Monitoring Conservation Success in a Large Oak Woodland Landscape[1]

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Abstract

Monitoring is essential in understanding the success or failure of a conservation project and provides the information needed to conduct adaptive management. Although there is a large body of literature on monitoring design, it fails to provide sufficient information to practitioners on how to organize and apply monitoring when implementing landscape-scale conservation projects. We describe a decision framework currently being developed by The Nature Conservancy. It can be used to help set monitoring goals, prioritize monitoring efforts, and select monitoring metrics. Monitoring goals should be organized around at least three purposes. First, they should be closely tied to each specific conservation action and measure progress in implementing that activity. Second, monitoring should measure the impact the strategy has on abating its targeted threat. Third, the measures should test and validate the assumptions made regarding how the natural community functions. We provide examples of how these three types of monitoring are being applied to a large blue oak woodland landscape in the Lassen Foothills of northern California.

Introduction

Monitoring, the repeated measurement of variables over time and space, is an essential component of understanding the eventual success or failure of any conservation project. It also provides the foundation for an adaptive management approach to project activities (Christensen and others 1996). The act of monitoring in the context of conservation projects, however, is both complex and multi-faceted. It could include measures which provide information on threats, the condition of conservation targets, legal compliance, and testing hypotheses about how an ecosystem functions. Monitoring projects in large landscapes are further complicated by the fact that they occur within and across complex ecological systems with multiple anthropogenic threats. Consequently, more than a single conservation strategy is often employed in an attempt to abate those threats.

Although there is abundant literature regarding monitoring methods (Elzinga and others 1998, Thompson and others 1998), a significant challenge for conservation practitioners working in large landscapes is the design of efficient and affordable monitoring programs which can assess progress towards achieving

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conservation goals. We propose that monitoring programs have the highest chance of success if they arise from a well-organized conservation plan and continually provide feedback to managers. Given that there are few examples of successful monitoring programs and a much larger number of failures (Gibbs and others 1999, Yoccoz and others 2001), we describe a decision framework which can be used to help project managers set monitoring goals, prioritize monitoring efforts, and select monitoring metrics in a large landscape scale project. This framework is based on ideas being developed by The Nature Conservancy (TNC) as they attempt to design a monitoring framework to support TNC's emerging Conservation by Design methodology (TNC 2000, 2001). We present some of these ideas, and illustrate their current or anticipated application (presented in boxes) to a large oak woodland conservation project in the Lassen Foothill region of Tehama County, California.

Study Area

Blue oak (*Quercus douglasii*) woodland is a biologically rich and widespread vegetation community found primarily in the western foothills of the Sierra Nevada, the southern Cascade, the eastern foothills of the Coast Range and the Transverse Range (Barbour and Major 1988, Standiford and Tinnin 1996). Despite its vast spatial extent, the landscape's rolling topography and proximity to valley urban centers has focused development pressure in the blue oak woodlands. Additionally, most of this woodland occurs on private ranch land which is increasingly being subdivided for housing or converted to vineyards and orchards. This trend is encouraged by poor returns in the cattle industry and by aging ranchers passing monetarily valuable properties to heirs with other interests. Unlike California's conifer forests, few large blue oak woodlands are protected within public parks or other conservation ownerships.

The Lassen Foothills oak woodland covers approximately 300,000 acres and is surprisingly intact, primarily because of large private cattle ranch ownerships. The woodland occurs on rocky volcanic soils, and the oaks vary in density from sparse savannas to thick groves. The shrub layer is spotty over much of the landscape and is mostly composed of *Ceanothus cuneatus* and manzanita's *Arctostphylos sp.* The ground layer is predominantly non-native annual grasses mixed with native and introduced forbs. Native perennial grasses such as *Nassella pulchra* and *Aristida sp*. are present, but are found only in small scattered patches. Troublesome non-native species which have become common in the region include medusahead (*Taeniatherum caput-medusae*) and yellow starthistle (*Centaurea solstitialis*). Wild fires and grazing are important processes in the landscape. Fires occur most often during the hot dry summer months, while cattle graze the woodland from October to late May.

Conservation by Design

Developing a monitoring plan for a complex project becomes easier if the conservation approach is clearly organized. The Nature Conservancy uses an approach called *Conservation by Design* to select and plan its projects (TNC 2000). TNC's vision is to conserve a portfolio of functional conservation areas within and across ecoregions. We define ecoregions as relatively large units of land containing a distinct assemblage of natural communities and species. Site selection within ecoregions is an iterative process built around five steps:

- Identifying the species, communities, and ecological systems within the ecoregion;
- Setting specific goals for the number and distribution of these conservation targets to be captured in a portfolio of sites;
- Assembling information and relevant data on the location and quality of conservation targets;
- Designing a network of conservation areas that most effectively meets the goals;
- Selecting the highest priority conservation areas in the portfolio for conservation action.

The ultimate selection of conservation strategies is made by:

- Identifying the most serious stresses (threat) impacting the viability of the conservation target and its supporting ecological systems;
- Understanding the sources or causes of the stress;
- Developing an array of actions necessary to abate the threats.

The process outlined above was used to set a goal of preserving at least two large blue oak woodlands in the Northern Sacramento Valley ecoregion and the Lassen Foothills was identified as one of those sites in 1995 (TNC 1995).

In the Lassen woodlands the major known threats in order of severity were determined to be: home development and land conversion to vineyards and orchards, invasion of non-native species, and alteration of the fire and grazing regimes leading to a change of vegetation composition and structure. Even though development is not occurring in this region as quickly as in other areas, it was placed first because it is a threat that is irreversible.

Three primary conservation strategies and quantitative goals have been developed to abate or reduce the threats listed above:

- Conservation easements are being purchased from willing sellers to prevent development, vineyards, transfer of water, commercial woodcutting, and mineral extraction. A goal of up to 165,000 acres of conservation easements has been set.
- A prescribe fire program has been implemented to reduce medusahead and starthistle. A goal of 10,000 acres per year burned and 200,000 acres under fire management has been set.
- Grazing programs are being implemented to fence 20 miles of riparian habitat, and to establish a 6,000-acre grassbank (reserve) to encourage ranchers to rest private rangeland after prescribed burns.

Monitoring Conservation Success

One component of TNC's Conservation by Design initiative involves establishing Measures of Success (TNC 2001). Measures of Success provides a foundation on which to develop conservation project monitoring programs, however, to date TNC has not been able to implement a comprehensive, system-wide monitoring protocol. To this end, we have distilled some of the emerging ideas being considered by TNC and present them in the context of the Lassen Foothills Project.

Once conservation strategies and goals have been selected, monitoring should be organized around at least three purposes:

- First, monitoring should be closely tied to each specific conservation action and measure progress in implementing that activity;
- Second, monitoring should measure the impact of the conservation action (i.e., is the action reducing the identified threat?);
- Third, because conservation strategies are often based on assumptions of how the project's ecosystem functions, monitoring should test and validate those assumptions, inform adaptive land management and establish some long-term indices of ecological health.

Presented below is a discussion of the types of monitoring which address these three purposes. For each type we present a case study from the oak woodland community of TNC's Lassen Foothills Project to further illustrate feasible monitoring techniques.

Monitoring that Evaluates Conservation Actions

This type of monitoring enables a project manager to assess his or her performance in implementing the specific conservation activities which characterize the project. This should not be confused with measures of how the conservation strategies are working to abate the identified threats (discussed next). The purpose here is to simply track and assess the progress of getting strategies implemented. The results are used to help steer annual planning objectives and operate in a relatively short time span. These results, often in the form of maps or graphs, are also critical to communicate progress internally within an organization and externally to funding partners. Too often the results of monitoring are undermined, or even wasted, if they are not presented in a clear and easily digestible format and in a timely manner. *Figure 1* gives an example of this type of monitoring.

Monitoring that Evaluates Threat Abatement

In order to monitor the ability of a particular conservation action to abate threats, the project manager must be able to track the extent and severity of the threat. These measures often need to occur over a longer time scale than monitoring the implementation of conservation actions. *Figure 2* provides an example of how monitoring can be used to assess the prescribed fire program's ability to abate weeds. Although the indicator of a successful strategy in this case might be a reduction in the target non-native species, monitoring activities should also consider what is replacing these species, thereby providing additional information on the many feedback loops that exist in the ecosystem.

CASE STUDY

Conservation Action:	- acquiring conservation easements
Monitoring Technique:	- GIS map and database
Spatial Scale of Analysis:	- landscape
Temporal Scale of Analysis:	- 6-12 months

Measures which track the implementation of conservation strategies have been made relatively easy in the Lassen project because quantitative goals have been set. Within the project's Geographical Information System (GIS) database, there is a spatial layer pertaining to conservation easements. Because each easement is a unique agreement between the land owner and TNC, new easements with their specific legal terms are entered into the GIS. The attributes include binomial codes showing whether: grazing is allowed, water rights are purchased, mining is restricted, or if riparian fencing needs to be constructed.

The GIS offers a number of ways to manipulate conservation easement information. Queries can be conducted selecting for specific attributes of the data and an overlay analysis can be used to assess the relationship of easements to other spatial information - such as which habitat types it encompasses. Finally, maps can be periodically generated by overlaying the easements with advancing threats such as subdivisions and vineyards. In a complex project with many conservation strategies and threats, convenient manipulation of such information is essential.

Figure 1—Monitoring the implementation of a conservation easement program in the Lassen Foothills.

CASE STUDY

Management action:	- spring burns
Monitoring technique:	- vegetation plots
	- hyperspectral imagery
Spatial Scale of analysis:	- site scale
	- landscape scale
-Temporal Scale of Analysis:	- 12-24 months

The effectiveness of the prescribed fire program on abating weeds is monitored by sampling vegetation composition before and after burns. Burns are declared successful if weeds are reduced by at least 20 percent . In research plots at Vina Plains, an important focal area which includes vernal pools, statistical comparisons of the success of burns have been made at alpha = .05 and beta = .2 , although, in general, lower power comparisons are acceptable for most management data. Data from the Lassen Foothills shows an average reduction of 58 percent cover of medusahead and 35 percent reduction of yellow starthistle after prescribed burns (Hujik 2000, Hilken and Miller 1980). Because before and after monitoring only produces yearly updates on the effectiveness of individual fires, permanent long-term vegetation transects are being established. Transects are 50 meters long, are stratified by soil type, and each have 500 points identified to species. If resources permit non-treatment controls to be established, this monitoring could be expanded to ascertain cause-effect relationships (van Mantgem and others 2001).

The use of remote sensing (1.5m multi-band imagery) is being investigated under the premise that medusahead and yellow starthistle have unique spectral characteristics that can be distinguished in the imagery. (Qi and others 2000). If this approach proves successful, future monitoring might be conducted by automated image processing techniques for selected transects within areas managed by fire. This would substantially reduce the amount of time and human intensive groundwork.

Figure 2—Monitoring the effects of prescribed fire on exotic weeds.

Monitoring that Validates Ecological Models

Because our perception of threats are most often based on assumptions of how the ecosystem functions (i.e., reduced grazing leads to increased oak survival), it is important to utilize monitoring as a means of validating these assumptions. The development of a visual conceptual model is a useful way to organize relationships between various components of an ecosystem. These models can ultimately help guide the selection of variables for monitoring. Models are an efficient way to describe the pathways that lead from causes (including management actions) to outcomes (such as a more desired or a less desired ecological condition) (Manley and others 2000, Yoccoz and others 2001). Consequently, models take monitoring a step beyond simply identifying pattern and provides management with information on the underlying mechanisms.

One way to characterize relationships in a natural community is to break it into components and then describe the relationship between those components. Franklin and others (1981) propose to divide communities into three components; composition (species diversity), structure (vertical and horizontal pattern), and function (ecological and evolutionary processes). Alternatively, Davis (1993) suggests beginning with an exhaustive list of system elements (e.g., species, processes) and a description of their relationships. *Figure 3* illustrates a merging of these two approaches for the blue oak woodland of the Lassen Foothills (Allen 1990, Swiecki and Bernhardt 1998).

On the left side of the diagram are three components of the ecosystem; structure, composition, and function. Nested within each of these components are loosely assigned elements of the oak woodland. For example, birds can be considered an element in the composition of blue oak woodlands (e.g., acorn woodpeckers are recognized as a keystone species) (PRBO 2000). The box to the right of this reflects Davis's (1993) recommendation of listing the various attributes of the ecosystem that could be monitored for that element. For example, in the case of birds, surveying for snags and cavities could help supplement more intensive, and costly, bird surveys.

A model such as *Figure 3* is obviously a simplification of the ecosystem: realistically it should include the complex web of one- and two-way relationships between attributes that are related. For example, fire has a feedback loop to ecosystem vegetation—in particular to non-native species. *Figure 4* expands that portion of the model and portrays it as a set of state variables linked by a web of relationships. Some of the relationships are well know, others are not. For example, the relationship between "medusahead thatch increasing with lack of fire, causing natives to decrease" has been well established and does not require further research (Hilken and Miller 1980). However, the relationship between "an increase in native grass and forbs leading to greater oak and shrub survival" is less certain (Keeley 1975, Swiecki and Bernhardt 1998). The latter should be a high priority for research and should be incorporated into monitoring designs. *Figure 5* provides an example of testing of a conceptual model hypotheses within a monitoring program.

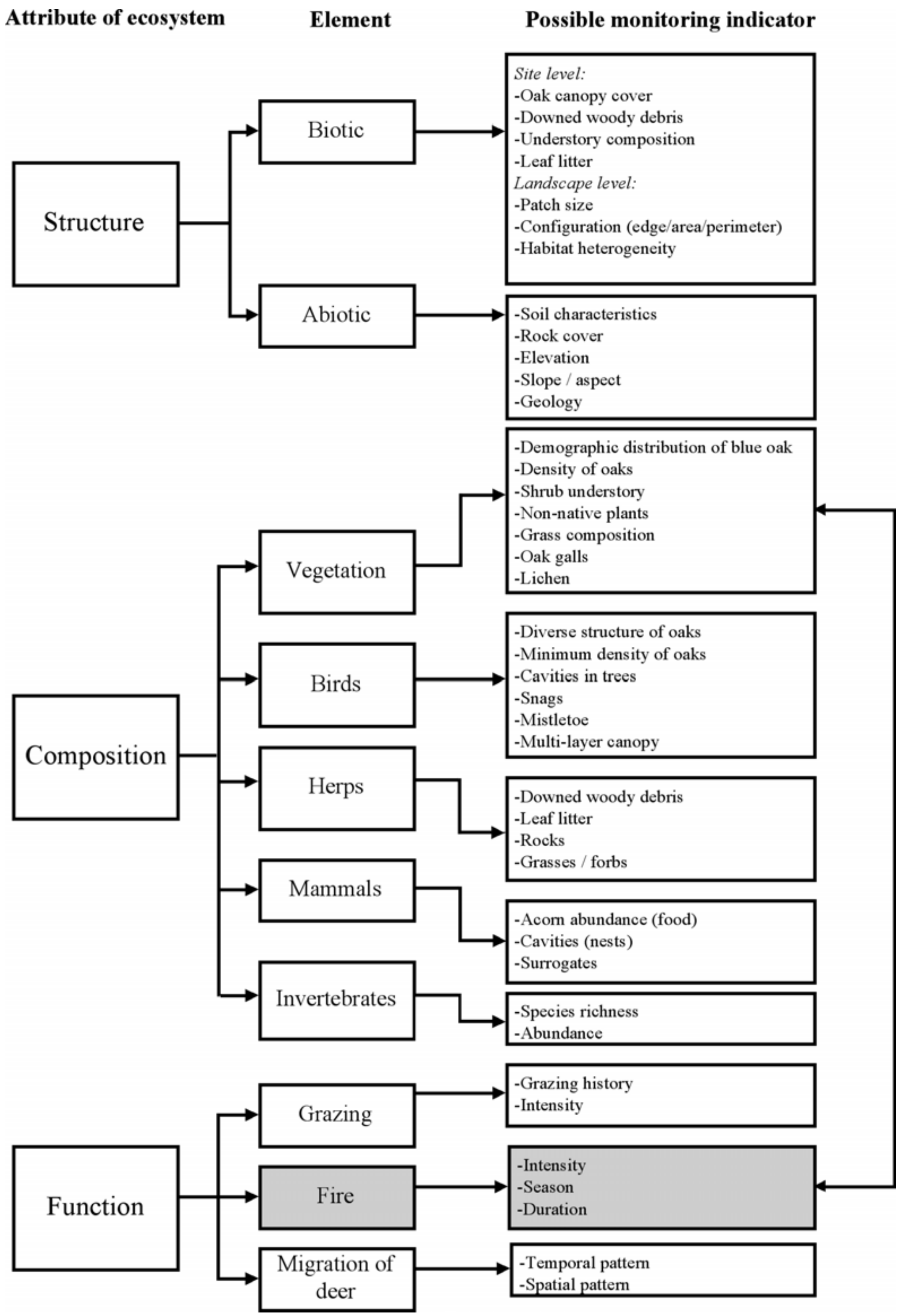

Figure 3—Conceptual model of some components of a blue oak woodland.

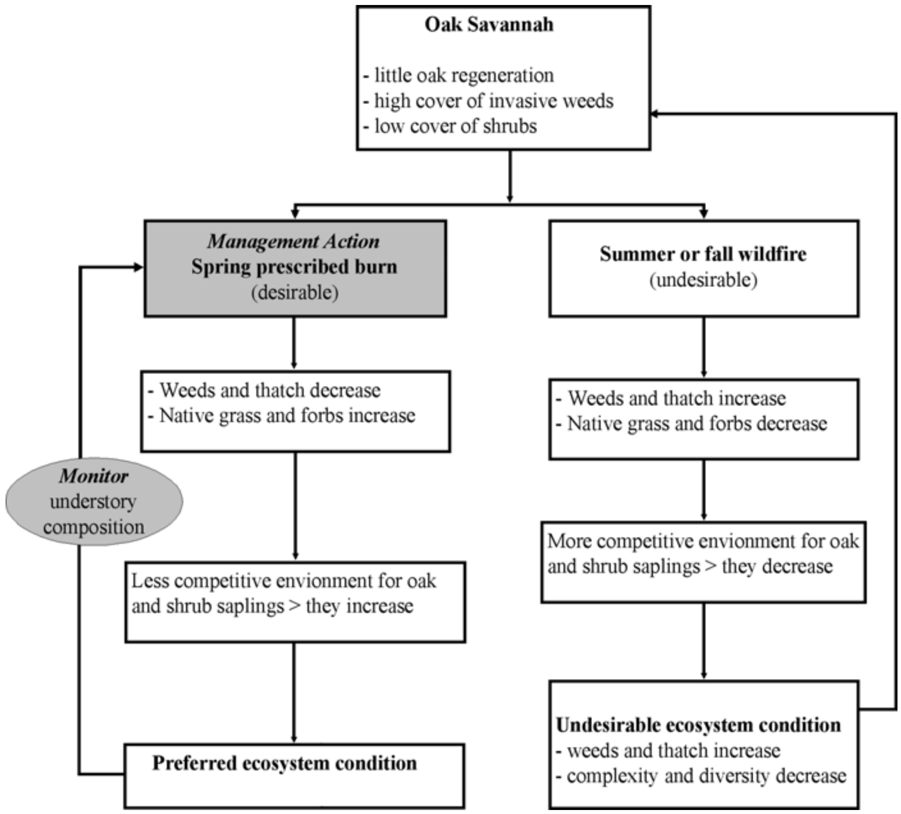

Figure 4—Conceptual model of fire impacts on non-native plants: management action and monitoring.

CASE STUDY

Management action:	- fire and grazing
Monitoring technique:	- vegetation transects and plots
	- bird and invertebrate surveys
Spatial scale of analysis:	- site and regional scale

Our conceptual model of the Lassen oak woodland presumes that fires and grazing effect shrub density, oak reproduction, and wildlife diversity. Both experimental and correlative monitoring approaches are being used to validate the model. In terms of monitoring, advances in the development of GPS and GIS have facilitated the establishment of long term monitoring transects for vegetation composition, residual dry matter, oak seedlings, and annual acorn production. In addition, significant native grass patches are being mapped. All monitoring data, including grazing and fire records, are recorded in a GIS database. This archive is an important observational record to eventually validate or modify the conceptual model.

In terms of experiments, the hypothesized relationship between shrub density and wildlife is being investigated. It is suspected that birds, such as blue-gray gnatcatcher and lark sparrow, forage in denser vegetation (Fleischner 1994, PRBO 2000) and studies in other ecosystems have indicated that invertebrate diversity is correlated to plant diversity (Southwood et al. 1979). Plots have been established to compare bird and invertebrate (ant) diversity in areas where there is a significant shrub compared to where the understory is primarily non-native annual grass. Preliminary data indicate that there is a higher diversity in both taxa where the composition and structure of the oak woodland is more complex. If future analysis prove this to be true, then managing and monitoring for a dense shrub understory would be a logical activity to preserve bird and invertebrate diversity in this woodland.

Figure 5—Monitoring to validate conceptual models on the impacts of fire and grazing.

Additional Ways to Prioritize Monitoring

It is likely that, even after using a selection framework as described above, the number of proposed monitoring projects will still be more than is possible to implement. To further prioritize projects, monitoring should be subjected to additional filters.

"Cost" is always a consideration, and much of the cost of monitoring is determined by the sampling intensity required to detect significant change. Because the power to detect change in a statistical design is inversely related to the magnitude of the system's variability (Hayes and Steidl 1997), it is important to conduct pilot studies. For example, in the Lassen foothills grasslands perennial plants generally exhibit less year-to-year variability than annuals. After a specific monitoring metric is selected, further increases in statistical power or economy of sampling can be obtained by stratifying samples to reduce variability (for example, concentrating sampling within one soil type or range of elevation). Other methods of increasing statistical power without increasing the sampling intensity and cost include nesting samples at different spatial scales, optimizing the shape of the sampling units, and implementing data handling procedures which minimizes recording errors (Gibbs and others 1999, Steele and others 1984). Also, sampling intensity may be reduced by considering an increase in the alpha (chance of error) and beta levels in which the statistical tests are conducted (Kendal 1992).

Another method to reduce costs is to consider selecting "indicators" which are related in a known way to other environmental conditions. Umbrella species (a species that needs such large habitats that saving it will automatically save many other species) and keystone species (species whose activities have an impact disproportionate to their abundance) should be considered (Karr 1987, Noss 1990). If possible, data could be collected which would serve duplicate purposes. For example, imagery might be used to detect invasive plants as well as identify changes in land-use.

The prioritization of monitoring also should consider the project's "investment" in different conservation strategies. Monitoring should be directed towards the most expensive conservation strategies, whether expense is interpreted as financial, human-power, or time. In the Lassen Foothills the greatest expense is undeniably the purchase of conservation easements where millions of dollars have been expended to date. The long term success or failure of these easements in protecting the viability of this woodland will be known only through monitoring.

Monitoring variables which directly relate to "ecological relationships" which can be manipulated should be considered a priority. For example, in the Lassen woodlands there is some control over timing and frequency of fire though the prescribed burn program. It is thus important to understand how fire impacts the woodland's native biodiversity. On the other hand, we have little control over global climate change. Even though climate change may ultimately be a major threat, it is not within our project's control and thus should receive a lower priority for monitoring.

"Collaboration" with other institutions already collecting and archiving information offers valuable information for project monitoring. We surveyed the literature and looked for other organizations collecting data in the Lassen Foothills region that potentially could be useful for the project. *Table 1* shows some of those monitoring programs.

Integrating outside data into a monitoring program can be challenging as meta-data regarding the monitoring programs of others maybe difficult to obtain. Understanding the limitations and assumptions of the data often requires personal visits with researchers. Regardless, the benefits of using others' data most often outweighs the disadvantages. For example, the California Department of Forestry has undertaken a state-wide land use change detection program Fire and Resources Assessment Program (FRAP) which highlights, at a landscape level, changes in the cover of oak woodland which have occurred in the Lassen region each five years. Since this program measures change at the landscape scale, our project does not need to replicate this expensive monitoring and can focus its efforts on elucidating the mechanisms responsible for this change at a finer scale.

Table 1—*Some organizations already collecting data on the Lassen woodland site.*

Type	By whom	Data	Web site
Landscape images and coverages	CA Dept. of Forestry & Fire Protection	Fire and Resources Assessment Program	http://frap.cdf.ca.gov/
	CA Dept. of Fish and Game	California Wildlife Habitat Relationships Information Data Base	http://www.dfg.ca.gov/whdab/html/cwhr.html
	Center for the Assessment and Management of Forest and Environmental Resources	Fire history mapping	http://camfer.cnr.berkeley.edu/
	U.S Geological Survey	California Gap Analysis	http://www.biogeog.ucsb.edu/projects/gap/gap_home.html.
Wildlife surveys	CA Dept. of Fish & Game	Deer counts	http://www.dfg.ca.gov/hunting/part2.pdf
	CA Dept. of Fish & Game	Nocturnal animal counts	N/A
	Point Reyes Bird Observatory	Bird surveys	http://www.prbo.org/
	U.C. Hastings Natural History Reserve	Statewide acorn surveys	http://www.hastingsreserve.org/OakStory/OakIntro.html
Water	CA Dept. of Water Resources	Stream flow	http://cdec.water.ca.gov/

Conclusion

The scientific literature abounds with rigorous methodology designed to monitor and quantify change over time. Yet most long term monitoring programs associated with conservation projects have failed. Most fail because they have not been closely tied to specific goals and thus do not provide timely adaptive feedback to project directors. If the information generated is not immediately useful, monitoring projects quickly become fiscally unsustainable. We have illustrated in this paper a step-by-step guide for linking monitoring to specific conservation project goals, and have demonstrated how to prioritize monitoring in a large blue oak woodland landscape.

To be effective, a monitoring program must provide sufficient information to allow project managers to practice adaptive management and determine the success or failure of their projects. Only through monitoring will we be able to correct past mistakes and be able to truly know the long-term value of today's conservation efforts.

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