Conservation goals and responsibilities, the biology of the species or ecosystem, and the extent of limited monitoring resources all affect the scale at which monitoring will take place. For example, adaptively managing a population of threatened orchids might require monitoring on a single site within one ownership, whereas tracking the change in wolf populations in response to anti-poaching measures may be a region-wide undertaking involving many hundreds of land ownerships.

Time Frame
This identifies the amount of time that must pass before the effects of management can be accurately monitored and assessed. The biology of the species, the intensity of management, and the amount of change desired all influence the time required to meet a management objective. Populations of short-lived species that reproduce annually may respond quickly, but long-lived species and those with episodic reproduction may require more time. High intensity management will result in more rapid changes than low intensity or no special management. Large changes will require a shorter time frame to detect than smaller changes. In general, the shorter the time frame for monitoring the effects of management, the better, because: (1) changes in agency budgets and personnel often doom long-term monitoring projects; (2) short-term objectives promote regular reassessment of management and implementation of management changes; and (3) the adaptive management cycle must occur within a short enough period that opportunities for species recovery or alternative management are not lost.

Many adaptive management projects concern endangered species for which we lack information. Gathering information over the long-term assists scientists in making adaptive management decisions as they learn more about population cycles, reproductive cycles, longevity, and general adaptability of the species and its food resources or habitat needs to environmental variation. For these reasons a long-term perspective on monitoring is valuable. Moreover, the designated time frame must be sufficient to permit the project to adapt to new information gathered. In reality, short-tem objectives often prevail because of the short-term and cyclical availability of funds for monitoring but long-term monitoring, whenever feasible, can be valuable.

When defining any of the above six types of management objectives, you may need to develop new definitions or unique indicators to meet the needs of a project. For example, your management goal may be to maintain a "healthy and diverse forest ecosystem." To identify monitoring objectives, however, you would need to identify some functional component of the ecosystem as an indicator of "healthy." Similarly, you would need to choose some indicator(s) of "diversity." Keep in mind that these need to be specific, measurable entities and attributes. Were all of the essential components included? If not, what was missing?

We have emphasized the importance of setting and defining management objectives here because managers often fail to identify one or more of them when defining their management objectives. We recognize the difficulties involved in converting general goals for management to specific measurable objectives for monitoring. Without doing so, however, we cannot gauge whether management activities are effective and if management goals are met. Below we provide an example of how to develop specific management objectives for a general management goal.

An Example of Translating a General Management Goal Into Specific Management Objectives

General Management Goal: Sustain and maintain a healthy and diverse forest ecosystem.

Some Possible Specific Management Objectives and Related Monitoring Objectives in Support of this Goal:

1. By the beginning of next year, reduce by 50% silt loads in the main river originating in the forest.
2. Within each forest ecosystem type, maintain 2000-2001 compositions of native grass, shrub, and tree cover from 2010-2015.
3. Prevent fragmentation in the southern block by maintaining the road network at 2000 levels from 2000-2015.
4. In forest interior areas within buffer zone, maintain current (2000-2002) densities of harvested mammals from 2002-2010.

Defining Sampling Objectives From Monitoring Objectives

Complete management objectives (the "what, where, and when" of a project) make a foundation from which monitoring objectives can be defined. Once you have identified your monitoring objectives, you will then have to collect some data. Unless you plan to conduct a complete census, most monitoring will require some sampling of the environment. To sample, you repeatedly measure the environment in a quantitative fashion to determine if your management plan has succeeded in changing (or maintaining) the state of the resource in question. In other words, the sampling objective for a monitoring objective is to estimate the parameter in the population (the "what, where, when") under management and compare this estimated value to the threshold value desired.

Sampling always involves some uncertainty because with sampling we are never entirely sure that we have properly estimated the true value of the parameter for the population. We have to consider the possibility that any difference that we see between two estimated parameters (before and after) could result from sampling errors. A *Type I statistical error* occurs when two populations sampled by chance give the incorrect appearance of being different when, in fact, they are not. It happens when our random sample is not representative of a population as a whole. We also want to be careful about committing a *Type II statistical error,* which involves wrongly concluding that there is no difference among data sets when in fact we simply failed to sample adequately to detect it. We guard against both of these kinds of errors by using increasingly smaller and more stringent levels of alpha or "significance levels."

Increasing the alpha level comes at a cost, however, because it generally involves more sampling to get higher confidence, and gathering samples takes time and money. In addition to balancing cost versus confidence we also need to worry about precision when formulating sampling objectives. How accurate do we really want or need to be? To some extent, the answer to this question depends on the importance of what we are monitoring. Resources of high value, such as quality timber and endangered species, may need to be estimated with greater precision than less critical resources like forage levels or water quality. General estimates, and hence less precision, may suffice for these latter two because the consequences of incorrectly estimating them are less dire (e.g., a slightly thinner cow versus an extinct species).

So when we translate specific management objectives into monitoring objectives, we also need to define how statistically powerful we want our sampling to be. We need to specify information such as the confidence level (false change error rate), the power (the probability that we will detect a change if it occurs), and the precision of the measurements we will take. Without specified targets for these parameters, estimates of population parameters might have excessively large *confidence intervals* or *low power* (e.g., only a 20% chance of detecting the magnitude of change that was desired). We need to specify these parameters so that we know how much sampling we need to do to monitor adequately. More specifically, setting sampling objectives for target/threshold management objectives will help avoid studies that provide unreliable measurements. No one is willing to apply to management decisions to a population estimated at 1200±1300.

Example of a Sampling Objective for a Target Management Objective

General management goal: Improve the health of the elephant herd.

Management objective: Increase the density of young elephants to 1 per 1,000 hectares at site A by 2005.

Sampling objective for monitoring: Estimate with 90% confidence the density of young elephants to within 10% of its estimated true value.

The sampling objective here is to determine if the resource has attained a particular threshold state. We want the true value and the measured value of the resource to fall within a set confidence interval.

Detecting Change

Detecting Change With Confidence Intervals

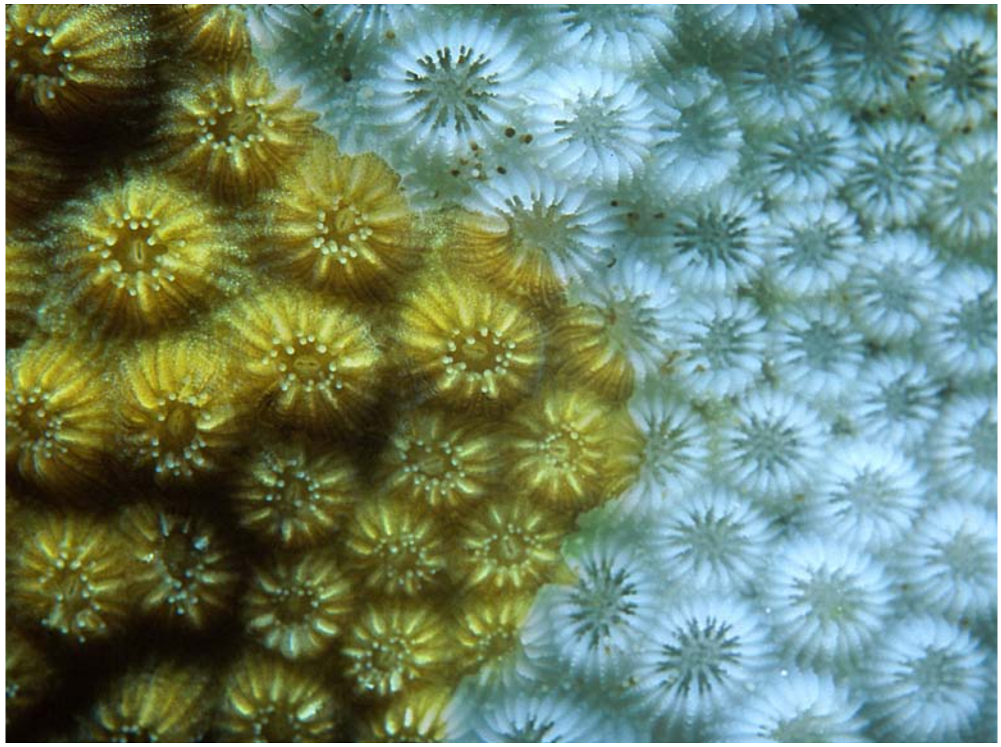
Once you have collected your monitoring data, you can compare it to the baseline data you collected earlier—presumably before management actions occurred. By contrasting conditions before and after management, you can evaluate whether your have met your management objectives, and hence whether you should continue or alter your management practices.

If you are estimating a quantity based on a single independent sample (i.e., you are not trying to relate the sample to another year or another site) then calculating the precision of your estimate using confidence intervals is the correct approach. Confidence intervals can be calculated for a mean, proportion, or a population estimate. Examples include total number of individuals within the sampled area, mean number of individuals per unit area, the proportion of quadrats (generally rectangular plots used in ecological and population studies) occupied by the species, the mean height or weight of individuals within your sampled population, the proportion of occupied nesting boxes, the mean number of motorcycle tracks per unit area, etc.

If your management objective is a target or threshold objective, it is sufficient to estimate the parameter (mean, total, or proportion) and construct a confidence interval around the estimate. The analysis required is to calculate the sample statistic (mean, total, or proportion) and the confidence interval (the desired confidence level should be specified in your sampling objective). Any basic statistics book will instruct you on how to construct confidence intervals. Once the confidence intervals are calculated, the mean and confidence interval of each sample can be compared to the target or threshold to determine if action is necessary or if the objective has been reached.

For example, your management objective is to maintain a population of at least 2000 individuals of *Nectophrynoides asperginis* (the Kihansi Spray Toad) in the Upper Spray Wetland of the Lower Kihansi Gorge over the next 5 years. Your sampling objective is to annually estimate the population size of *Nectophrynoides asperginis* at the Upper Spray Wetland and be 95% confident that the estimate is within 250 toads of the true population total. This is a threshold objective, because you are concerned with the population falling below the threshold. Therefore, data analysis consists of estimating the population size from the sample mean (by multiplying the total number of possible sampling units by the sample mean) and calculating the confidence interval for this estimate.

The estimated total and confidence interval are then compared to the threshold of 2000 toads. If both the estimated total and lower bound of the confidence interval are above the threshold, you can be confident (relative to the alpha level chosen) that you have met your objective. If both the estimated total and upper bound of the confidence interval are below 2000 toads, you can be confident (again relative to the selected alpha level) that you have failed to meet your objective. Less clear are situations where the threshold value is included within the confidence interval, with the estimated total either above or below the threshold. One way to address this problem is to decide that if any part of the confidence interval crosses the threshold you will take action, based on the possibility that the true parameter has crossed the threshold. This minimizes the risk that one will fail to take action when action is needed.



Bleached coral due to warming waters (Source: D. Brumbaugh)

Remember, however, that the size of the confidence interval depends on the confidence level you choose, the degree of variability in your sampling data (as expressed by the standard deviation), and your sample size. Thus, an inefficient sampling design and small sample size will result in much wider confidence intervals, which in turn will result in complicated situations. Good sampling design and reasonable sample sizes will facilitate interpretation by making narrower confidence intervals and reducing the likelihood that threshold values will fall within the confidence interval. These are complicated concepts so do not hesitate to consult with someone with statistical training if you need help with confidence interval estimation or data interpretation.

Detecting Change With Significance Tests

If your management objective requires detecting change in some average value (such as a mean or proportion from one time period to another), then your statistical analysis should consist of a significance test, also called a *hypothesis test*. This situation often occurs in monitoring and involves analysis of two or more samples from the same monitoring site at different times (usually in different years, before and after management). The hypothesis of interest is that of no change; it is called the *null hypothesis*.

The major question asked in hypothesis testing is whether there has been change in the parameter of interest over a particular period. This parameter is often the mean, but we will also look at situations where the parameter is a proportion. If a change has occurred, the direction of change is a question usually (but not always) of equal importance. Significance tests are used to assess the probability of an observed difference being real or simply the result of the random variation that comes from taking different samples to estimate the parameter of interest. You can apply the material in this section in conjunction with any standard statistics book and, in particular, any computer software package that performs simple

Table 1. Summary of statistical tests available to analyze typical monitoring data		
Purpose of text	**Parametric Test**	**Nonparametric Test**
Testing for change between two years; samples independent; not frequency data	Independent sample t-test	Mann-Whitney U test
Testing for change between two years; samples paired (permanent sampling units); not frequency data	Paired t-test	Wilcoxon's signed rank test
Testing for change between two years; samples independent; frequency data	None available	Chi-square Test (2x2 contingency table)
Testing for change between two years: samples paired (permanent sampling units); frequency data	None available	McNemar's Test
Testing for change between 3 or more years; samples independent; not frequency data	Analysis of Variance; Independent-sample t-tests with Bonferroni correction	Kruskal-Wallis test; Mann Whitney U test with Bonferroni correction
Testing for change between 3 or more years; permanent sampling units; not frequency data	Repeated Measures Analysis of Variance; paired t-tests with Bonferroni correction	Friedman's test; Wilcoxon signed rank test with Bonferroni correction
Testing for change between 3 or more years; samples independent; frequency data	None available	Chi-square test (2 x 3 contingency table)

statistical tests. We have not presented detailed formulas in the interest of focusing on concepts.

One important distinction to make is whether the significance tests are for independent vs. paired samples. *Independent samples* are ones in which different sets of sampling units are selected randomly (or systematically with random starts) in each year of measurement. *Paired samples* are those in which sampling units are randomly selected only in the first year of measurement. The sampling units are then permanently marked, and the same (or at least approximately the same) sampling units are measured in the subsequent monitoring year. We make this distinction because different significance tests are used for independent versus paired samples.

Another important distinction to make is whether the data are *parametric* or *nonparametric*. Data that are parametric are typically those that form an approximately "bell-shaped curve" when their frequencies are plotted. Non-parametric do not display this characteristic pattern, e.g., count data that have many zeros and a few counts > 0. This distinction is important because different kinds of statistics are used to analyze parametric versus nonparametric data.

The approaches described above are basic ones used for detecting change in monitoring data as well as estimating sampling needed for effective monitoring at a given point in time and for detecting change over time if some pilot data are available. There are many other approaches to sample size and change estimation more suited to complex monitoring designs (e.g., see Elzinga et al., 2001, Table 1); however, the basic methods presented here will suffice for most situations.

Data Management and Communicating Monitoring Data

A successful monitoring project, be it a biological- or threats-based program, is characterized by three traits. First, it is well designed, and technically feasible and defensible. Second, it is implemented as planned in spite of changes in personnel, funding, and priorities. Third, the information from a successful monitoring program is organized, archived, analyzed and communicated. In the end, the information is applied, resulting in management changes or validation of existing management.

All three of these traits depend on clear communication and adequate documentation over the life of the project. Good design is usually a product of collaboration with stakeholders, other specialists, and help from experts. Consistent implementation requires the support and knowledge of managers and documentation of methods to survive personnel changes. Finally, application to management decisions requires communication of results. A monitoring project that simply provides additional insights into the natural history of a species, or that languishes in a file read only by the specialist, does not meet the intent of monitoring. Not incidentally, extensive monitoring programs rapidly accumulate vast amounts of information. Organizing these data so that they can be analyzed and quickly communicated is a substantial task that involves considerable planning unto itself.

To communicate effectively, results of monitoring should be analyzed each year (or each year data are collected) and reported in a short summary. Analyzing data as soon as they are collected has several benefits. The most important is that analysis is completed while the fieldwork is still fresh. Questions always arise during analysis, and the sooner analysis takes place after the field work the more likely those questions can be answered. Analysis after each data collection episode also means that the monitoring approach will be assessed periodically. Periodic assessment insures a long-term monitoring project against problems of inadequate precision and power, and problems of interpretation (Elzinga et al., 2001). Cooperators should create a management plan and schedule times to get together periodically to review data as a project moves along. The timings of these meetings should be outlined in the project goals to ensure that the meetings transpire.

At the end of the specified monitoring period, or when objectives are reached, results should be presented in a formal monitoring report. This report provides a complete document that describes monitoring methods and results, and should be distributed to interested parties. It offers a complete summary of the monitoring activity for successors, avoiding needless repetition or misunderstanding of the work of the predecessor. Finally, a professional summary lends credibility to the recommended management changes by presenting all of the evidence in a single document.

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Glossary

Adaptive management: a way of thinking about and implementing natural resource management that recognizes that any management we impose on the system can be viewed as an experiment that we can learn from.

Biological monitoring: tracking the biological state of the target condition.

Confidence interval: an interval used to estimate the likely size of a population parameter.

Hypothesis test: a statistical test designed to measure the likelihood that observed results occurred because a hypothesis was valid as opposed to due to random chance (compare with Null hypothesis).

Implementation monitoring: tracking progress in accomplishing project activities to ensure that project activities are being completed.

Independent sample: sample in which different sets of sampling units are selected randomly (or systematically with random starts) in each year of measurement.Management goals: specification of the general types of conditions or trends desired in resource conditions.

Monitoring: the collection and analysis of repeated observations or measurements to evaluate changes in condition and progress toward meeting a management objective.

Nonparametric: Data that do not form an approximately "bell-shaped curve" ("normal curve") when their frequencies are plotted.

Null hypothesis: the hypothesis that an observed difference (as between the means of two samples) is due to chance alone and not due to a systematic cause. (Merriam-Webster Online Dictionary: www.m-w.com)

Paired sample: sample in which sampling units are randomly selected only in the first year of measurement.

Parametric: Data that form an approximately "bell-shaped curve" ("normal curve") when their frequencies are plotted.

Power: the ability of a statistical test to reject the null hypothesis (see below) when it is actually false. The power measures the probability of not committing a type II statistical error. (Adapted from Statistics Glossary: http://www.cas.lancs.ac.uk/glossary_v1.1/main.html)

Threats monitoring: tracking of threats to the target condition.

Type I statistical error: concluding incorrectly that the populations we sampled do not actually differ because we drew unrepresentative samples by chance giving the mistaken appearance of a difference.

Type II statistical error: wrongly concluding that there is no difference between sampled populations when in fact we simply failed to sample adequately enough to detect it.