Framework Management Plan

Guidelines for best practices with examples of effective monitoring and management

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Key Abbreviations and Acronyms

AM	Adaptive Management
ASMD	Area specific management directive
BIOS	Biogeographic Information and Observation System
CDFW	California Department of Fish and Wildlife
CNDDB	California Diversity Database
CSS	coastal sage scrub
DB	Database
GIS	Geographic Information System
HCP	Habitat Conservation Plan
IEMM	Institute for Ecological Monitoring and Management
MOM	Master Occurrence Matrix
MSCP	San Diego Multiple Species Conservation Plan
MSP	Management Strategic Plan
MU	Management Unit
NCCP	Natural Community Conservation Plan
PAR	Property Analysis Record
RMP	Resource Management Plan
SANDAG	San Diego Association of Governments
SC-MTX	South Coast Multi-Taxa Database
SDMMP	San Diego Management and Monitoring Program
TNC	The Nature Conservancy
USFWS	US Fish and Wildlife Service

Prologue

Adaptive management (AM) is the linchpin of current conservation efforts. It is the cohesive process that holds together the many parts of monitoring and management so they function as a unit. Adaptive management is also very difficult. This document organizes and synthesizes current best operating procedures for implementing adaptive management for a Habitat Conservation Plan/Natural Community Conservation Plan (HCP/NCCP) plan like the San Diego Multiple Species Conservation Plan (MSCP). This document is intended to be used by preserve managers and their biologists, resource specialists, environmental consultants, field staff and rangers (sometimes referred to as the preserve team) to prepare and implement their biological resource adaptive management plan and activities.

Adaptive management is an iterative process of learning while doing (Figure P.1). Although adaptive management is a looped or iterative process, it is not simply management through trial and error. Substantial planning and a thoughtful approach to the adaptive management process are needed to reduce uncertainty and strengthen management and monitoring efforts.

Figure P.1. Adaptive management (AM) is an iterative process of learning while doing. Efficient implementation of AM is much more difficult than it seems.

State of the science

This document draws on the lessons learned in implementing monitoring and management in the San Diego MSCP and other regional plans. This document references technical reports by management agencies in the US, the European Union, and several commonwealth countries, notably Canada, Australia, and New Zealand aimed at improving and standardizing adaptive management practices. Finally, this guidance document reflects the growing and rich peer-reviewed scientific literature on applied conservation. Together, this body of information provides a much stronger foundation for adaptive management than was present ten or even five years ago. The material cited within this framework based on best-available science and information. Citations to this knowledge base are noted as numbered superscripts e.g.[x] throughout the document. A list of acronyms and abbreviations used throughout can be found after the Table of Contents. References can be found at the end of each chapter and then again in the complete Reference section. As such, the document captures the state of the science of adaptive management.

There have been many guidance documents written on the adaptive management process. We build on these published templates, referencing where appropriate and providing concrete examples and guidance for each step of the process. By providing real-world examples and direct recommendations, we aim to operationalize the adaptive management process in a way that has not been done in a single document.

Common framework, not "one size fits all"

It is important to recognize that while the concept of adaptive management is simple and easily understood, the implementation of the adaptive management process is complex and context dependent. As a result, this guidance document cannot and should not be used as a fixed set of steps that must be applied in the exact same fashion at all preserves. Indeed, the success of adaptive management depends on our ability to optimize the approach depending on the scale of the system, our understanding of the dynamics, and constraints on monitoring and management actions. Additionally, the adaptive management process is embedded in a social, political, institutional system that reflects subjective values of stakeholders.

This step-by-step approach provides a common framework that is designed to support site managers and planners as they develop management documents and monitoring and management plans at individual preserves. We present this work in a linear series of chapters but in practice, the process is more fluid and iterative. Having a common template will encourage and support standardization among preserves that may have dissimilar management goals or directives.

Implementation through coordination with related efforts

Successful implementation of adaptive management requires the integration of input from multiple stakeholders with data on species and ecosystems across multiple temporal and spatial scales. Since resources are always constrained, successful adaptive management involves the prioritization of activities from a large list of important objectives. It is important that this prioritization reflect regional priorities as well as preserve specific directives and regulatory requirements. Not surprisingly, the complexity of the landscape of adaptive management has led to a gap between the ideal concept and cost-effective results on the ground.

Substantial progress has been made in improving adaptive management in the San Diego region (Figure P.2). The San Diego Management and Monitoring Program (SDMMP) was created to improve regional prioritization and coordination. Several regional strategic plans have been developed or are in development. In addition, the diverse set of stakeholders are operating in a more deliberate and concerted fashion.

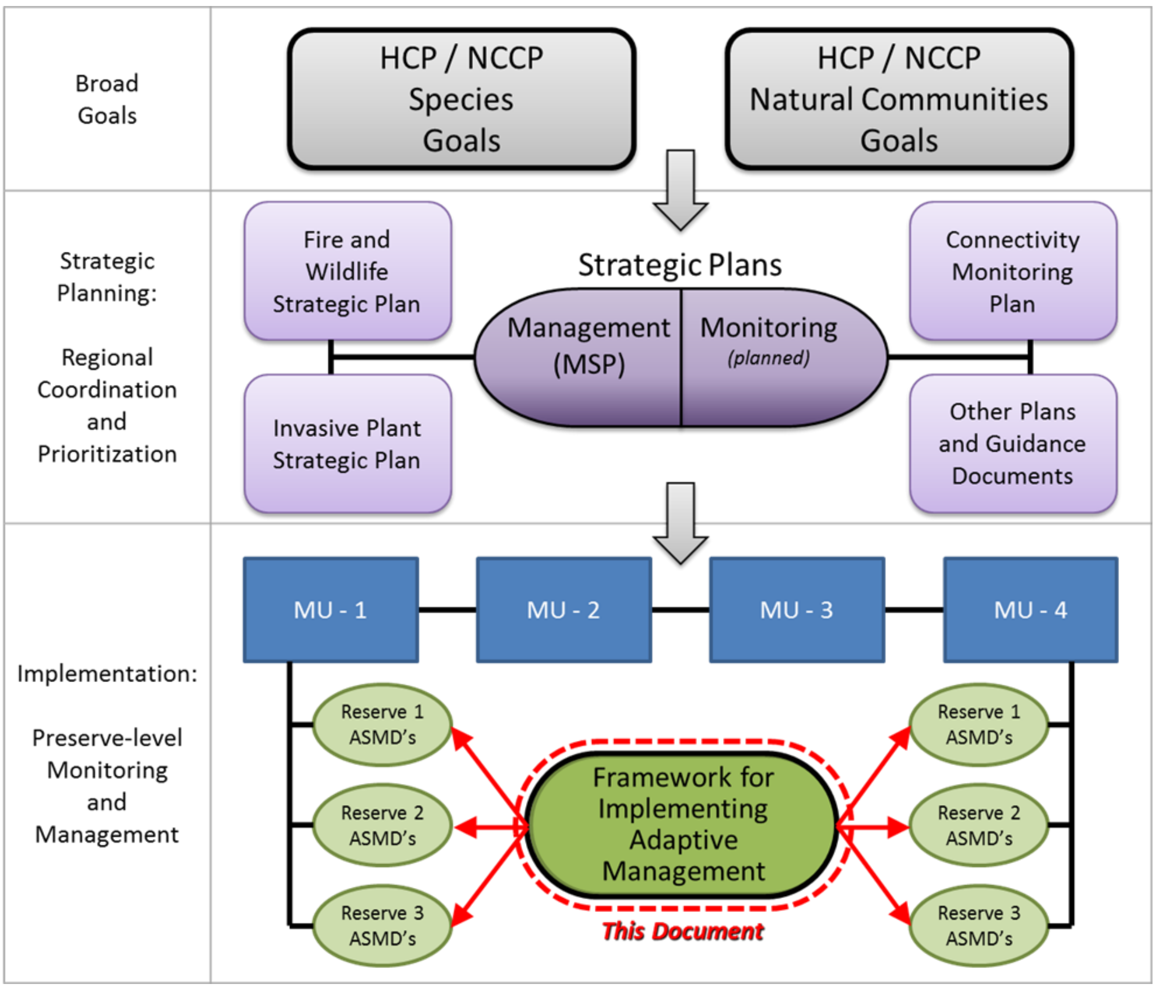

Figure P.2. The context of adaptive management in San Diego. This document is a guide to difficult process of implementation of AM in a complex system with multiple stakeholders and constraints.

Improving preserve-level monitoring and management

This framework is designed to address the basic steps of adaptive management. This guidance document has been written to improve preserve-level monitoring and management. It provides a clear and well-supported description and discussion of the elements of effective adaptive management, with examples to illustrate, demonstrate and contextualize each element. As part of this process, we also provide our working definitions of key terms and concepts.

With proper implementation of this step-wise process, this document will also strengthen and support field operations and activities at the preserve level. Because of the need to discuss, illustrate and critically review the science-based adaptive management process, this document is written with the assumption that the reader has basic familiarity and training with ecological science. As such, this is not a field guide for rangers or field technicians. That said, this document is relevant to managers and planners as well as field staff as members of the preserve team. The chapters cover specifics on best practices regarding monitoring and management (e.g. Chapters 5-8) that have direct relevance to field operations and provide guidance on cost- effective and efficient monitoring approaches. What the chapters emphasize is the need to support efforts at a preserve that best meet stated management goals and objectives *while also* being cost-effective and a good use of limited resources.

The adoption of recommendations from this document will require expertise and financial resources to support its widespread adoption and use. This document, like any framework or guidance document, will also require periodic review and revision to incorporate new information from several recent or concurrent initiatives (e.g. recently published Management Strategic Plan (MSP) and other ongoing regional plans under review and in development). The process itself will change over time as ongoing adaptive management efforts provide information that reduces critical uncertainties and improves conservation/management outcomes.

Chapter 1:
Introduction to this document

Chapter guide

In this chapter we introduce you to the adaptive management context, the challenges with the process, and the need for adaptive management at the preserve to align with MSCP-wide and regional priorities. We also introduce you to this document and discuss the structure of the guide and how this guide can help improve adaptive management at the preserve level.

Introduction

Implementing adaptive management requires the cooperation and coordination of many stakeholders. This document serves as a guide or manual to provide a step-by-step description of this complex process and gives concrete examples to illustrate the underlying concepts. In this chapter, we summarize the adaptive management context. We also describe the structure and the organization of this document.

First, we introduce the stepwise approach this document takes through the iterative steps of adaptive management at the preserve level. We also familiarize you with the format of each chapter. Each chapter will have an introduction summarizing the content of the chapter. This is followed by a general discussion of the key concepts and ideas, providing examples and recommendations where appropriate. At the end of each chapter, we will provide a bulleted list of key concepts and ideas covered in the chapter. For some chapters, we provide a checklist to help managers keep track of the critical elements needed to successfully complete each particular step.

The iterative adaptive management process

Adaptive management is an iterative decision making and learning process that seeks to reduce uncertainty in natural systems[1,2]. When a particular management experience is successful in one area or ecosystem, we naturally want to apply the same techniques in other management efforts. However, similar physical and ecological systems may not respond identically and predictably to management techniques[3,4]. This is why no single, detailed "prescription" can be used in ecosystem management, as it ignores the inherent variability and uncertainty in natural systems. By following an adaptive management process it becomes easier to build on and share best-practices in monitoring and management and identify common approaches that can improve adaptive management beyond a single preserve.

The fundamental premise of adaptive management is that management actions and related monitoring data are used systematically to improve conservation outcomes through increase understanding and more effective action. As a general concept, adaptive management is easily understood (Figure 1.1).

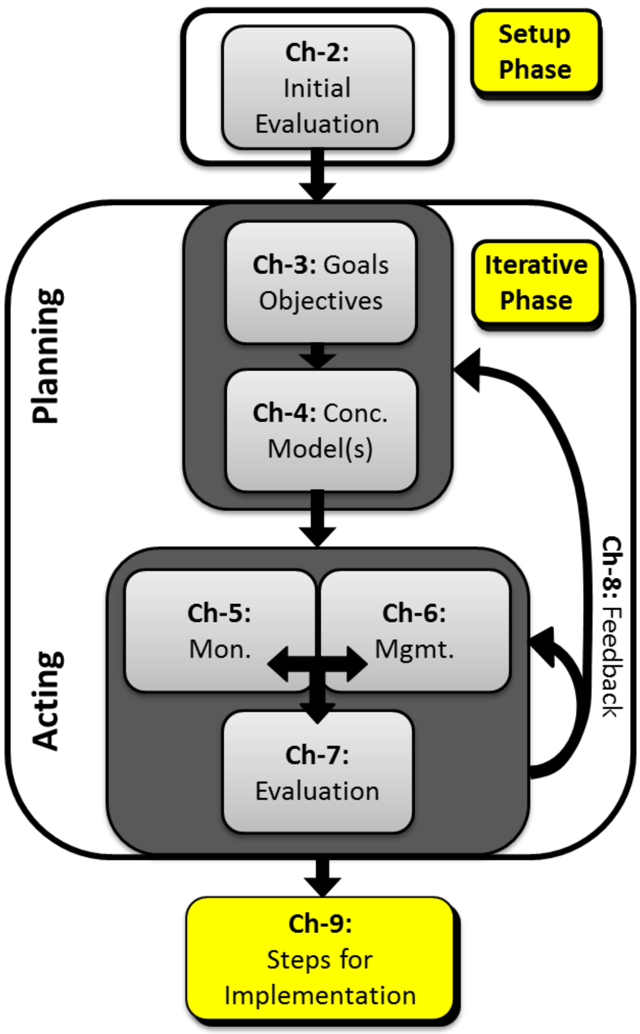

Figure 1.1. The iterative nature of adaptive management .Feedback occurs at multiple levels and on different time schedules. We use this schematic of adaptive management to represent the process as whole and to orient the reader to each step as they progress through the document.

In this iterative process, a management action is outlined (**Setup Phase**), employed (**Iterative Phase**) and the results of the management action are monitored and used to improve future efforts (**Feedback)**. Based on the monitoring data collected, the efficacy, cost-effectiveness and suitability of the management action can be evaluated and revised if necessary. This assessment is used to directly guide the next round of management actions, a step-wise process that is repeated and repeated. One feedback loop involves rapid updates to management and monitoring. This should happen on a short time scale, e.g. 1-5 years. While this relatively rapid feedback loop may need to contend with administrative hurdles from associated organizations and agencies, an ability to integrate data and knowledge gained to refine objectives and conceptual models is critical. A second important feedback loop links all management and monitoring activities back to a re-assessment of goals and objectives. This should happen on a longer time scale, e.g. 10 years. We use this figure to capture the elements of the adaptive management process as well as identify the specific steps and framework described in this document.

Adaptive management is intuitive but challenging to implement

The concept of adaptive management is intuitive, yet adaptive management has been the focus of intense criticism in large part because of the failure to implement of this seemingly simple process[5,6]. Clearly, the devil is in the details. Despite the criticisms, adaptive management approaches have been shown to be effective[7] in improving resource management. For adaptive management to work effectively, it requires all participants in the process to have an understanding of the inherent complexity of doing adaptive management.

One of the most fundamental and repeated themes throughout this document is the need for priorities to guide the adaptive management process. Prioritization occurs at a number of different stages in the adaptive management process: priorities are established at the regional level (for the MSCP as a whole), can be set for sub-regions within the area (MSCP Management Units) and at the local level (at a preserve) in terms of what species and natural communities should receive the most management attention. There have been a number of papers that has described how species and systems can be prioritized at both the regional and local level[8,9] as well as a substantial number of papers from other regions[10,11]. Prioritization is, in essence, a subjective process. As such, there is no single “right” way to rank management units, species, natural communities or threats. What is critical is that whatever ranking or prioritization method is used is a) robust b) transparent c) repeatable and d) is informed by existing knowledge and data. Furthermore, priorities need to be aligned at each spatial scale. Preserve-level priorities should reflect and support priorities for management units, which in turn are guided by regional priorities for the MSCP as a whole.

Although this document focuses on adaptive management at the preserve level, the activities at a single preserve must work towards the goal of supporting the MSCP as a whole. It is essential that regional MSCP priorities serve as the starting point for individual preserves and that the adaptive management activities at a preserve align with regional priorities. A document that outlines regional priorities for the MSCP is in development and this management strategy document, titled the Management Strategic Plan (MSP), will provide preserve managers with clear guidance on the species, systems and threats of highest priority for the MSCP network. This document will also cluster areas of the MSCP into sub-areas, called Management Units (MUs), and provide guidance on management priorities for these MUs as well. Even with specific regional priorities in hand, a preserve manager is still faced with the task of “stepping-down” the regional priorities to the preserve level. Communicating and coordinating with other managers within an MU and across the MSCP will support this priority translation process.

Alignment and Concordance

The concept of alignment is also critical to the adaptive management process itself. As we move through discussion of the steps, we'll demonstrate why there must be alignment and concordance between goals and objectives, a management team's understanding of the system, the management actions proposed, the monitoring data collected, how these monitoring data are analyzed and how this information is used to inform future management. In many chapters, we'll refer back to this concept of alignment to help ensure that each step of the process builds on previous step and supports the next.

No "one size fits all" approach

One of the central challenges to the adaptive management process is the inherent variability: variability among environmental conditions or physical structure among preserves, in the human impacts that may challenge a preserve, or in the type of management structure by which a preserve is managed. One clear way to articulate this challenge is to recognize that "adaptive management is prescriptive only in process"[6]. What unites different preserves is the common steps of the adaptive management process, which is what this document lays out.

How to use this guide: elements and structure

The content of this document was guided by a stakeholder steering committee that supported the development process. The steering committee had representatives from USFWS, CDFW, The Nature Conservancy (TNC), SDMMP, and SANDAG (see **Key Abbreviations and Acronyms** for more information). Representatives from these organizations reviewed the Scope of Work several times before the project was initiated. Once started, we met with steering committee members formally and informally over the course of the project. We convened 8 times over the course of two years and also presented interim results to the EMP Working Group in 2012 and 2013 (see Appendix 1.1). Using guidance from the committee and feedback from other stakeholders, our goal was to create a document that was easy to navigate, used accessible and clear language, was science-based and referenced relevant and current materials. For readers interested in reading supporting literature, we have included key citations, where cited material is noted by a superscript[x] and full citation information can be found in the References section.

Each chapter follows a common organizational structure. First, we present the context for the chapter, providing Figure 1.1 to orient the reader to which stage of the adaptive management process the chapter refers. With that context in hand, we then provide concrete examples of and recommendations related to the concepts discussed. At the end of each chapter, we also provide a summary to capture the key concepts and material from each chapter. For chapters 2 through 9, we also provide a checklist that outlines the critical steps or fundamental elements for each chapter to help managers keep track of their progress through the adaptive management process.

Our goal was to complement, rather than duplicate, the large number of general adaptive management templates and guide documents already written, e.g.,[12,13,14]. What sets this guide apart from these other documents is that it provides concretes examples and direct guidance on the adaptive management process drawing from more than 2 years of work with individual preserves and workshops within the MSCP. The document presents information in a "How To" format and operationalizes the adaptive management process

Figure 1.1 is designed to focus on alignment and concordance between management questions and actions. Because different preserves and parcels are at different stages of adaptive management process, application of this guide will be site-specific. This figure reinforces the importance of a stepwise process, but also demonstrates that this is not a “one size fits all” approach in that it can be used by managers of sites that are at different stages in the adaptive management process. For example, one preserve may be ready to initiate the monitoring-management-evaluation loop (Chapters 5, 6, and 7) whereas other sites might not have any management documents developed and may be initiating the adaptive management process for the first time (Chapter 2). This document will be relevant for preserves across all stages of management development and managers can access and utilize whatever chapters are relevant to their preserve needs.

Chapter 1: Summary

- Adaptive management is an iterative decision-making and learning process that seeks to reduce uncertainty. Although intuitive, implementation of adaptive management is challenging.
- MSCP-wide priorities should serve as the starting point for individual preserves so that adaptive management activities at a preserve align with regional priorities.
- This document follows a stepwise approach to adaptive management at preserve level, identifying critical elements and providing recommendations and examples.
- There is no “one size fits all” prescriptive approach to monitoring and management. However, the process of adaptive management should be comparable across preserves.
- Preserves will be at different stages of the adaptive management process and can use chapters of this document accordingly.
- A common figure will be used throughout the document to orient the reader to each phase, with preceding and subsequent steps in the adaptive management process clearly detailed.

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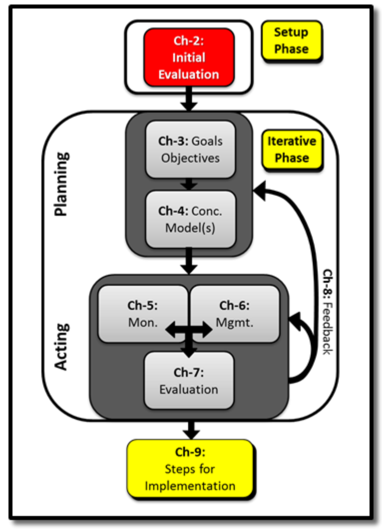


Chapter 2:
Initial site evaluation:
Getting started at a new site

Chapter guide

For newly acquired parcels or preserves that are under a new management agency, an initial and often rapid characterization of the species, systems, threats and stressors on the site is needed to move into the iterative monitoring and management phase and inform the development or updating of management documents. This chapter defines terms and describes how preserve managers can move efficiently and effectively through this site evaluation process. The steps outlined in this chapter follow the same structure as the material detailed in Chapter 5 of this guide. The key difference between this Chapter and Chapter 5 is that here we focus on inexpensive and rapid techniques to develop a fairly coarse level of understanding. Even at this stage, monitoring and management activities should be concordant with other local and regional priorities. Before any field work is planned, a thorough search of existing databases must be performed.

Initial characterization should also be guided by a clear statement of the objectives, even if the objectives are uncertain. Once these steps have been taken, data gaps can be addressed using well understood methods.

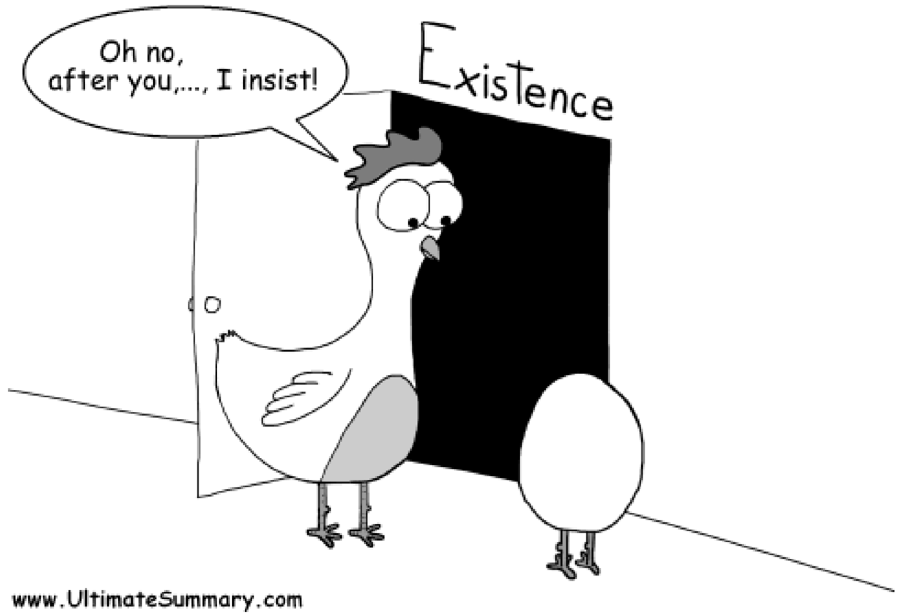


Figure 2.1. Getting started is like the riddle – *What comes first? The chicken or the egg*. You need information and data on which to base goals and objectives, but you need relevant and well defined goals and objectives to know what data is most important to management collect.

Introduction: Getting started at a new site

For sites that are newly acquired or do not have an adequate/current management plan, managers must start at the beginning of the adaptive management process. This first step entails evaluating and characterizing a site. To do this, data must be collected efficiently and in a cost-effective manner so they can be used to formulate a management plan. Even before site characterization occurs, it is important to review and align your activities with regional priorities.

Context: Identify existing regional and local priorities

Managing conserved lands in southern California requires understanding a complex web of regulations, stakeholders, and ecosystems. Many conserved lands have Area Specific Management Directives (ASMD's) or budgetary constraints based on financial analyses like a Property Analysis Record (PAR) or similar financial analysis (Figure 2.2). It is important to determine how these regional priorities can guide the setup phase of adaptive management, e.g. What should the focus of site characterization activities be given regional and mandated (permit) priorities? What species, natural communities, threats and stressors will be characterized? Prioritizing site characterization activities in this regional context can help ensure resources are used efficiently and that information gained can help provide a solid foundation for the subsequent adaptive management steps.

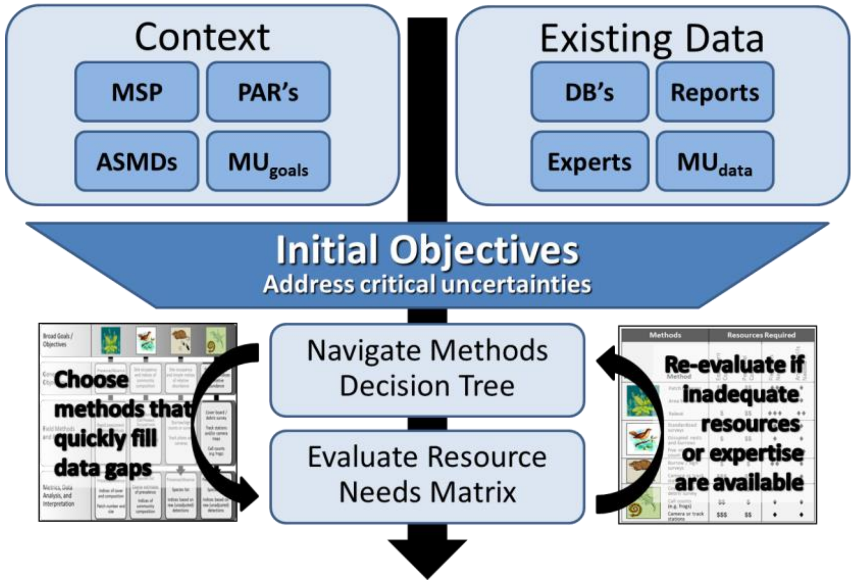


Figure 2.2. Determining site characterization activities based on synthesis of local context (MSP, ASMDs, PARs) with what is known (existing databases, expert opinion, regional data). Initial objectives should address critical uncertainties from the large number of potentially important taxa/issues. Rapid assessment methods should be selected based on their ability to address these uncertainties quickly and with low cost. More detailed (and expensive) monitoring (see Chapter 5) is not appropriate until these basic uncertainties have been addressed. See list of Key Acronyms and Abbreviations for more information.

Mining existing databases

With this contextual information in mind (Figure 2.2), the first step to site characterization is to find out what information is already available about your site from existing sources like databases, reports, and local experts. This fact-finding step ensures that you are aware of the existing surveys, research, or other management actions that have been conducted on the site. These could include species lists, species or natural community occurrence or abundance, or past management projects and monitoring activities. There are a number of relevant databases where this information may be available (Table 2-1). Reviewing past projects and monitoring efforts by mining databases will help reveal the history of the site and identify critical plant or animal species that are of particular concern. The San Diego Management and Monitoring Program (SDMMP, www.sdmmp.com) is overseeing the development and deployment of databases specific to southern California. These include the South Coast Multi-taxa database (SC-MTX) and the Master Occurrence Matrix (MOM) overlaying the Conserved Lands database. These databases can be accessed from the SDMMP website and are an important starting point. As these databases are developed and populated, they should serve as a primary source for many projects. Species and natural system survey data can be found in several databases, including Biogeographic Information and Observation System, California Diversity Database, San Diego Association of Governments GIS Data Warehouse, and South Coast Multi-Taxa Database. More taxa-specific databases, such as the San Diego County Bird, Plant, and Mammal Atlas's, can also provide valuable information.

The level of detail for species observation varies between databases. In some databases, the query tool allows the user to search for observational data by setting parameters such as species, genus, location, and project. Several of these databases also include a map viewer to search for any supplementary data that may be available at the management site. While some provide exact coordinates, others only provide observational data at a regional scale. Some of the databases allow data to be downloaded in GIS shapefile format, which can be directly imported into most GIS software.

Table 2.1 outlines the databases in San Diego County that can be used to search for site-specific species and system data as well as past project reports and documentation. Some observation databases are broad and offer a wide range of species and reference data, while other are more focused and only provide information regarding a few species. More information and URL links for these databases are included in Appendix 2.1.

Table 2.1. Databases that may provide information for initial planning. The first two rows are databases being developed for monitoring and management. They should be the starting point in the search process.

Data Source Name	Data Available					Search Method		Level of Detail	Download Format	Managing Entity
	Birds	*Plants*	*Mammals*	*Other Data (Fire, Conserved Lands etc)*	*Reports / Documents*	*Database Query*	*Map Viewer*			
South Coast Multi-Taxa Database (SC-MTX)	☑	☑	☑	*Database still being developed and populated with data*		☑	☑	Regional, XY Coordinates	Tabular, GIS Shapefile	SDMMP and USGS
Conserved Lands Database Master Occurrence Matrix (MOM)	☑	☑	☑			☑	☑	XY Coordinates	Tabular, GIS Shapefile	SDMMP and USGS
Biogeographic Information and Observation System	☑	☑	☑			☑	☑	XY Coordinates	Tabular, GIS Shapefile	CDFW
California Natural Diversity Database	☑	☑	☑			☑	☑	Quadrangle (Free) and XY Coord. (Pay)	Tabular	CDFW
CEQAnet Database					☑	☑		N/A	N/A	CA Office of Planning & Research
SanGIS/SANDAG GIS Data Warehouse		☑		☑		**N/A:** Download Maps		Polygons	GIS Shapefiles	SANDAG
San Diego Plant and Animal Atlases (Plant, Bird, Mammal)	☑	☑	☑			☑	☑	XY Coordinates	Tabular	SDNHM
San Diego Management and Monitoring Program				☑	☑			N/A	PDF	SDMMP

Collecting field data to characterize a preserve

Once you have gathered all the information available for your site from existing data sources, it is likely additional data collection will be needed. For most sites, there are likely to be significant information gaps even after tapping into best-available information on species, systems, threats and stressors, as well as monitoring and management history from existing databases. Regional or management unit priorities should be used to prioritize what knowledge gaps are most important (e.g. critical uncertainties). Driven by these priorities, managers can decide what field-based site characterization activities would be most informative and cost-effective. In Figure 2.3, we have compiled a suite of basic monitoring goals and methods that meet the criteria of being relatively inexpensive, rapid techniques that can be used to develop a fairly basic or fundamental level of understanding of species or systems at the new site.

Resource evaluation

Even with a particular method in hand, there is a second critical step to evaluate your approach. Once a method is selected, a preserve team must evaluate whether there are adequate resources (equipment, expertise, personnel) to conduct the work (Figure 2.4). Rapid methods are often inexpensive and don't require specialized expertise, but this is not always the case. If a preserve does not have the resources needed for that method, another method must be identified.

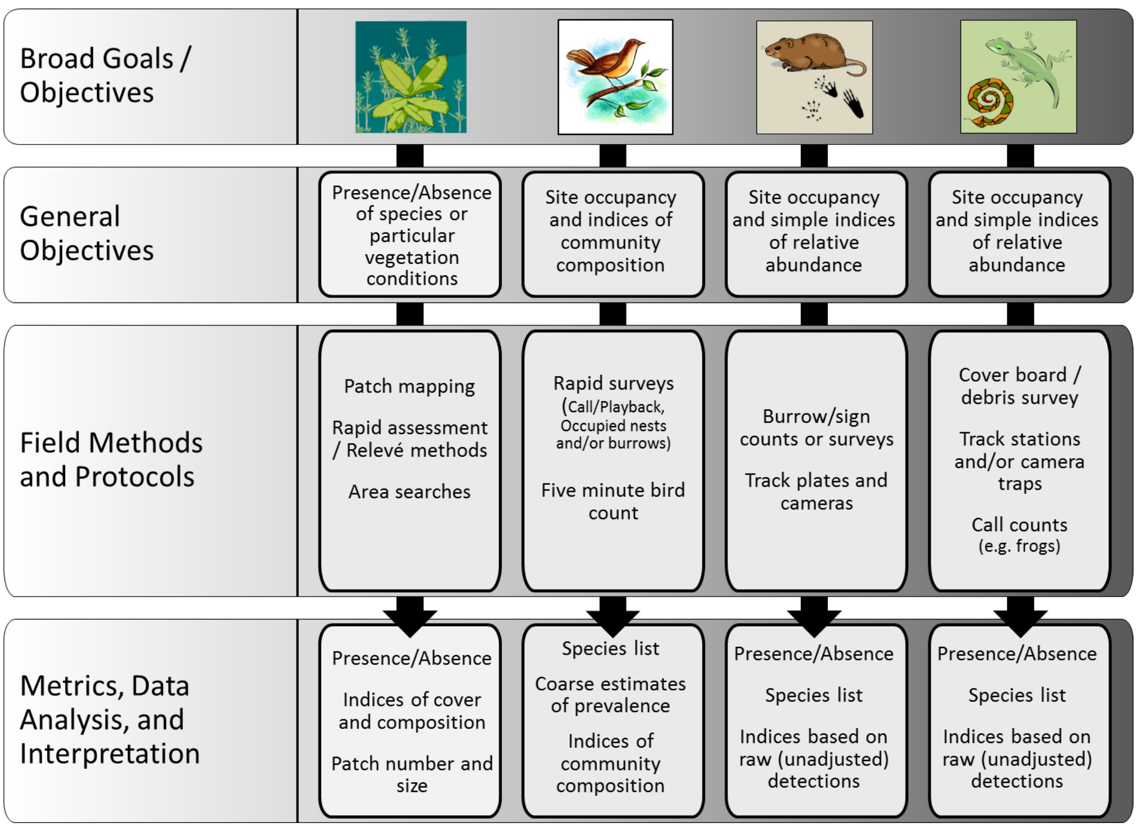


Figure 2.3. Methods for rapid assessment and baseline surveys. Scientists and managers are not limited to these taxonomic groups or the methods listed. These methods are commonly used and well understood, but there are many others that may be appropriate. At this stage in adaptive management, the focus needs to be on rapid acquisition of information that will inform the initial steps in adaptive management.

Methods		Resources Required			
Taxa	**Method**	Equipment Costs	Personnel Costs	Field Skills Needed	Analytic Skills Needed
	Patch Mapping	$$$	$$	♦♦	♦
	Area Searches	$	$	♦♦	♦
	Relevé	$	$$	♦♦♦	♦♦
	Standardized surveys	$	$$	♦	♦
	Occupied nests and burrows	$	$$	♦	♦
	Five minute bird count	$	$$	♦♦♦	♦♦
	Burrow / Sign surveys	$	$	♦♦	♦
	Camera or track stations	$$$	$$	♦	♦
	Cover board / debris survey	$	$	♦♦	♦
	Call counts (e.g. frogs)	$$	$	♦	♦
	Camera or track stations	$$$	$$	♦	♦

Figure 2.4. Resources needed to implement methods for rapid assessment and baseline surveys.

An example

To demonstrate this process, we provide an example for a newly established preserve called Preserve Central. Preserve Central is in a management unit for which *Planticus raricus* is known to occur. This information is described in the Management Strategic Plan and Preserve Central is in a management unit for which this rare plant has been identified as a priority. After mining the databases shown in Table 2.1, the preserve team found data that demonstrated that the plant had been documented on the preserve land in the past 10 years, although high resolution spatial coordinates were not provided in the databases. Rare plant experts, when queried, also confirmed that *Planticus raricus* was likely to be found on the preserve land, particularly in seeps or areas of poor water drainage.

Given this information, the preserve team decides that confirming the presence (or absence) of this rare plant is an important objective for the site characterization process. After reviewing the potential rapid assessment methods available to answer the presence/absence question, the preserve team selects patch mapping as the most appropriate data collection method. Patch mapping is a simple survey technique to assess and map the boundaries of clearly defined patches that has been shown to be useful for tracking the distribution of a rare native plant of conservation concern. The preserve team then carefully considers whether they have sufficient resources to adopt this site characterization method. Based on existing information, the team sees that patch mapping has relatively high equipment needs, moderate personnel and expertise requirements and modest analytical skill required. While the preserve has the personnel, expertise and analytical skills on their team, they do not have the equipment needed to use this method. As a result, the team needs to select an alternate method that still provides an answer to whether *Planticus raricus* is present at the site, but requires fewer equipment resources. Instead, the team decides to select area searches as the best-fit site characterization method for this objective, which like patch mapping, is a simple, semi-quantitative method to find and document the distribution of a species, but has lower resource requirements.

Conclusions

Even at this early stage of adaptive management, the process is intuitively simple but can be challenging to translate into a coherent set of activities on the ground. The goal of this stage of the process is a rapid assessment of the preserve that provides maximum information on species, systems, and threats over a very short time period, i.e., several weeks to a few months. There are many documents that discuss the importance of using site-specific data at the outset of management plan development and these are a tremendous resource that preserve teams need to use. To facilitate the review process, some of the best of the documents that describe the rapid assessment methods are listed (Table 2.2) and additional information on these methods as well as the complete list of citations for the source documents is in Appendix 2.2. These reflect best-practices internationally and are methods that have been developed to avoid common sources of inaccuracy or bias in this approach, e.g., observer effect, variance in detection probability within and among different natural communities, and daily or seasonal biases.

Even with all these guidance documents, it is clear that there is no single “best” method for conducting a broad-based, comprehensive, and rapid assessment. Scientific papers and management reports vary in their use of terms like inventories, rapid assessment, baseline survey etc. There is no clear agreement on what these terms mean.

Rather than focusing on the imaginary “best”, the preserve teams instead should focus their attention on finding a robust and rapid method that a) reflects the management and regulatory priorities (The context), b) takes advantage of existing information from all available sources (existing data) c) meets the objectives of the preserves (Initial Objectives) , d) uses a best-practices or validated method (i.e. Figure 2.3) and e) is feasible given the resources at the preserve (i.e., Figure 2.4).By following these steps, the preserve team will be able to provide the data needed In this very early stage of the adaptive management process by generating data that can broadly describe the condition of the system and the presence of key species.

Table 2.2. Some Robust, rapid assessment or site characterization methods.

Rapid Assessment or Site Characterization	Summary	Methods	Citation
Rapid Ecological Assessment	Targeted rapid survey of vegetation types and species of a region	Coarse filter/ fine filter. Utilizes GIS, remote sensing, aerial photography and ground survey by discipline. Often used at broad scales	Sayre et al 1999, Groves et al. 2002, Noss 1987
Rapid Assessment Program (RAP)	Rapid biological surveys to compile a species list of an area	Scientists from several disciplines work as a team to compile species inventory lists with emphasis on biological field surveys of taxonomic groups using appropriate standard field methods	Groves et al. 2002, Alonso et al 2011,
Reconnaissance (Recce) Descriptions	Mostly for vegetation to describe composition, structure and variation	Height tiers, cover estimates and site characteristics recorded to understand vegetation-environment characteristics	Hurst and Allen 2007, Wiser 2001, Leathwick 1987
California Native Plant Society Rapid Assessment	Standardized protocols for rapid survey and mapping of vegetation consistent with CDFW and National vegetation classification standard (USGS Federal Geographic Data Committee)	Hierarchical approach that can be used at broad and fine scales (continental scales down to habitat patches within preserves)	CDFW vegetation classification and mapping program, CNPS 2007, CNPS 2012
CBCB Series Species Inventory Fundamentals	Detailed series of manuals for biodiversity Inventory methods. Not necessarily rapid. Good description of bias, accuracy and precision, survey methods, usefulness of sampling intensity	"Inventory" by Presence/Not Detected, Absolute and Relative Abundance surveys	BC Ministry of the Environ. Lands and Parks 1998

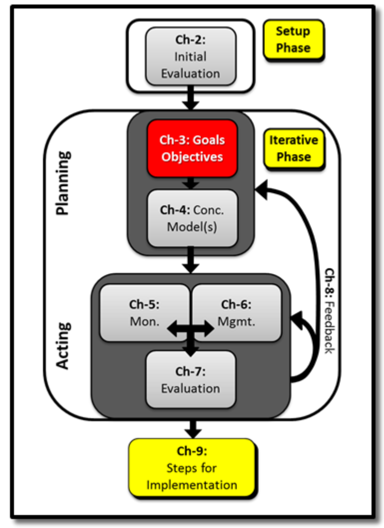
Chapter 2: Summary

- Effective and efficient site characterization is required for newly acquired parcels or preserves that are operating under a new management regime.
- This characterization (target species, natural communities, threats, stressors) should reflect and align with regional management priorities and be coordinated with neighboring preserves.
- The initial site characterization effort should start with mining existing reports, databases, and expert opinion.
- There is no single accepted approach, but there are a number of best-practices and approaches for robust resource characterization that provide meaningful and cost-effective information.
- Rapid assessment methods are not a replacement for more precise monitoring. On the other hand, expensive and complex methods are inappropriate for initial site characterization.

Checklist

√	Task / Activity
☐	Identify and align with MSCP-wide priorities. *Verify that initial work is both necessary (important information needed is absent) and sufficient (the initial characterization will be provide adequate new information)*
☐	Communicate with managers at nearby preserves (MUs). *Verify that planned work is informed (based on any insight/data from nearby preserves) and relevant (provides useful information for new site and beyond)*
☐	Identify what target species, natural communities, threats and stressors will be characterized. This may be guided by management priorities for your Management Unit, regional priorities and permit requirements.
☐	Identify, compile, and synthesize information available from reports, databases, museums, experts and other sources (where possible). *Databases and links from www.sdmmp.com should be the starting point.*
☐	Identify and prioritize information gaps and document the short-term data collection objectives *Verify that planned work addresses priorities, ASMDs, easements etc*
☐	Determine which rapid assessment method is most applicable to your preserve based on initial objectives and site characteristics. Evaluate resources needed to conduct rapid assessment.

Chapter 3:
Starting the iterative phase: Setting goals and objectives



Chapter guide

In this chapter, we move to the first step of the iterative phase, setting goals and objectives. Setting goals and objectives is the planning that guides all of the management and monitoring activities within a preserve. As with the other steps, alignment with regional and MU priorities, which may have existing goals and objectives, is critical. Another key piece in the development of goals and objectives is making sure they meet the S.M.A.R.T. criteria, which we define and discuss in this chapter.

Introduction: Setting goals and objectives

Once resources at a site have been characterized, site managers must lay the foundation for the active, iterative portion of the adaptive management process: setting goals and objectives. Utilizing existing data are key to development of robust goals and objectives – this ensures that managers and field staff are using the best-available information to inform their activities. Once goals and objectives are established, these specific activities should be detailed and included in management documents. Developing goals and objectives is challenging and will require the expertise of both managers and field staff to develop goals, objectives and tasks that will form the backbone of both long-term management activities as well as short-term, or annual work plan (or ASMDs).

Goals and objectives serve as the foundations of effective monitoring and management. ***Goals* are broad, concise, visionary statements that set overall direction for monitoring and management**. In contrast, ***objectives* are concrete and measurable statements that detail how a specific goal can be attained**. An excellent definition of an objective is "concise statement of what we want to achieve, how much we want to achieve, when and where we want to achieve it, and who is responsible for the work"[1]. Often, multiple objectives are needed to meet a single goal, and prioritization of objectives must occur to guide active management. Once goals and objectives are set, managers can then designate specific monitoring and management tasks that are needed to meet each objective.

Recent reviews of established goals and objectives from various programs across the U.S. provide insight into the fundamental challenges of developing robust goals and objectives[1,2,3]. The major challenges relate to the complexity of capturing best-available science (which may be influenced by limited resources, time, and/or expertise), a desire to maintain flexibility on the part of managers, and the difficulty in concretely quantifying change either in species or natural communities, or both. These challenges hinder the development of robust goals and well-articulated objectives and continue to limit effective monitoring and management in many cases[1].

Here we provide some examples of robust goals and objectives for species and systems within the MSCP along with justification and discussion of what elements within these examples are particularly challenging for, or supportive of, management. These examples should not be used to replace regional or management unit goals set out by the Management Strategic Plan or other related documents. While elements of the examples will be relevant to particular preserves, the examples are used to illustrate the process of developing and refining goals and objectives.

Developing goals

It is important to keep in mind that there are no "right" or "best" management goals. In developing goals and objectives for an individual preserve, the first step is to align with MSCP-wide management goals outlined in regional or management unit documents. These landscape goals will provide a common direction for all MSCP preserves and ensure that the MSCP network of preserves can work effectively to meet the conservation goals and targets for the MSCP as a whole. Likewise, having shared and common goals with neighboring preserves in your management unit can support both preserve-level and MSCP-level resource management.

Once regional or management unit goals have been adopted, a manager may need to develop locally relevant goals that align with but are not specified by regional management documents. The examples provided in this Chapter provide the rationale and concrete examples of how these can be developed.

What makes an objective good?

While goals are broad visionary statement or targets, objectives capture the *who, when, where, why* and *what* actions that will actually be taken at the preserve. S.M.A.R.T. is an acronym that has been used to guide the development of robust objectives: objectives should be **S**pecific, **M**easurable, **A**chievable, **R**esults-oriented, and **T**ime-fixed. These criteria are often difficult to achieve and evaluate[1,2], but the inherently iterative nature of the adaptive management process facilitates revisiting objectives at regular intervals to make them "smarter" as time goes on.

Table 3.1. Objectives should be "S.M.A.R.T." [4]

4

- **S**pecific – objectives should be detailed, clear, concise, and unambiguous
- **M**easurable – requires criteria for measuring progress towards attainment of objectives
- **A**chievable – objectives should not be unrealistic to achieve nor below acceptable standards
- **R**esults-oriented – objectives should specify an end result
- **T**ime-fixed – objectives should specify an end-point for being met
- 4

Once an objective is evaluated and accepted, the next step is to designate specific tasks that will be completed to meet that objective. Tasks should also designate the *who, when, where*, *what* as another way of evaluating feasibility of the objective relative to expertise and resource of field staff.

Here are some examples of goals and S.M.A.R.T. objectives for species and systems within the MSCP. These were developed during a 2011 workshop for MSCP stakeholders that focused specifically on developing robust goals and objectives[5] (IEMM Goals and Objectives workshop proceedings). These examples and the associated critiques and comments illustrate the power of SMART objectives but also capture the challenges in developing them.

Example 1: Ecosystem processes and natural communities

There were two broad goals defined for maintaining ecosystem processes and natural communities within the MSCP (Table 3.2). Four associated objectives were created and ranked according to the S.M.A.R.T. criteria. In general, objectives met these criteria well, but "smartness" depends largely on specific conditions (e.g., size, habitat conditions, funding limitations, etc.) of the preserve where objectives are being implemented. No implementation tasks were developed for these objectives.

One of the stated goals was to ensure persistence of native-dominated vegetation mosaics. As is often the case, several objectives were linked to achieving this goal. The first objective was to develop baseline community-level maps as part of any resource management plan. This objective is an example of how regional activities can support local activities and vice versa. In this case, a vegetation classification was developed for western San Diego and used to create a community-level map (information and GIS layer available from the regional data warehouse at SANDAG). The map will provide an important starting point for preserve-level mapping as defined in this objective. The broad-scale map may not be at the level of detail needed by some individual preserves or questions. Even so, individual preserves can re-map their lands using the same classification system. Ultimately, the larger map could be updated with this new, more detailed information.

Table 3.2. Example goals and objectives for ecosystems and natural communities.

Ecosystems and Natural Communities			
Goal	Maintain long-term net sub-regional habitat value		
Goal	Ensure persistence of native-dominated vegetation mosaic		
Objective	**Smart Criteria (with notes)**		
Develop baseline community-level (California Standardized Vegetation Classification) maps as part of RMP preparation.	**S**	●	Specifies system that will be used
	M	●	Individual preserves are the measurable unit
	A	●	Classification already developed; just needs to be applied
	R	●	Addresses goal of generating baseline preserve data
	T	◐	Assumed to be associated with RMP timeline
Annually map and maintain list of invasive plants of management concern that threaten persistence of native dominated vegetation mosaic.	**S**	◐	Methods and species could be more specific
	M	●	Map implies range is measurable
	A	○	Depends on degree of invasion and funding
	R	○	Depends on degree of invasion and funding
	T	●	Time frequency specified
Annually prevent expansion of reduce cover and distribution (# of occurrences) of invasive plants of management concern.	**S**	●	Outcomes specified (expansion, cover, distribution)
	M	●	Expansion, cover, and distribution of invasive are measurable
	A	○	Depends on degree of invasion and funding
	R	○	Depends on degree of invasion and funding
	T	●	Time frequency specified
Using available information (edge, fire history, roads, geotech, rainfall, land managers), identify and map areas of high risk of degradation and/or conversion due to disturbance every 5 years or following a disturbance event.	**S**	●	Specifies information to be used and frequency
	M	●	Yes, depending on quality of available information
	A	●	Yes, using existing information to identify high risk areas
	R	●	Results in map of high risk areas in need of management resources
	T	●	Time frequency specified

● Clearly Meets the Criteria

◐ May Meet the Criteria

○ Needs Further Refinement to Meet the Criteria

A second objective associated with this goal was to *"annually prevent expansion and reduce cover and distribution (# of occurrences) of invasive plants of management concern."* (Table 3.2, 3rd objective). This objective will be difficult to implement for several reasons. The objective is likely too broad. It does not limit the invasive plants to a community type (e.g. riparian trees or vernal pool annuals). In addition, it conflates the cover at a site with the distribution across sites. These may have different impacts on the ecosystems and require different management strategies and should be elaborated more carefully. Finally, it is not at all certain that this objective is achievable. The achievability depends on the species and community of interest, the spatial scale of control, and the resources available.

An additional objective was focused on collating available information to create a map of areas at high risk for degradation or conversion. This is more specific and achievable then the previous objective. In addition, the objective sets a concrete deadline for updating the information (every 5 years or after a major disturbance event). Well-defined objectives may be ranked highly because they will be easier to implement. In addition, their success will be easier to measure. Prioritization based on SMARTness is sensible, but it isn't the only aspect that could be used to prioritize an objective. The key is that prioritization is needed because there are many potential actions and limited resources.

Example 2: Stewardship, outreach, and education

There were two broad goals developed to enhance stewardship, outreach, and education at MSCP preserves (Table 3.3). The goals complement each other and represent very different aspects of management. The first goal is focused on managing sustainable access to a preserve that is compatible with preservation of conservation value of the natural environment. The second goal envisions a public education and outreach program. Clearly the objectives needed to meet these goals will differ.

The final objective from this group is an illustration of the level of detail that may be needed to achieve S.M.A.R.T. The objective is written as *"Establish and maintain, through training by preserve management, a volunteer program that provides support staff which includes docents giving at least 1 tour per month, labor performing 1 work event per month, and 4 monitoring patrols within 1 to 5 years."* This detail promotes implementation and evaluation by providing specific benchmarks of success. These details are a key component of S.M.A.R.T. objectives.

Example 3: Management of a rare plant, San Diego Thorn-mint

A single broad goal was developed to protect and enhance populations of San Diego thorn-mint within the MSCP (Table 3.4). The first objective was *"Determine the San Diego thorn-mint spatial distribution by monitoring annually for 5 years (within a preserve)".* There are several important ideas embedded in this objective. For example, the objective focuses on the spatial distribution of the species and not the number or condition/size/status of individuals. This is an important factor since it influences the achievability and cost of monitoring as well as the kind of information generated. The objective also specifies that this monitoring must be done annually for five years. This idea is important for an annual forb that may vary year to year with rainfall, temperature and other factors.

Table 3.3. Example goals and objectives for stewardship, outreach, and education.

Stewardship, Outreach, and Education			
Goal	Control access by providing sustainable and appropriate access to the preserve that maintains and/or enhances the conservation values of the natural environment while providing compatible uses.		
Goal	Develop a public education and outreach program about the natural and cultural resources and compatible uses within and adjacent to the preserve.		
Objective	**Smart Criteria (with notes)**		
Close trail(s) that access naturally and culturally sensitive areas, using natural and artificial barriers, within 1 to 5 years (in relation to the need/ size of the preserve).	**S**	●	Specifies what will be done and how it will be done
	M	●	Patrols could monitor the barriers using staff, cameras, and/or pressure sensors.
	A	◑	Dependent on funding
	R	●	Addresses goal of controlling access
	T	●	Time period specified
Procure, install, and maintain informational kiosks at all approved access points within 1 to 5 years.	**S**	●	Specifies what will be done
	M	●	Staff can confirm kiosk installment and monitor their maintenance
	A	●	Eagle Scouts could be utilized to implement the project
	R	●	Addresses goal of developing a public education and outreach program
	T	●	Time period specified
Establish and maintain, through training by preserve management, a volunteer program that provides support staff which includes docents giving at least 1 tour per month, labor performing 1 work event per month, and 4 monitoring patrols within 1 to 5 years.	**S**	●	Specifies what will be done
	M	●	Number of volunteer hours can be measured
	A	●	Volunteer base sufficient to fulfill these specifications
	R	●	Addresses goal of developing a public education and outreach program ; Increases protection of resources and enhance both the resources and educational experience
	T	●	Time period specified
Implementation Task	Docents to give at least 1 tour per month, volunteer staff will work 1 event per month and conduct at least 4 monitoring patrols each month.		

● Clearly Meets the Criteria

◑ May Meet the Criteria

○ Needs Further Refinement to Meet the Criteria

Table 3.4. Example goal and objectives for San Diego thornmint.

San Diego thornmint			
Goal	Ensure the survival of San Diego thornmint within "X" preserve for 50 years		
Objective	**Smart Criteria (with notes)**		
Determine the San Diego thornmint spatial distribution by monitoring annually for five years.	**S**	●	Specific techniques outlined in existing documents
	M	●	Measurement methods include % of potential habitat monitored/surveyed
	A	◐	The spatial distribution can be mapped in a preserve, although there is always the potential for new populations to occur
	R	●	Addresses goal of ensuring survival of San Diego thornmint
	T	●	Frequency and time period specified
Rank and identify threats to the specific San Diego thornmint occurrence at least annually or more frequently as appropriate for specific occurrence and threat	**S**	●	Specific techniques outlined in existing documents
	M	●	The proportion of populations assessed for threats is measurable (some issues with defining populations)
	A	●	Possible to visit all occurrences (within a reserve) at least annually
	R	●	Addresses goal of ensuring survival of San Diego thornmint (facilitates management)
	T	○	Not clearly time fixed. Ranking threats may need to be done in perpetuity. Perhaps this objective is better as an implementation task under a broader objective.

● Clearly Meets the Criteria

◐ May Meet the Criteria

○ Needs Further Refinement to Meet the Criteria

A second objective was to identify and rank threats to this plant on an annual basis. This objective is an excellent complement to the first because it looks at threats. Identifying current or potential future threats is forward looking and could be a leading indicator of change. On the other hand, changes to the spatial distribution of the plant may only be obvious after populations have started to decline (i. e. a lagging indicator). The difficulty with this objective is that the idea of “threats” encompasses a large range of potential concerns. As a result, it may be hard to define monitoring and/or management that characterizes all threats. Moreover, the need to update this frequently (at least annually) is expensive and has no stopping rule. As with previous examples, the discussion of these objectives illustrates the one-to-many relationship between broad goals and S.M.A.R.T. objectives and the need for prioritization.

Goals and objectives are the foundation

We have defined goals and objectives in this chapter and illustrate their use in several different contexts. It is important to understand that the goals and objectives listed here are not prescriptive and should not be taken as guidance for any particular preserve or natural system. Likewise, not all objectives can meet all of the S.M.A.R.T. criteria. An evaluation the S.M.A.R.T-ness of a proposed objective, as demonstrated in these examples, provides a robust method to assess individual management and monitoring actions.

Prioritization

Once goals and objectives have been developed, and evaluated for their S.M.A.R.T-ness, the preserve team has another challenging task – to prioritize the objectives. Most preserves will try to reach multiple goals and every goal may be linked to multiple objectives. Thus, prioritization among goals and objectives is vital to timely and cost-effective adaptive management.

One way to prioritize among the multiple goals and multiple objectives would be to use S.M.A.R.T evaluation as a ranking instrument, i.e. S.M.A.R.T-er objectives are ranked higher than others. Another way would be to prioritize objectives based on funding or other resource constraints. Irrespective of how a preserve team ranks the objectives, it’s essential that the prioritization occurs.

Chapter 3: Summary

- Goals and objectives serve as the foundation for adaptive management
- Preserve-level goals and objectives must align with regional and management unit priorities
- The SMART criteria provide direct guidance on whether an objective can support an efficient adaptive management process.
- Even with time, expertise and experience, creating objectives that meet all of the SMART criteria is challenging. In some cases, perfect can be the enemy of SMART-enough.
- Going through the process of evaluating the SMART-ness of particular objectives and making changes, whenever possible, to address SMART criteria is an important step.
- Prioritizing is a must for all objectives. SMART objectives will be easier to prioritize because the information needed for prioritization will be more evident.

Checklist

√	Task / Activity
☐	Identify regional, MSCP-wide and management unit goals and objectives relevant to your preserve
☐	Identify preserve-specific goals and objectives from other management directives, guidance documents, and requirements (if any)
☐	Establish and prioritize broad goals
☐	Establish and prioritize objectives and tasks that meet SMART criteria
☐	Use developed goals, objectives and tasks to develop an annual work plan (or ASMDs). Ensure the specific activities are detailed in management documents and developed and reviewed with direct input from field staff

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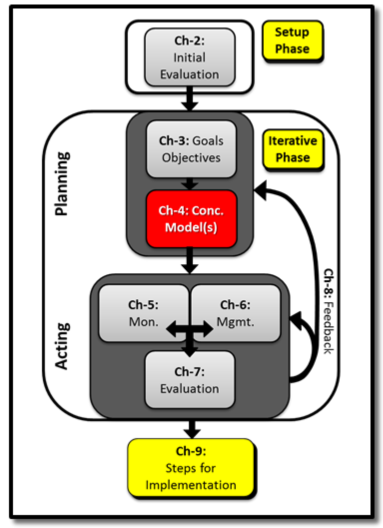
Chapter 4:
Using conceptual models to guide and strengthen management and monitoring



Chapter guide:

Conceptual models play an important role in the adaptive management process because they require a manager to formalize and document their understanding and assumptions of how a species or system of interest works and how potential management actions affect that species or system. This documentation process, whether it's done on a scrap piece of paper or through a more formal model development process, is central to ensuring that an evolution of knowledge is occurring, i.e. this documentation allows a manager to test his or her assumptions and evaluate management actions accordingly. In this chapter we discuss the utility of conceptual models, describe their basic features and then provide two examples for how more formal conceptual models can be developed. It is important to note that not all models require this level of formal development. Whether done informally or formally, this step is critical to ensure the adaptive management process of knowledge acquisition can progress.

Introduction: Understanding the utility of conceptual models

The central premise of adaptive management is that management will improve over time as more accurate information is collected and evaluated[1,2,3]. For that evolution to occur, we need a way of organizing our current understanding of how a species or natural community or stressor operates on a preserve, as this understanding is what drives preserve-level management activities. This understanding can be based on opinion, expertise, or published research at a site or at other similar sites. The key is to follow a process that helps capture our understanding of a system, uncover any hidden assumptions, and to identify critical gaps in our monitoring or management[4,5].

Conceptual models are a template or process that documents our understanding of how a species or system of interest works. As such, they are an important tool for managers to use as a means of strengthening and improving monitoring and management activities at the preserve level. This chapter is designed to introduce managers to conceptual models, focusing specifically on what information these models capture, how to read the models, and how conceptual models can be used to guide management and monitoring.

How to utilize conceptual models for individual preserves

Conceptual models can come in many forms, ranging from a simple text narrative or flow chart, to a complex diagram with numerous inter-connected elements. Irrespective of the form, these types of models serve to formalize our current understanding of system processes and dynamics, identify critical linkages and relationships within the system, and identify the bounds of the system of interest. There are no guidelines on the level of complexity a model should have, e.g. on whether it should be formal or informal. Likewise, there are no inherently right or wrong components to include in a conceptual model. The decision to adopt a particular structure or to include or exclude elements in any given model will depend on the users' preferences, how much is known about the system and the stated management goal for the model.

For many conceptual models for conservation, key response variables as well as natural and anthropogenic drivers should be included. Effective models carefully balance complexity and clarity in based on our understanding of the system and the management objectives that have been set[5] Most importantly, the decision-making and thought-processes behind model development should be well documented. Outsiders who had no part in model development should be able to use this documentation to understand why certain elements were or were not included and comprehend relationships depicted in the model. Finally, because no conceptual model is inherently right or wrong, the model building process must be iterative. Models must continually be updated based on new information and ideas.

A number of conceptual models already exist for many species and systems of interest within the San Diego MSCP. Managers should check with neighboring preserves, the San Diego Monitoring and Management Program, land manager groups, or other peers to determine availability of existing models for different species and systems. A number of stakeholders who reviewed this document expressed interest in having existing models maintained in an accessible library to facilitate their use. If these models exist, they should be used or adapted to a given individual preserve. If a formalized conceptual model does not yet exist, managers should still document their understanding of the species or system in collaboration with neighboring preserves and other managers, biologists, or peers within the MSCP. This can be as simple as writing a paragraph that includes key elements and drivers and how they operate at a given preserve, or could be a more formal process of meeting with additional stakeholders, neighboring managers, or biologists to generate a graphical depiction and narrative of the species or system. Whether an informal paragraph or more formal, collaborative process, current understanding should be documented to provide a baseline from which to learn and improve. Irrespective of the format, the model should explicitly identify management and monitoring targets within the system. These should link directly to the goals and objectives developed in the proceeding chapter.

In the context of this support document, we present conceptual models as a step that follows the designation of SMART objectives. Several reviewers shared experiences where the development of a conceptual model can be instrumental in the development of SMART objectives, particularly when the focus of the efforts are data-deficient species or natural systems. In these cases, it may be useful to develop a conceptual model first to help capture existing knowledge of the species or system, capture the drivers governing them, and identify critical uncertainties. Whether the SMART objectives precede the model or vice versa, what's important is that the objectives and the model are aligned in terms of information, key features, and their output or conclusions.

Here we provide one example of an informal model and two examples of formal conceptual models that were developed as part of a collaborative workshop held in the San Diego MSCP[6]. The informal model demonstrates how much can be captured with a simple sketch on the back on an envelope or napkin. Although a cartoon, it still serves to focus monitoring and management. In the first formal example, we present two models developed for a rare butterfly species for which little information exists, the Hermes Copper butterfly. The second formal model represents a management issue, recreational trails and access control, for which extensive information exists yet for which management remains extremely difficult.

For readers interested in learning more about the importance of conceptual models, their utility, development, structure, components (or anatomy as we refer to it), we direct you to the proceedings from the 2012 Conceptual Model Workshop which provides supporting information[6] (IEMM Conceptual model workshop proceedings).

Example 1: Simple model of plant dynamics

In grassland and CSS communities, native herbs and shrubs are strongly influenced by non-native grasses and forbs. The relationship is complex as it is influenced by weather, natural disturbances and anthropogenic activities. This simple model (Figure 4.1) places the two-way interaction between the native and non-native plants in the center of the model. External drivers are arrayed around the outside and include rainfall, fire, and human disturbance. The model does not explicitly describe the nature of these relationships, but does document what the manager knows about the systems, and identify what the manager believes to be the most important aspects for monitoring and management.

Example 2: Hermes Copper butterfly

Due to the paucity information available, the conceptual model for this species focuses primarily on identifying critical uncertainties and prioritizing future research needs. Initially, management and monitoring goals were established. In addition, a list of anthropogenic drivers, natural drivers, and response variables was created (Table 4.1).

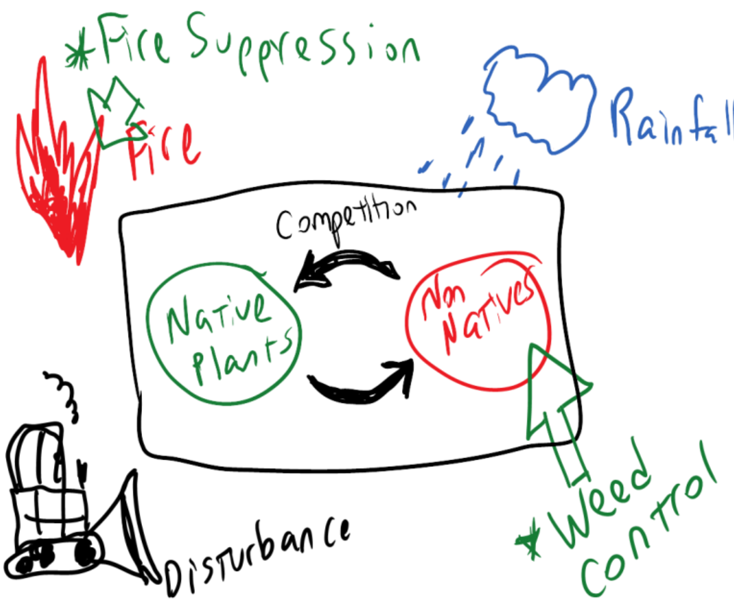


Figure 4.1. Simple conceptual model for plant communities. Potential management actions are marked with an asterisk.

Two distinct conceptual models were generated for Hermes Copper (Figure 4.2). The first was a simple model which provided a concise overview of the species' biology, including the importance of dispersal and host plants, and major threats such as fire and habitat fragmentation (Figure 4.2.A). The second was more complex and included a more comprehensive depiction of population processes, drivers, and threats and their complex relationships (Figure 4.2.B). Additional information related to these models, including management priorities, monitoring targets, and critical uncertainties, can be found in Appendix 4.1.

Table 4.1: Hermes copper. (Top) Initial and revised monitoring and management goals. (Bottom) Comprehensive list of anthropogenic drivers, natural drivers, and processes / response variables.

Management Goal:
(Draft) *Preserve Hermes copper populations at currently occupied sites and research critical uncertainties key to management.*
(Revised) *Ensure Hermes copper persistence throughout the historic range.*

Monitoring Goal:
(Draft) *Monitor long-term site occupancy, discover new populations in San Diego County, and to resolve questions relevant to management options.*
(Revised) *N/A - no monitoring goal adopted by group because of too many critical uncertainties at this time.*

Anthropogenic Drivers		**Response Variables**		**Natural Drivers**	
Human Disturbances	*Fire, Roadkill, Recreation*	Life Stages	*Eggs, Larvae, Pupae, Adults*	Weather / Climate	*Temperature Spring Precip.*
Habitat Change	*Invasive Plants Argentine Ants*	Adult Behavior	*Mating, Dispersal, Oviposition*	Habitat Quality	*Redberry (larvae) Buckwheat (adults)*
Development	*Habitat Fragmentation*	Population Processes	*Pop. Structure Gene Flow*	Biotic Interactions	*Predators Parasitoids*

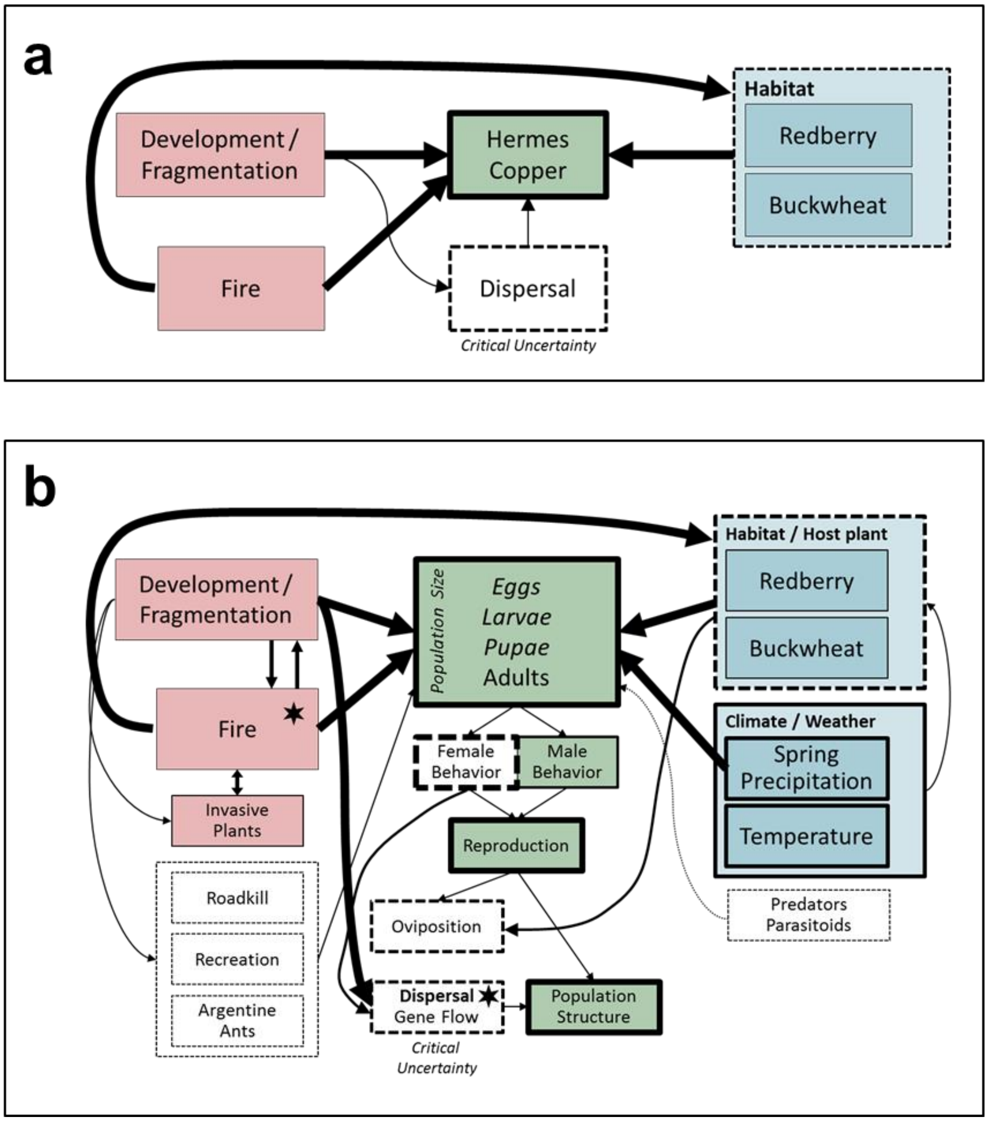


Figure 4.2. Conceptual model for Hermes copper Butterfly. (A) Simple (strategic) model that identifies the key drivers and (B) Comprehensive (tactical) model that identifies the complex relationship among drivers. For both models, anthropogenic drivers (red) are on the left, natural drivers (blue) are on the right, and population processes (green) are in the center. Processes that are poorly understood are left uncolored (white). In addition, arrows represent directional relationships and width reflects both the strength and understanding of relationships. Thick lines are major relationships, thin lines are minor relationships, and dotted lines are uncertain.

Example 3: Recreational trails and access control

The conceptual model for recreational trails and access was developed using the same process of defining the goal and listing key drivers followed by description of the relationships. The model contains five primary sub-models or "modules." Specific relationships between all of the individual model elements were not generated, but focus is instead on the major modules and how they were related (Figure 4.3.).

Capturing the nature of the relationships between individual model elements is challenging because frequency of occurrence and magnitude of impact among drivers is highly variable. For example, fishing may be common at a given preserve with little impact on resources, while equestrian use may be infrequent but have a relatively high impact on response variables. The use module (authorized vs. unauthorized) serves as a filter between the anthropogenic drivers and the response variables in that the degree of impact caused by any of the anthropogenic drivers depends on, at least in part, whether use is authorized or unauthorized. From a management perspective, the planning module is used to determine both the type and volume of authorized uses which allows enforcement to be focused on unauthorized uses. The relationship between authorized and unauthorized use is an important part of the model as authorized users may participate in unauthorized activities and vice versa depending on user satisfaction levels and understanding of their impacts on resources. Additional information related to these models, including management priorities, monitoring targets, and critical uncertainties, can be found in Appendix 4.2.

Table 4.2. Recreation trails and access control. (Top) Initial and revised monitoring and management goals. (Bottom) Comprehensive list of drivers and response variables.

<u>Management Goal</u>:
(Draft) Balance the protection of biological and cultural resources with recreational use.
(Revised) *Maintain and enhance biological resources and protect cultural resources while allowing for sustainable recreation in appropriate places.*

<u>Monitoring Goal</u>:
(Draft) *Monitor the impacts of recreational use.*
(Revised) *Measure recreational use and how it is affecting biological and cultural resources.*

Anthropogenic Drivers		Response Variables		Natural Drivers	
Authorized / Unauthorized Use	*Equestrian, Biking Climbing, Hiking, Dogs, Hunting, Fishing*	Altered Resources	*Disturbance to: Wildlife, soil, and Vegetation Non-Native Species Water Quality*	Structure	*Slope and Aspect Topography Soil Characteristics Vegetation Comm.*
Unauthorized Use	*Vehicles*	Cultural Resources	*Disturbance to Cultural Resources*	Dynamics	*Weather/Climate, Hydrology, Fire*

Do all conceptual models need to be formal, developed models?

In short, the answer to this important question is absolutely not. These formal models are helpful in their ability to identify critical uncertainties, prioritize research needs, and highlight management and monitoring targets. However, any documentation that captures how a species or system is conceptualized by a manager (and thus under what assumptions it is being managed) can be used to link monitoring data (data on what happens in the system) to the effectiveness of management action. These case studies introduce managers to two fully developed models and provide guidance on how these, and other, existing models can be used and modified to suit site-specific needs.

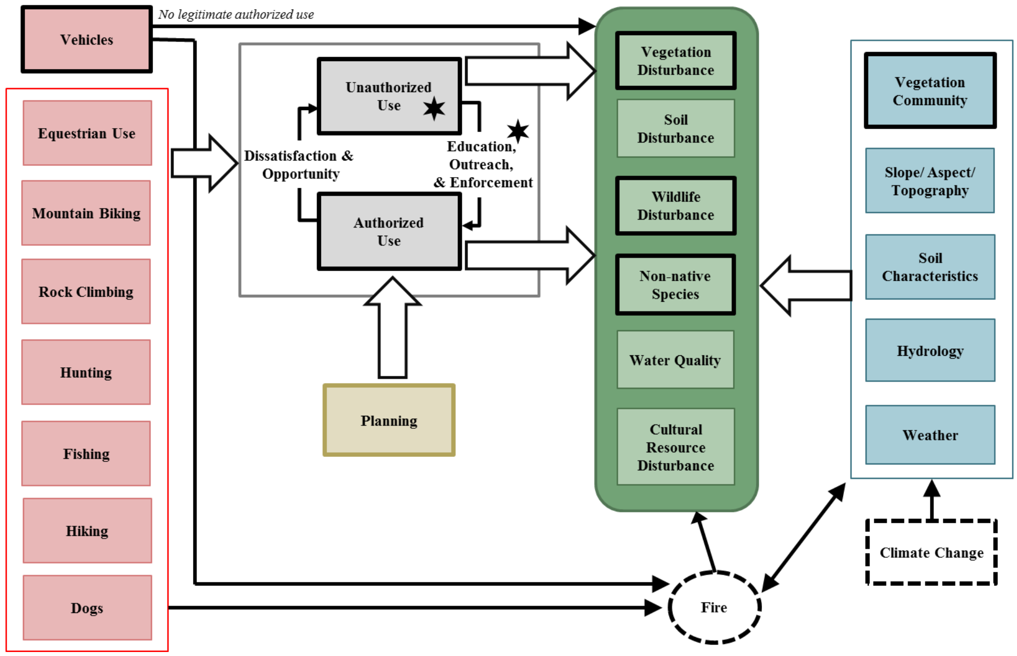


Figure 4.3. Conceptual model for recreation trails and access control. This model has five major modules: anthropogenic drivers (red), authorized/unauthorized use (gray), planning (brown), response variables (green), and natural drivers (blue). Two other elements also appear in the model: fire and climate. Arrows indicate directional relationships between model elements and modules; the size of the arrow signifies the magnitude of the relationship. Red outlines signify monitoring targets identified. In addition, arrows represent directional relationships and width reflects both the strength and understanding of relationships. Thick lines are major relationships, thin lines are minor relationships, and dotted lines are uncertain.

Chapter 4: Summary

- Conceptual models form an integral component of management and monitoring as they require some form of documentation of the drivers and other factors that influence the management a species or a system of interest
- Many conceptual models have been developed for a number of species or systems. Managers should identify existing models on their species or system of interest
- Whether an informal narrative or a formal model structure, conceptual models should capture key elements (natural, anthropogenic drivers and the pathways that connect them) that influence management decisions
- Conceptual models need to be periodically updated to include best available information or direct evidence from the data collected at the preserve

Checklist:

√	Task / Activity
☐	Identify whether models have already been developed for your species or system of interest. Use existing models as a starting point to be modified with site-specific characteristics
☐	Decide whether the conceptual model will be simple narratives, flow chart, or a more formal graphical model
☐	Ensure the conceptual model distinguishes natural drivers, anthropogenic drivers as well as management and monitoring targets
☐	Ensure the conceptual model documents data, information, and hypotheses used to create key variables and relationships
☐	Revisit the model once monitoring data have been collected to review the performance of the model and the management actions in light of data collected. Revise if necessary

Literature for Chapter 4:

1. Williams, B. K., 2011. Adaptive management of natural resources—framework and issues. Journal of Environmental Management 92: 1346-1353.

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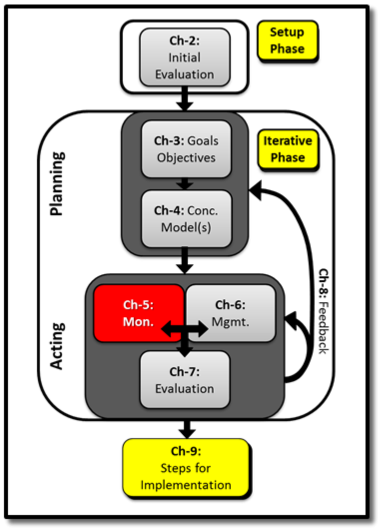
3. Bormann, B. T., Haynes, R. W., Martin, J. R. 2007. Adaptive Management of Forest Ecosystems: Did Some Rubber Hit the Road? Bioscience 57: 186-191.

4. Margoluis, R., Salafsky, N., Brown, M. 2009. Using conceptual models as a planning and evaluation tool in conservation. Evaluation and Program Planning 32: 138-147.

5. Rumpff, L., Duncan, D. H., Vesk, P. A., Keith, D. A., Wintle, B. A. 2011. State-and-transition modelling for Adaptive Management of native woodlands. Biological Conservation 144: 1224-1236.

6. Lewison, R. L., Deutschman, D. H., Marnocha, E., Tredick, C., McIntyre, P. 2012. Developing Conceptual Models, Translating Knowledge into Action: Building and implementing an integrated framework for monitoring and management in San Diego County. Workshop proceedings for San Diego Association of Governments, MOU # 5001562 http://iemm.sdsu.edu/publications/ConceptualModelWorkshopreport.pdf

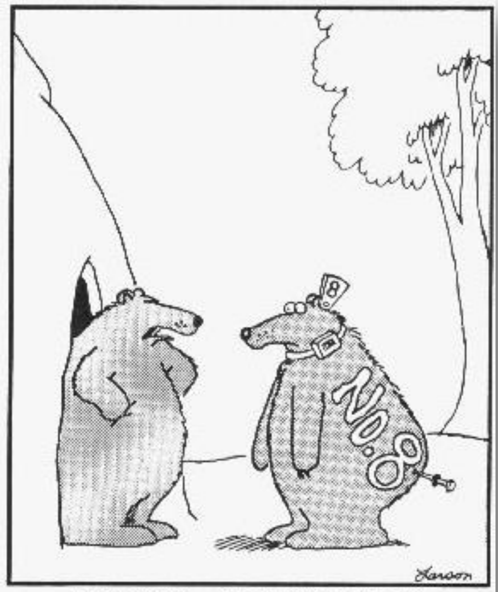


Chapter 5:
Best practices in monitoring: linking objectives and models to action

Chapter guide:

Monitoring programs must address the key goals and objectives within the constraints of budget, time, and expertise. In this chapter, we summarize the general components of effective monitoring programs and discuss common pitfalls. We provide specific guidance on best-practices for the most common monitoring methods for vegetation communities, birds, small mammals, and herpetofauna. This information builds on the site characterization methods presented in Chapter 2.

For each group, we describe the monitoring approaches using a decision tree. Your path through the decision tree will be driven by your monitoring objectives (i.e. it is question-driven). In addition, we provide a table that summarizes the utility of each monitoring method as well as describes the cost in terms of labor, specialized equipment, and specialized expertise needed to successfully carryout the method.



"Late again! ... This better be good!"

We would be remiss if we didn't add several important disclaimers. There is no "one size fits all" approach to monitoring. The methods described in this chapter will be adequate for many users and objectives. This chapter is not (and cannot) be a comprehensive list of all possible methods nor is it an in-depth evaluation of common methods. Specialized expertise is frequently needed to design and interpret data from complex monitoring programs. In addition, complex monitoring programs are often time consuming and expensive. Although this chapter provides a general framework for making rational decisions to align monitoring goals with monitoring methods, users should be cautious about over-reliance on this chapter as a sole reference.

Introduction

Monitoring is an essential part of adaptive management. Information gained through monitoring should improve our understanding of the system and drive management decisions. Monitoring programs are often criticized as inefficient, useless, or even misleading because they fail to provide scientifically sound information that improves conservation outcomes[1,2]. This criticism stems, in part, from the misalignment between the goals and objectives, the monitoring methods and monitoring data generated. The aim of this chapter is to help preserve teams align their monitoring efforts with goals and objectives. It is important to realize that **there is not a "one size fits all" prescription for good monitoring**[3,4]. The answer always depends on the objectives of a program, the nature of the species/ecosystem, and the social, scientific, and economic constraints on the program.

Before getting into methods, we'll explore the many different ways and contexts in which the term monitoring can used [5,6,7]. As illustrated in Figure 5.1, this wide range of type of monitoring can lead to confusion, thus it is important to understand the context and definitions of these terms. To reduce this confusion, we define and organize the terms to help a preserve focus on the type of monitoring and the methods of monitoring best suited for the site.

compliance/implementation monitoring, mandated monitoring, inventory, baseline, surveillance, passive, general monitoring, outcome monitoring, result monitoring, question-driven monitoring, active monitoring, effectiveness monitoring, status and trend, targeted monitoring, validation monitoring, species monitoring, community monitoring, ecological effects monitoring, and habitat and ecosystem monitoring

Figure 5.1: Monitoring means many different things to different scientists, regulators, and land managers. It is not necessary to create a definitive dictionary for these terms. Instead, it is more important that you simple explain how you use terms like inventory, baseline, status and trend etc.

What is monitoring?

Monitoring is not one single thing. It may be a single event or involve a sophisticated sampling design and protocol that is designed to evolve through time. It may require minimal expertise or require specialized expertise (biological or statistical). There is no single right or wrong way to monitor. The focus of this chapter is to align the goals of the monitoring, i.e., the questions the monitoring is purposed to answer, with the methods employed.

The simplest forms of monitoring are often called **implementation** or **compliance** monitoring (Figure 5.2). These often refer to monitoring routine activities and management including tracking land acquisition, monitoring fencing and signage, access control and tracking routine management. Compliance monitoring is simple but the information is often lost or underutilized in future assessments and management.

Most monitoring efforts will need to go far beyond compliance monitoring. Initial monitoring efforts are often very broad in order to characterize the system (See Chapter 2, "Initial site characterization, getting started at a new site"). This process involves compiling existing information and, in many cases, rapid field assessments**.** Once completed, more formal surveys are often designed and implemented. **Baseline** and **inventory** monitoring usually refer to these efforts to quantify the presence and/or distribution of a system or species at a single point in time, usually early in the adaptive management process (Figure 5.2). This type of monitoring is usually based on more rigorous sampling designs and field protocols but is usually performed without trying to characterize change through time. In other words the monitoring is "one and done" where monitoring is complete after a single rigorous sample. The focus of baseline or inventory monitoring is on the current **status** of the system or species.

When monitoring moves beyond the “one and done”, it moves into a type of monitoring typically called general **surveillance** or **omnibus** monitoring. This type of monitoring is designed to track changes in populations and resources and focuses on detecting change through time **(trend)** in a broad suite of species or **indicators**. This is the type of monitoring that requires particular attention to program design. Often this type of monitoring is criticized because of a lack of focus coupled with inadequate design[8,9]. Within this type of repeated monitoring effort, you may also encounter the terms **targeted (active) monitoring** which often describes a rigorous a monitoring design based on very clear and precise questions, **results** monitoring which often refers to the direct result of management (e.g. Did predator control activities reduce the number of predators?), and **outcome** monitoring which focuses on the more complex response of the system (e.g. Did predator reduction lead to increased fecundity of the focal species?).

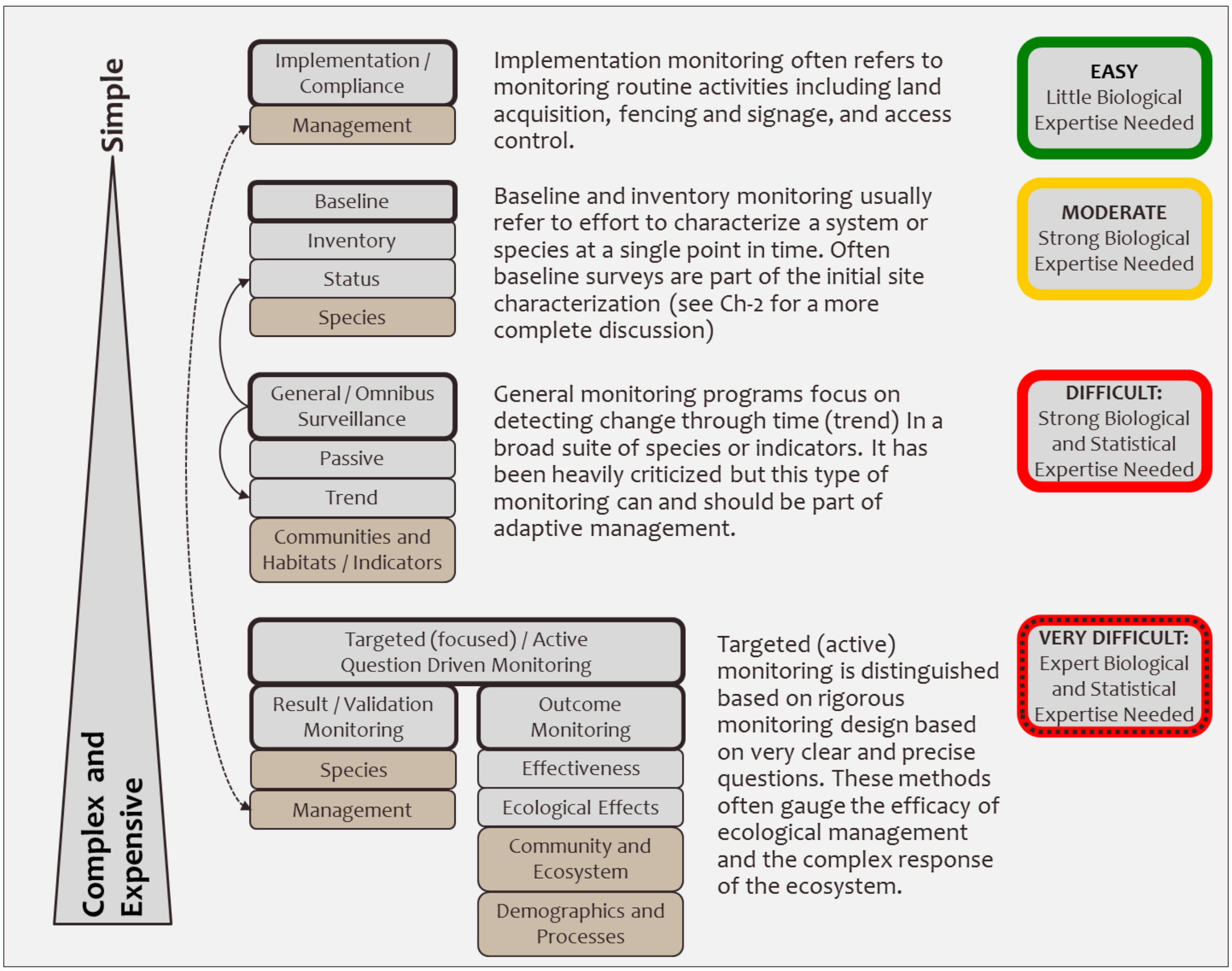


Figure 5.2: Common terms used in monitoring for adaptive management. This figure presents a continuum from simple compliance monitoring (top) to complex question-driven monitoring of species, communities, and ecosystems. Generally, tasks become more complex as you move

down the chart. As a direct result, there is increased need for specialized biological and statistical expertise. Increased complexity and specialized expertise drive the cost up. As a result, budget constraints become increasingly restrictive for more complex approaches.

Since monitoring programs are all of these things, it is important that you identify which type of monitoring is needed to meet your objectives given the constraints of your preserve, organization, and budget. Monitoring can only succeed if there is adequate expertise and resources. Naïve design and implementation of a monitoring program may be worse than no monitoring at all. Lack of expertise could lead to inaccurate results. Under-funded monitoring efforts often lead to inconclusive results. In either case, management could be delayed or misapplied with significant negative consequences. The rest of the chapter is aimed at making sure that users understand how to assess their needs (expertise and resources) and make informed decisions about monitoring. In the following sections, we will walk through the process of aligning a program's objectives with monitoring methods and evaluating the biological, statistical, and resource requirements needed to make monitoring count.

Making monitoring count

Successful monitoring starts with clear and well-defined objectives that address programmatic needs and/or satisfy statutory/permit obligations. As stated in earlier chapters, monitoring is part of a larger process. This is often presented as series of sequential steps but the process is iterative. Early in the adaptive management process, the most effective monitoring will likely employ simple and robust methods to determine status. As more information is collected and analyzed, the adaptive management process from refining objectives to designing additional monitoring will need to be updated.

The monitoring process is often divided (somewhat arbitrarily) into several design phases. The most common terms are the **sampling design** and the **response design**. The sampling design answers the questions of "Which, Where and When?" (Table 5.1). The response design answers the questions "What and How?." Successful monitoring hinges on choosing the appropriate sampling and response designs to meet the specific objectives of the monitoring program.

Census or Sample?

In some instances, it may be possible to count every individual in the target population. A complete count is called a **census**. If it is possible (given the nature of the system and the available resources) to count all individuals, then there is no need to sample. There is no need to use statistics to describe uncertainty in a census (since, by definition, you have measured the population parameter completely and it is not an estimate at all). In most cases, it is impossible or impractical to census the population. As a result, we must **sample** the population. If the sample is well designed, it will provide reliable information about the population without the cost of having to census every individual.

The sampling design

A good sample must be representative of the whole population. The sampling design involves making decisions about how to select individuals (organisms, sites etc.) to be sampled to ensure that the sample is representative. The gold standard for sampling is the simple random sample **(SRS).** In a simple random sample, all individuals in the population have an equal chance of being selected in the sample. Simple random samples have several important statistical properties. First and foremost, they are unbiased. A statistic estimated from a SRS will not have any systematic tendency to over- or underestimate the true population parameter. Second, simple random samples tend to be very robust to incomplete information or imprecise implementation of the sampling design. It makes few assumptions and statistics based on a SRS are unlikely to be strongly impacted by minor mistakes. On the other hand, simple random sampling can be very inefficient. SRS does not use any additional information about the system to reduce uncertainty or cost.

There are several common modifications to SRS that can improve precision and/or reduce cost (Figure 5.3, top). Stratified random sampling is based on the idea that the parameter of interest varies across several distinct regions (formally "strata" the plural of "stratum"). Stratified random sampling involves the careful allocation of effort across the strata in order to improve the performance on the sample. In general, stratified random samples will be superior when they allocate greater effort to larger and more variable strata since this will give the greatest information. Although stratified sampling can provide improved estimates, it is important to recognize that imperfect or inappropriate stratification can actually hurt a monitoring program. As a result, it is important that the rationale for stratification and data to support stratification are well supported.

Cluster sampling is an alternative to stratified random sampling. Cluster sampling is mainly used to decrease the cost of sampling. In cluster sampling, the population is divided into many, many small clusters (as opposed to a few large strata above). In the first stage, A SRS is used to select clusters to sample. In the second stage, all members of the cluster are sampled. The rationale for this is easy to understand for anyone that has done sampling in dense chaparral or remote forest locations. A simple random sample might locate a single point in the middle of a dense stand far from any trail or access point. It is very expensive (and often unpleasant) to reach the sample point to make a single measurement or observation. In cluster sampling, the basic unit of effort is the cluster. As a result, you would take a set of several observations/measurements once you reach the sample location. As with stratification, cluster sampling requires additional steps to estimate the mean and standard deviation of the quantity of interest.

For monitoring programs that measure change through time, it is necessary to decide how to allocate effort through time (Figure 5.3, bottom). One option is to create a new list of sampling sites each time period. This approach means that more and more sites will be visited over time which provides greater information about the status of the response variable. Alternatively, revisiting the initial sites will provide greater precision to measure trend at the expense of information about status. Intermediate designs (often called rotating panel designs) create several sets of samples ("panels") and then cycle through them over the course of several sampling periods. This intermediate design provides a balance between information about status (space) and trend (time).

Finally, it is important to decide whether the sampling design will be fixed or adaptive. Most classical statistics techniques assume the design is fixed and that standard estimates like sample averages and sample standard deviations are accurate. Adaptive designs are attractive since they allow the monitoring program to adapt and evolve as more information is collected. Despite the conceptual simplicity of this idea, it is often quite difficult to calculate unbiased and accurate estimates from these adaptive designs. These techniques are likely to pose greater risks than rewards for most management applications.

Table 5.1: Components of the Sampling Design.

Component / Question	Explanation
Sample Size: How many sites need to be sampled?	The sample size must be appropriate for effective monitoring. If it is too small, nothing will be learned. If the sample size is too large, the sampling program wastes resources. Where possible, the power and precision of a sampling design should be calculated in the initial design phase.
Sample Selection: Which sites (individuals, units …) should be included in the initial sample?	Sampling must be carefully planned to avoid **bias**† and ensure that the sample represents the entire population. Simple random sampling is robust but often wildly inefficient. In theory, stratified, cluster, and systematic sampling can improve efficiency but can be more susceptible to errors in poorly planned and/or executed.
Frequency: How often should data be collected?	The frequency of sampling depends both on the nature of the response variable(s) and the question be asked. For example, yearly surveys are often appropriate for annual plants. In contrast, sampling every 5 or 10 years may be sufficient for long-lived shrubs and trees. However, monitoring for an emerging pathogen (e.g. GSOB) on a long-lived tree may warrant very frequent monitoring.
Revisits: Should new sites be selected each sampling period? Or should sites be revisited?	The ability to estimate trend depends on how the sampling effort is allocated through time. Selecting new sites each time period is robust and ultimately results in a large sample of sites that have been visited once. Power to detect trend through time is limited by variability among sites. Revisiting sites every sampling period often improves power to detect trend but only at a limited number of sites.
Adaptive Sampling: Should the sampling design be allowed to change as new information becomes available?	Traditionally, sampling decisions are made before sampling begins in order to avoid subjective decision making during the sampling process. In some cases, sampling designs can be employed that are adaptive. In these designs, the selection of the next sampling unit depends on the information from previous samples. It is important to realize that the analysis of data from adaptive designs is much more complicated than traditional designs.
Expected Precision and Power to Detect Change: Samples should be designed to be precise enough to meet objectives and aid management.	It is important to evaluate whether a proposed sample design will provide information that is both precise and timely. This will depend on the objectives, sample design, sample size, and natural variability. In theory, expected precision and the power to detect change can be (and should be) calculated before a program is initiated to make certain the program will achieve its goals. Often, the information available during the design phase of a program is not adequate to make these calculations. Precision and power estimates should be updated periodically as more information becomes available.

† *In this usage, **bias** refers to the tendency of a statistic to systematically overestimate or underestimate the true value. For example, if you asked a random sample of 100 adults "How much do you weigh?", their answers will tend to be lower than the actual values if you were to weigh them. In this case, self-reported weights are biased low.*

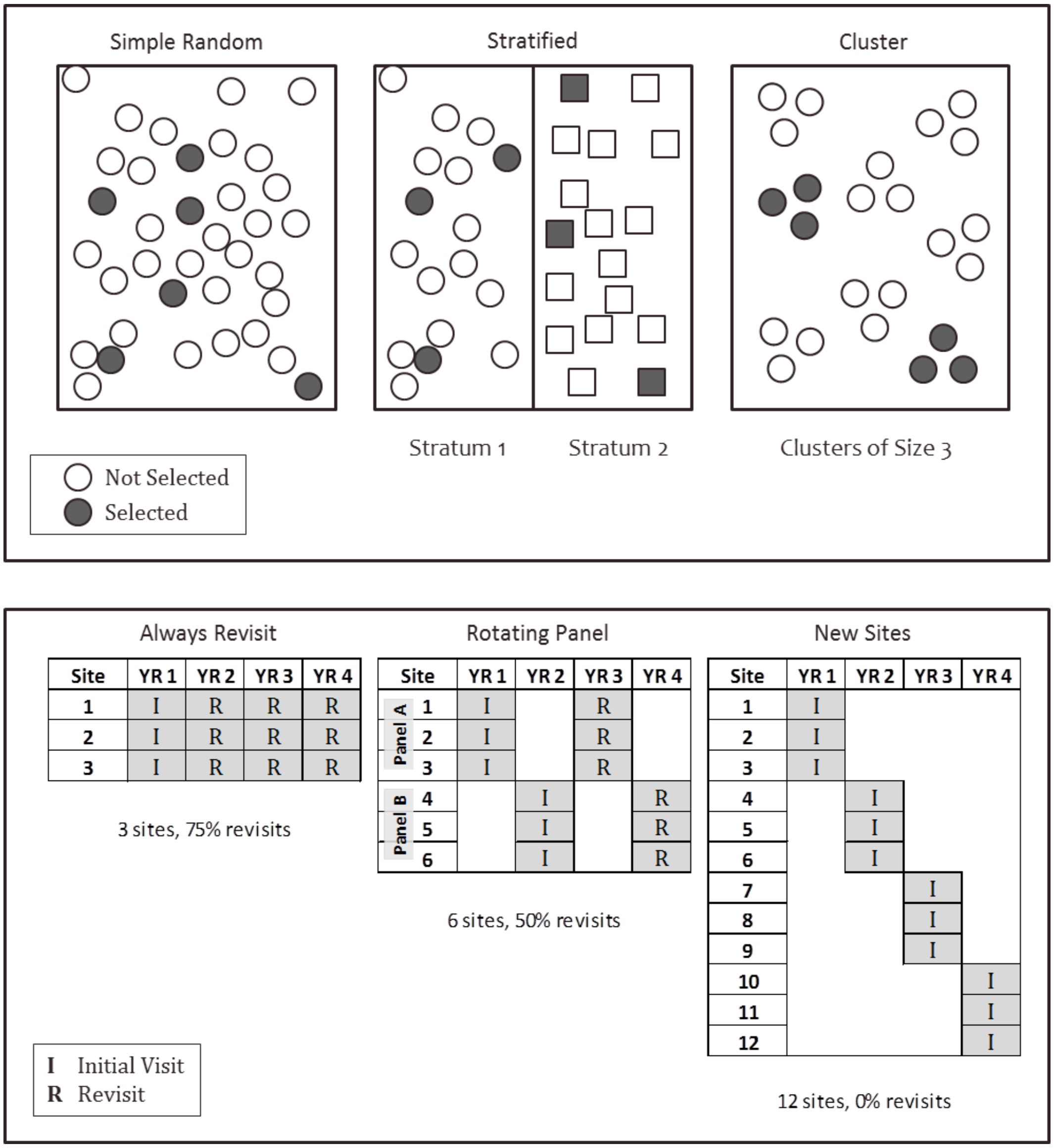


Figure 5.3: (Top) Schematic of common sampling designs including simple random sampling (left), stratified sampling (center), and cluster sampling (right). Stratified and cluster sampling can improve efficiency but are more complicated and vulnerable to errors. **(Bottom)** Common sampling designs include frequent revisits to a limited number of sites (left panel) to single visits to a larger number of sites (right panel). The symbol "I" denotes the initial visit while "R" denotes a revisit. Revisits improve a design's power to detect trends through time. In contrast, designs with limited or no revisit provide greater information on status and distribution but may not provide precise estimates of change through time.

The response design

The response design is often discussed independent of the sampling design, although they are not entirely separable. The response design characterizes what will be monitored and how it will be measured. As with the sampling design, it is important that the response design be aligned with the objectives of the monitoring program and available resources including equipment and expertise.

Choosing an appropriate response variable and method is tightly coupled with the nature of the species/community/resource being monitored. Clearly the methods used to measure vegetation cover will differ fundamentally from those used to estimate small mammal density or the frequency and impact of dogs that are not leashed. Despite these differences, the same set of ideas will guide selection of an appropriate method. We illustrate these guiding principles by comparing and contrasting different response designs for vegetation and small mammals.

When monitoring vegetation and plant community composition, techniques range from rapid visual assessment and mapping of large areas to detailed counts in many small quadrats (See Figure 5.4, left). The rapid visual assessments provide information on the presence/absence of species. They also provide qualitative information on dominant species. These methods could provide some information on invasion by new species or large-scale changes in dominance by one or several key species. However, these methods do not provide reliable quantitative information about cover of all the species in the ecosystem. Careful use of nested quadrats provides precise and repeatable quantitative information about all the species in a community. This information can be used to document small changes in absolute or relative cover of species. Point-intercept transects fall between these two extremes. Transects provide very precise quantitative data on the large and/or common species in the system. As a result, they can provide more information about changes in community composition and structure than rapid visual estimates. On the other hand, point transects often fail to detect small and/or cryptic species and as a result tends to underestimate diversity. The most effective response design for a given monitoring objective will depend on the information required and the available resources.

The same continuum of methods is available for monitoring small mammals. Sign/track surveys or baited track plates can provide very rapid information on the presence of many common species (Figure 5.4, right). This information is qualitative, since there is no clear relationship between track/sign frequency and animal density. Detection of sign/tracks may depend on animal size, activity patterns, placement of track plates, use of scented baits, and the skill of the observer. Careful use of trapping grids coupled with mark/recapture estimation can provide precise estimates of absolute population size that are corrected for partial observability and other sources of variability. Drift fall fences and pit fall traps are intermediate in effort and data quality. Relative indices of activity can be derived (e.g. captures per array-night) that can be compared among sites or through time. These indices are semi-quantitative and have the potential systematic prediction errors (i.e. **bias,** see discussion at the bottom of Table 5.1). On the other hand, systematic use of an imperfect method will often track meaningful changes in community composition.

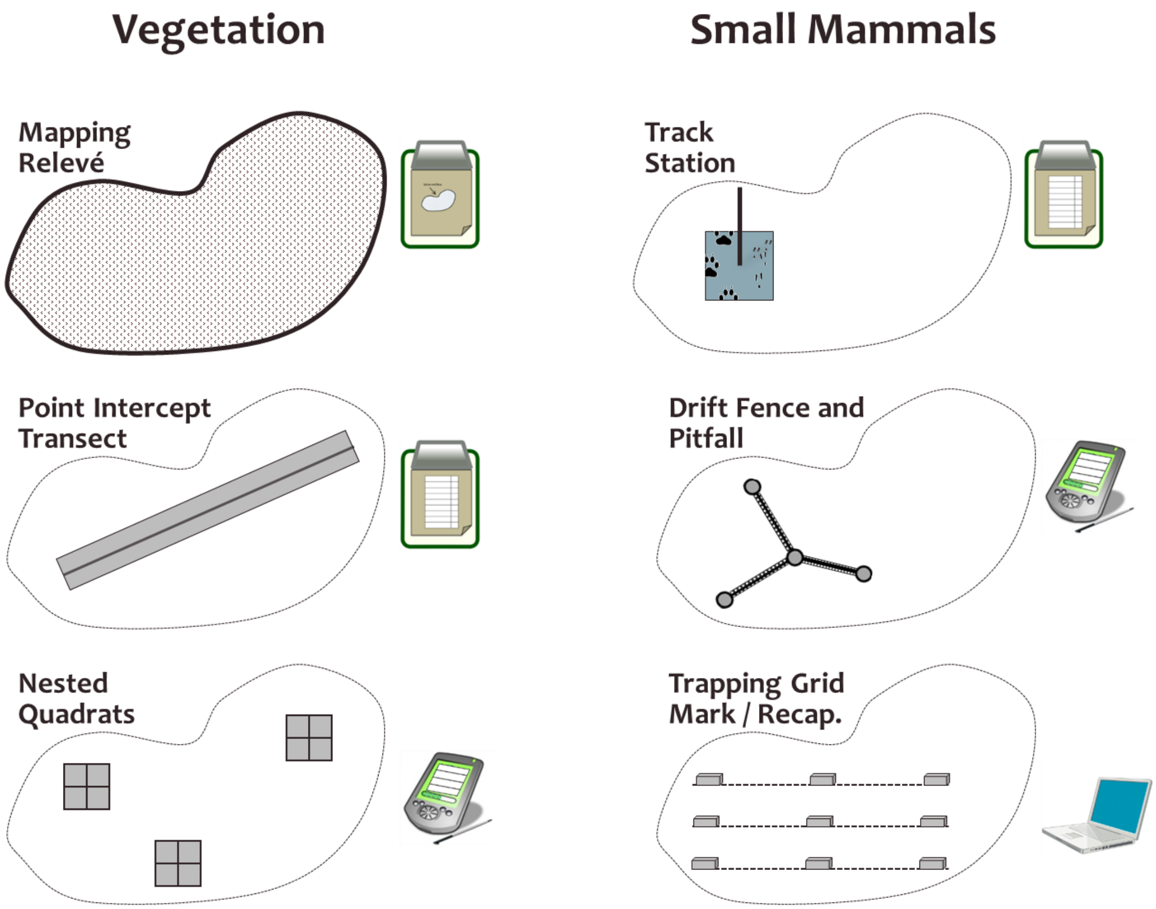


Figure 5.4: Examples of possible response designs for vegetation (left) and small mammals (right). **(Top Row)** Simple methods that provide relative crude information like presence/absence. **(Middle Row)** More complex methods that allow estimation of indices like relative density, composition, or activity. (**Bottom Row)** More detailed methods that allow estimation of absolute cover or population size.

Taxa-specific recommendations

The following sections provide a quick reference to common and accepted methods for several common monitoring targets for vegetation, birds, small mammals, and herpetofauna. These are by no means the only methods that can be used, but they do represent best-practices in the field. Other methods may be used but the choice of less familiar methods would require justification to ensure that the proposed methods generated the data required. The information is presented as a decision tree for the main methods followed by a matrix of applicability and resources needed to support the methods. This format builds on the idea that guidelines for choice and application of methods need to be published as open standards. See the excellent resources developed by the New Zealand Department of Conservation for even more detailed standard operating procedures (Appendix 5-1).

How to decide which method to use?

There are two steps to deciding which method to use and these steps are captured in two tables for each of the species groups. **In Step 1**, the preserve team can identify what specific data objectives are best aligned with particular methods. Each taxonomic group has a methods decision tree where methods are arranged from simple to complex. **In Step 2**, the preserve team needs to evaluate the methods to ensure the method selected generates the needed data, and aligns in terms of costs and expertise required. In the resource matrix, users evaluate the appropriateness, costs, and skills associated with each method.

Monitoring vegetation

Vegetation monitoring is conducted at many spatial scales and to address a diverse array of questions. In some cases, the **general composition and structure of a vegetation community** is monitored to provide information on habitat suitability or quality for a species of interest. In addition, these broad metrics are used to evaluate change in the landscape as a result of natural or anthropogenic processes including habitat fragmentation, invasion by exotic species, alterations to the fire cycle and changes in climate. Vegetation monitoring also includes tracking changes in population size, structure, and condition of **rare and threatened species**. San Diego is home to many endangered and/or endemic plants. Methods appropriate for assessment of broad-scale community characteristics will often differ from those needed to monitor rare plants.

Vegetation communities in San Diego are comprised of hundreds of species both native and non-native. The function of an ecosystem is influenced by the structure of the plant community as well as its floristic composition. For some objectives, relatively simple descriptions of the structure of the community (presence and thickness of thatch, height of plants, presence of shrubs or trees etc) may provide enough information to inform management. Other objectives, particularly those associated with **rare plants**, may require a very detailed assessment of species composition, density and even demography (age/size structure) of individuals. Some common methods are detailed in the decision tree and resource matrix (Figure 5.5)

<u>Patch Mapping</u>: Simple surveys to assess and map the boundaries of clearly defined patches. This approach can be used to track the distribution of invasive species. Changes in the patches can be used to calculate the rate of spread of an invasive species. Patch mapping may also be useful for tracking the distribution of a rare native plant of conservation concern.

<u>Area Searches</u>: Like patch mapping, an area search is a simple, semi-quantitative method to find and document the distribution of a species or resource.

<u>Relevé</u>: The relevé method is a semi-quantitative method to assess the structure and composition of a community. Typically, an observer estimates the cover of dominant plants in a relatively homogeneous area using ordinal categories (e.g. absent, less than 1%, 1-5%, 5-25%, 25-50%, 50% or more). There are many variations on how this method is implemented. This method is difficult to standardize across sites and tends to vary with the experience, skill, and background of the field scientist.

<u>Point Intercept</u>: There are many forms of transect/intercept methods. Point intercept involves placing a pin or dowel at intervals of 50cm or 1m along a long transect (often 50 or 100 meters). The observer records the ground cover at the base of the pin and the number of different species that touch the pin. Quantitative estimates of relative and/or absolute cover are calculated from the proportion or

number of “hits.” This method is usually fairly rapid and can be used with very coarse descriptors of plants like functional groups or growth habit.

Visual Obstruction: This method is used to measure structure of a vegetation community. The height and density of vegetation is measured by pairs of observers using a marked pole (Robel pole). This method is not intended to describe floristic composition. Instead, it is a rapid and repeatable method to assess structure.

Point or Belt Transect: There are many forms of transect methods. These methods are similar to the point-intercept describe above. The major difference is the focus on species and community composition. Belts transects cover more area and as a result are more likely to increase the number of small/rare species recorded.

Quadrat Sampling: In common applications, standard square quadrat frames (often 1mx1m or 50cmx50cm) are placed on the ground. The presence and absolute cover of each species is estimated and recorded. Estimates can be made visually or using nested quadrats or pins. Quadrate sampling tends to improve the description of diversity (particularly rare and/or small plants) relative to transect methods.

Nested Plots: The results from quadrat methods can depend on the size of quadrats used. One way to document this pattern is to use a nested series of plots from very large (e.g. 20x50m) in which smaller areas are sampled at finer scales (e.g. 2x5m, then 1x1m, and finally 25x25cm). Although several spatial layouts that have been suggested, this method is more expensive and difficult to deploy in the field and results in complicated data.

Total Census: Most methods provide estimates of relative cover that can be used as surrogates for absolute population size. In some cases, a population census (complete count) is desirable and feasible. Examples include endangered/endemic species like the Torrey Pine.

Probability Sampling: For this chapter, we use the term probability sampling to refer to the careful application of statistical sampling procedures to a suite of field techniques. For example, point-intercept or nested plots can be used to estimate change at any arbitrary location. Describing change across a community type or region requires that many sites be selected and sampled. This was discussed earlier in the chapter (see section labelled: The sampling design)

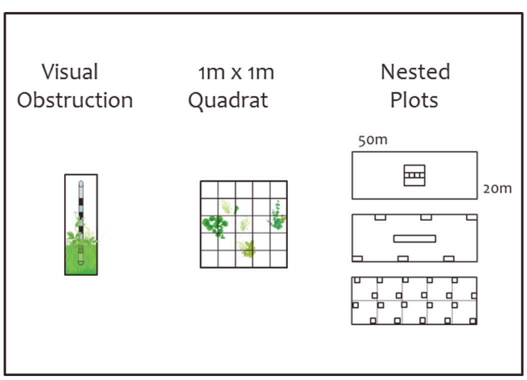
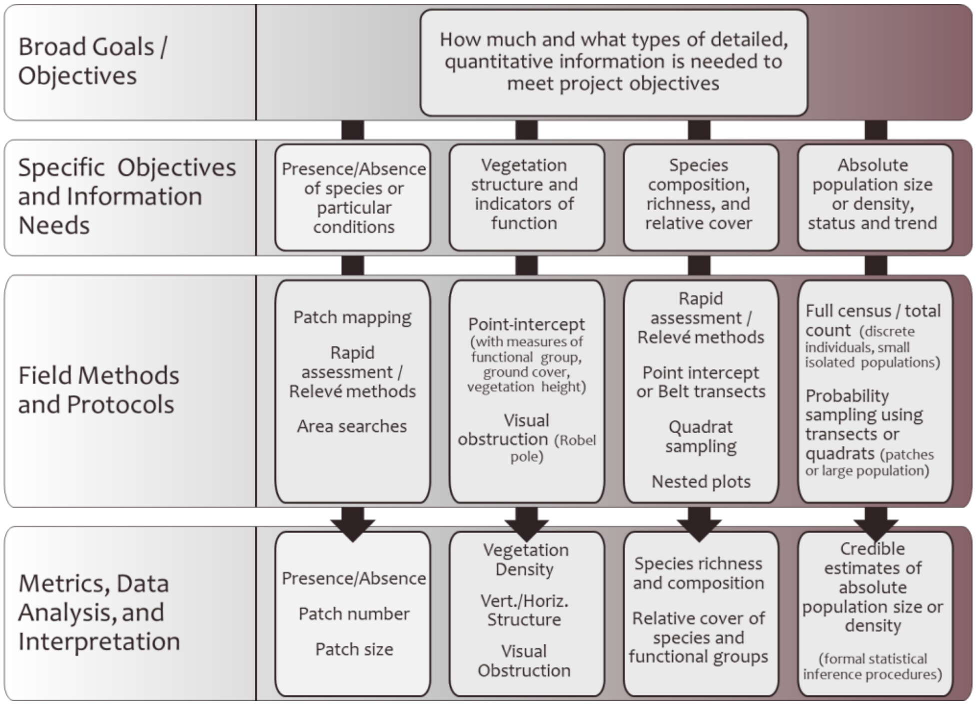


Figure 5.5: Simple Illustrations of several vegetation sampling techniques. Nested plots adapted from Keeley and Fotheringham 2005[10].

Methods Decision Tree



Resource Matrix

	Objective	Presence / Absence			Community Structure		Composition, Richness, and Relative Cover				Abs. Pop'n Size / Density	
	Method	Patch Mapping	Area Searches	Relevé	Point Intercept	Visual Obstruction	Relevé	Point or Belt Transect	Quadrat Sampling	Nested Plots	Full Census/ Total Count	Probability Sampling
Appropriate For	Inventory / Baseline	✓✓✓	✓✓✓	✓✓	✓	✓	✓✓	✓	✗	✗	✗	✗
	Change Detection	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓	✓	✓	✓	✓
	Status and Trend	✗	✗	✓	✗	✗	✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓
	Management	✗	✗	✓	✓✓	✓✓✓	✓	✓✓	✓✓	✓	✓	✓
Costs	Equipment	$$$	$	$	$	$	$	$	$	$	$$	$$
	Personnel	$$	$	$$	$$	$$	$$	$$	$$$	$$$	$$$	$$$
Skills	Field / Taxa	♦♦	♦♦	♦♦	♦	♦	♦♦	♦♦	♦♦♦	♦♦♦	♦♦♦	♦♦♦
	Data / Analytic	♦♦	♦	♦	♦	♦	♦	♦♦	♦♦	♦♦	♦♦♦	♦♦♦

Figure 5.6: Decision tree and resource matrix for monitoring vegetation. Vegetation includes monitoring the condition of diverse vegetation communities (e.g. CSS or Chaparral) as well as rare endemics (e.g. Otay tar plant). In the Methods Decision Tree**, top**, users identify the objective and select a protocol and metric. Methods are arranged from simple (left) to complex (right). In the Resource Matrix, **bottom**, users evaluate the appropriateness, costs, and skills associated with each method. Appropriate methods are denoted with increasing numbers of green checkmarks. Required costs and skills are denoted with dollar signs and diamonds, respectively. More symbols represent higher costs or required expertise.

Monitoring birds

Many birds are difficult to monitor because they are small, fast, and secretive. Detections by sight are often supplemented by auditory detections. Sometimes call-playback can be used to induce a response from a target species and improve detection. Birds are a diverse group and present many special situations. For example, many colonial-nesting shorebirds are relatively easy to count during the breeding season and nearly impossible to monitor away from nesting sites. In contrast, many large raptors occur at low density and can forage over large areas. Some common methods are detailed in the decision tree and resource matrix (Figure 5.7)

Standardized Surveys: Transects or observation period surveys that are standardized across sites or observers. Although detection of birds can vary with habitat and species, using a standardized approach may allow limited comparisons across sites. This method is most reliable at detecting fairly large changes through time at sites that are revisited using the same methods.

Occupied Nests or Burrows: All objects of interest, such as occupied nests or active burrows, within a designated area, are detected and counted. The nests or burrows are taken as an indicator or surrogate for population size.

Line Transects: Line transect sampling involves an observer travelling along a designated line of given length recording the number of birds, nests or other relevant objects (e.g. burrows, droppings and footprints) detected. Counting all individuals, groups, species and related objects of interest along a line can provide a useful and repeatable method to track relative abundance of a population.

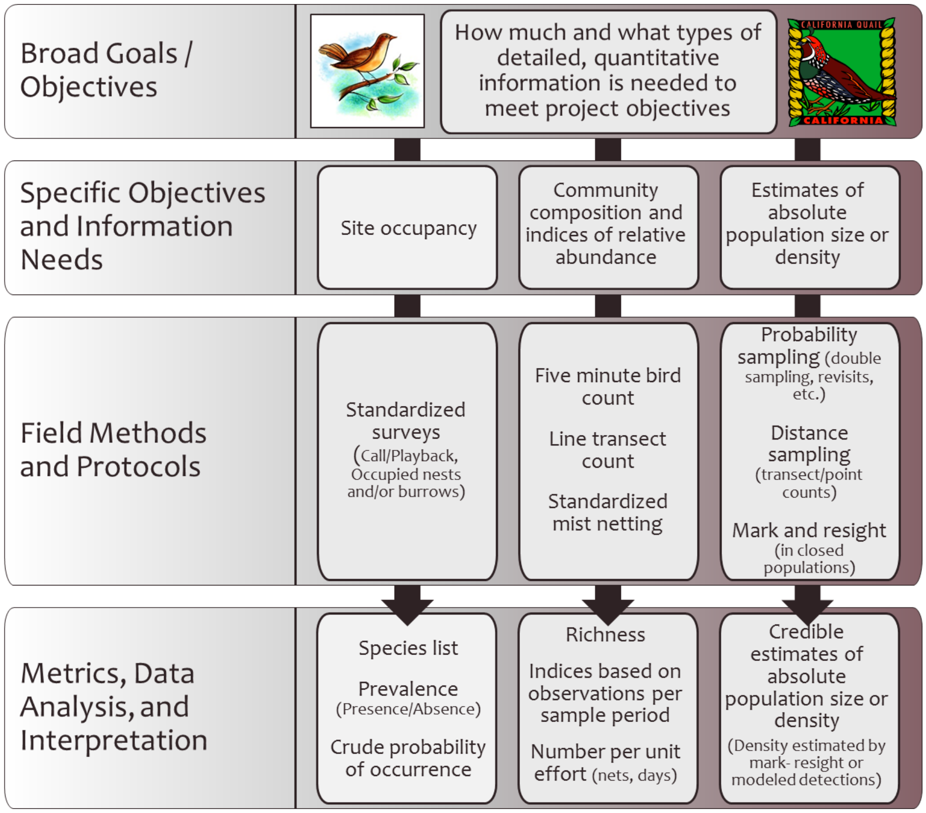
Standardized Mist Netting: Nets are placed in suitable locations on a study plot and operated over several days. Within a short time of capture, birds are extracted from the net and records are taken. Birds are marked with individually numbered aluminum bands so that recaptures can be recognized. Capture of birds in mist nets can provide data on population density and demography (productivity and survival).

Probability-based Sampling: Probability-based sampling refers to a modification of a standard technique that has been implemented with a statistically rigorous design like a simple random sample or a stratified random sample. Although detection rates are not modeled explicitly, change through time should be accurate if we can safely assume that detection rates are not changing.

Distance Sampling: A modification of the 5-minute bird count or line transect methods where the absolute density of a bird population is derived from measurements of distances either perpendicular to a line (line transects) or radially from a point to the object of interest (point counts). The distances are used to model detection probability and thus absolute estimates can be calculated.

Mark-resight or recapture: Individual birds are captured, marked, released and a proportion of these individuals are recaptured, or sighted. Analysis of the data is simplest in a clearly defined closed population. The population size can be estimated using the ratio of marked to unmarked individuals assuming that the marked and unmarked individuals are well mixed.

Decision Tree



Resource Matrix

Objective / Method		Site Occupancy / Presence		Relative Community Composition			Absolute Population Size / Density		
		Standardized surveys	Occupied nests/burrows	Five minute bird count	Line transect count	Standardized mist netting	Probability Sampling	Distance Sampling	Mark-Resight
Appropriate For	Inventory / Baseline	✓✓✓	✓✓✓	✓✓	✓	✗	✗	✗	✗
	Change Detection	✗	✗	✓✓	✓✓✓	✓✓	✓✓	✓✓✓	✓✓✓
	Status and Trend	✗	✗	✓✓✓	✓✓	✓✓	✓✓✓	✓✓✓	✓✓✓
	Management	✓	✓	✓✓	✓✓✓	✓✓	✓✓	✓✓	✓✓
Costs	Equipment	$	$	$	$	$$	$	$	$$$
	Personnel	$$	$$	$$	$$	$$$	$$$	$$$	$$$
Skills	Field / Taxa	♦	♦	♦♦	♦♦	♦♦♦	♦♦♦	♦♦♦	♦♦♦
	Data / Analytic	♦	♦	♦♦	♦♦	♦♦	♦♦♦	♦♦♦	♦♦♦

Figure 5.7: Decision tree and resource matrix for monitoring birds. See legend of Figure 5.6 for a detailed description on how to read the decision tree and resource matrix.

Monitoring small mammals

Small mammals can difficult to monitor because they are small, nocturnal, and often difficult to trap/capture. Detections of tracks, sign, and burrowing activity can be straightforward but are usually limited to providing crude data on presence of the most common or most active species. Several standardized methods have been developed to assess small mammal communities. Often these involve repeated sampling in order to identify individuals and account for probability of detection. Some common methods are detailed in the decision tree and resource matrix (Figure 5.8).

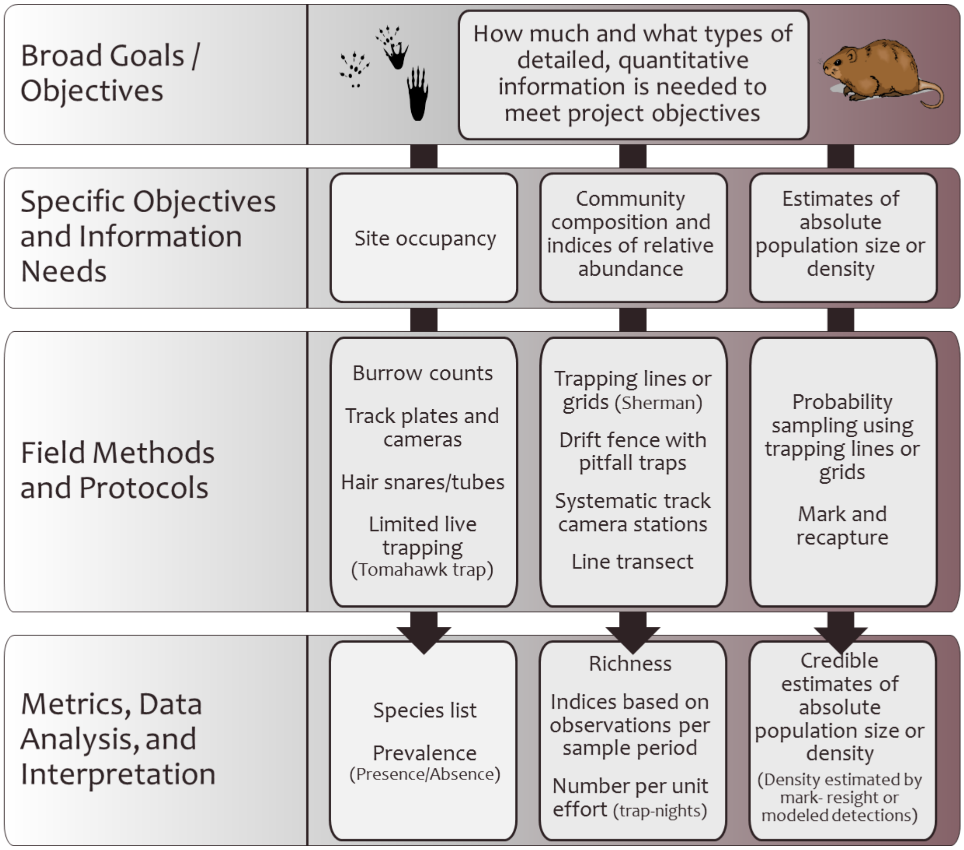
Burrow Surveys: Measuring the density and distribution of burrows can be a simple measure of crude activity for fossorial mammals. Although the correlation between number of burrows and population density can be highly variable, counts of active burrows along well defined transects an provide useful information.

Camera Traps or Track Stations: Camera traps and track stations are often baited to increase the number of observations. A camera trap is a baited station that triggers a camera when visited. Until recently, camera traps had a high initial cost and were generally used for surveys of medium to large mammal species. Newer, cheaper still and video cameras can be used to detect small mammals. Camera trapping and track stations may be an appropriate tool for rapid assessment of all mammal species in a study area.

Hair snares and tubes: Hair tubes are baited long tubes with double sided tape placed along the interior of the tube to catch hairs from passing small mammals. The diameter of the tube must be slightly larger than the target species so the animal may easily pass through the tube but snug enough to grab hairs. This technique does not provide information on the number of individuals of a given species and the identification of hair depends on the completeness of available keys to include the target species in a given survey. Collected hairs can be used for genetic typing.

Drift Fence / Pitfall traps: Drift fencing intercepts and guides small terrestrial animals into pitfall traps that are placed along the fence. Pitfall traps are generally 2-5 gallon plastic buckets that are buried in the ground to the rim of the bucket. Pitfall traps are often lethal to captured small mammals so careful consideration should be made in trap design in order to minimize trap mortality.

Live Trapping: Using solid walled and wire mesh box traps are the most common method for detecting presence and abundances of most small mammal species. Sherman live traps are solid walled lightweight folding aluminum traps. Longworth traps consist of a tunnel and a nest box and are considerably more expensive than Sherman traps. Longworth traps are associated with low trap mortality, have an optional shrew exit hole and are easier than Sherman traps to bait and clean. However, Sherman traps can fold and be transported easily in the field. Deliberate and thoughtful survey protocol will minimize trap mortality and the increased effort on the part of field crew to clean and bait may be worth the savings. Wire mesh traps are a one way baited trap that are typically used for the larger species of small mammals such as squirrels and wood rats. The two most commonly used wire mesh brands are Tomahawk and Havahart. The placement of traps are part of the study design and options include placement along a transect line, grid or web depending on project objectives.



	Objective	Site Occupancy / Presence				Relative Community Composition				Absolute Pop. Size / Density	
	Method	Burrow Surveys	Camera or track stations	Hair snares and tubes	Limited live trapping	Trapping lines or grids	Drift fence with pitfall traps	Systematic tracks or cameras	Line transects	Prob. sampling traps	Mark and recapture
Appropriate For	Inventory / Baseline	✓✓	✓✓✓	✓	✓✓	✓	✓✓	✓✓	✖	✖	✖
	Change Detection	✖	✖	✖	✓	✓✓✓	✓✓	✓✓✓	✓✓	✓✓	✓✓✓
	Status and Trend	✖	✖	✖	✓	✓✓	✓	✓	✓✓	✓✓✓	✓✓✓
	Management	✓	✓✓	✓	✓	✓✓✓	✓✓	✓✓✓	✓✓	✓✓	✓✓
Costs	Equipment	$	$$$	$	$$	$$	$$	$$$	$	$$	$$$
	Personnel	$	$$	$$	$$	$$	$$	$$	$$$	$$$	$$$
Skills	Field / Taxa	♦♦	♦	♦♦	♦♦	♦♦	♦♦	♦♦	♦♦	♦♦♦	♦♦♦
	Data / Analytic	♦	♦	♦	♦	♦♦	♦♦	♦♦	♦♦	♦♦♦	♦♦♦

Figure 5.8: Decision tree and resource matrix for monitoring small mammals. See legend of Figure 5.6 for a detailed description on how to read the decision tree and resource matrix.

Systematic or Probability-Based Sampling: Most of the methods above can be deployed in a systematic or probability-based sampling design. For example, drift fence pitfall arrays can be installed and opened seasonally for many years. The data provides a relative index of community composition and relative activity at a given site. Additionally, installing arrays using a stratified random sample (or other statistical design) may provide information about status. Caution needs to be exercised when interpreting these data since there is still the potential for unknown bias due to animal behavioral responses to the equipment.

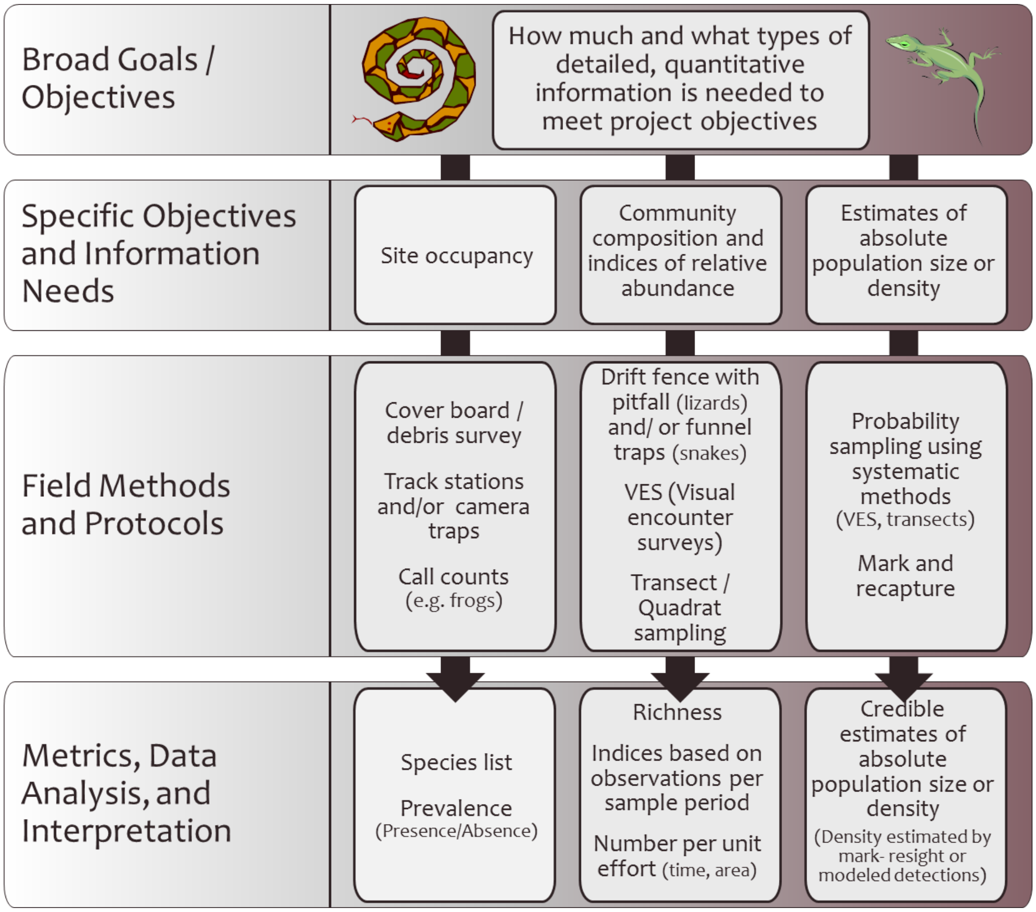
Probability-Based Sampling with Mark and Recapture: The strongest information on absolute population size comes from mark-recapture studies. Mark-recapture with live trap grids is the gold standard for small mammals. This approach is costly in terms of equipment and field personnel. Estimating absolute abundance adjusted for probability of detection is complicated and requires significant expertise. This method should only be chosen if the monitoring objective requires this level of precision and the expertise/resources are available to make sure it is done well.

Monitoring herpetofauna

There is no single all-encompassing best practice for herpetofauna monitoring or inventory. Significant research on methods for monitoring in San Diego has been conducted by scientists at the USGS[11] A method that employs drift fencing combined with pitfall and funnel traps has proven effective at capturing a high diversity of herpetofauna. Some common methods are detailed in the decision tree and resource matrix (Figure 5.9). Systematic searches and cover board / debris surveys are included for comparison though studies evaluating these sampling techniques have cautioned their use due to the risk of significant sampling bias based on the nature of the species and the skill level of the observer.

Cover Board or Debris surveys: Typical cover board surveys involve placing sets of untreated wood boards along transects or in a grid. Many herpetofauna will use the boards for shelter, particularly after they have “weathered” in the environment. This method may be used to document the presence of some species in an area. Care should be exercised since species may have different responses to the boards or their other occupants.

Track stations or Camera traps: Camera traps and track stations are improving as resolution and IR lighting improves and units become cheaper. Camera trapping and track stations may be an appropriate tool for rapid assessment for active and easily identifiable species.



	Objective	Site Occupancy / Presence			Relative Community Composition			Absolute Pop. Size / Density	
	Method	Cover Board Debris survey	Camera or track stations	Call counts (e.g. frogs)	Fence with pitfall or funnel	VES (Visual surveys)	Transect / Quadrat	Probability Sampling	Mark-Recapture
Appropriate For	Inventory / Baseline	✓✓✓	✓✓	✓	✓✓	✓	✖	✖	✖
	Change Detection	✖	✓	✖	✓✓	✓	✓✓	✓✓✓	✓✓✓
	Status and Trend	✖	✖	✖	✓✓	✓	✓✓	✓✓✓	✓✓✓
	Management	✓	✓✓	✓	✓✓✓	✓✓✓	✓✓	✓✓	✓✓
Costs	Equipment	$	$$$	$$	$$	$	$	$	$$
	Personnel	$	$$	$	$$	$$$	$$$	$$$	$$$
Skills	Field / Taxa	♦	♦	♦	♦	♦♦♦	♦♦♦	♦♦	♦♦♦
	Data / Analytic	♦	♦	♦	♦♦	♦♦	♦♦	♦♦♦	♦♦♦

Figure 5.9: Decision tree and resource matrix for monitoring Herpetofauna. See legend of Figure 5.6 for a detailed description on how to read the decision tree and resource matrix.

Track stations or Camera traps: Camera traps and track stations are improving as resolution and IR lighting improves and units become cheaper. Camera trapping and track stations may be an appropriate tool for rapid assessment for active and easily identifiable species.

Call Counts: Call count protocols are often used as a simple index of population size for frogs and toads. It is most appropriate for species whose calls are easy to hear and distinguish for a prolonged period. A typical ordinal scale would be 0 = no frogs heard, 1 = individual calls, not overlapping, 2 = calls are overlapping but individuals can be distinguished, and 3 = constant and overlapping chorus.

Fence with Pitfall/Funnel Traps: This method has been well established in San Diego County and beyond. The drift fences direct small animals toward the traps. Pitfall traps can catch many small mammals and lizards where the funnel traps are designed to catch snakes. Using this method as part of a long-term monitoring program provides an index of relative abundance for many species.

Visual Encounter Surveys: This classic method is usually implemented with a search of a known area for a specific amount of time. VES surveys can be along transects, in quadrats or other patterns. As with pitfall traps, indices of relative abundance can be estimated from the number of animals per unit time or area searched. In contrast, there is likely greater inter-observer variability in this method.

Transect and Quadrat methods: Transect and quadrat methods involve repeated visits to permanently marked transect or large plots. As with VES, the emphasis is on a carefully constrained effort that can be replicated.

Probability-Based Sampling and Mark Recapture: As is true with small mammals and birds, the relative indices based on pitfalls or VES surveys may be inaccurate due to a host of potentially confounding variables. Estimates of absolute density can be made from distance sampling, mark-recapture, or other statistical methods to estimate detection and capture probabilities. These methods are expensive and difficult. Moreover, many management questions may be addressed with indices of relative abundance. As a result, these methods should be used sparingly and with strong justification.

Discussion

In this chapter, we present a general framework for designing and implementing monitoring for adaptive management. What is clear is that there is not one single type or method of monitoring. Monitoring is used in many contexts from simple presence/absence of a species or resource to complex designs that involve multiple methods and/or repeated sampling to address sophisticated questions about changes in demographics or populations trends. Clear objectives are needed In order to develop or evaluate any monitoring program.

Monitoring involves decisions about site/sample selection, choice of field methods, and development of metrics that characterize the important aspects of the system. Successful monitoring programs will make and provide justification for each step in the process. Monitoring will be weaker or fail if the selection or samples and methods are flawed or poorly aligned with objectives. Even good decisions will be problematic if the information on which they are based is not reported to, and reviewed by, managers and regulators.

Guidance documents and standard operating procedures for conservation monitoring are being developed in many places. Ambitious plans have been proposed (and often criticized) including the Program for Planned Biodiversity and Ecosystem Research in Australia and Brazil, the Alberta Biodiversity Monitoring program in Canada, the integrated Biodiversity Monitoring & Assessment Tool and the European Biodiversity Observation Network in the European Union, and the Inventory and Monitoring Standard Operating Procedures (SOP's) developed by the Department of Conservation in New Zealand.

The sheer diversity and volume of these guidance documents and data templates is both good and bad news. The good news is that improving the rigor and efficiency of monitoring is being tackled by many people. The bad news is that there is still no single place to turn to for comprehensive materials. At this time, the closest thing to a complete reference is the New Zealand SOP documents (see Appendix 5-1). This collection of documents is hierarchical and starts with a general document on monitoring. In addition, there are more specific documents discuss monitoring for specific groups (vegetation, birds, bats etc.). Finally, there are dozens of method-specific publications. In total, the Department of Conservation in NZ has published ~6 general guidance documents and an additional ~36 specific method descriptions total more than 1,400 pages.

One of the most useful documents published as part of New Zealand's SOPs is a template for managers to use as they develop and implement a monitoring program. The file (published as a MS Word DOC file) requires the user to answer a series of questions from overview of the project down to very detailed questions about methods. It also includes placeholders for review and comments from managers, supervisors, or regulators. We present a schematic of this document in Figure 5.10. The development and adoption of a similar template would be an excellent next step in helping preserves navigate the monitoring process.. Importantly, the document would require input from land managers and participating jurisdictions as well as approval of the wildlife agencies.

Learning

A chapter on monitoring would be incomplete without re-iterating the need to management to learn (adapt) from monitoring data. This requires that data be collected, quality checked, analyzed, interpreted in a rigorous fashion. It also requires that the knowledge gained be made available to all relevant stakeholders. We describe these steps in more detail in the following three chapters.

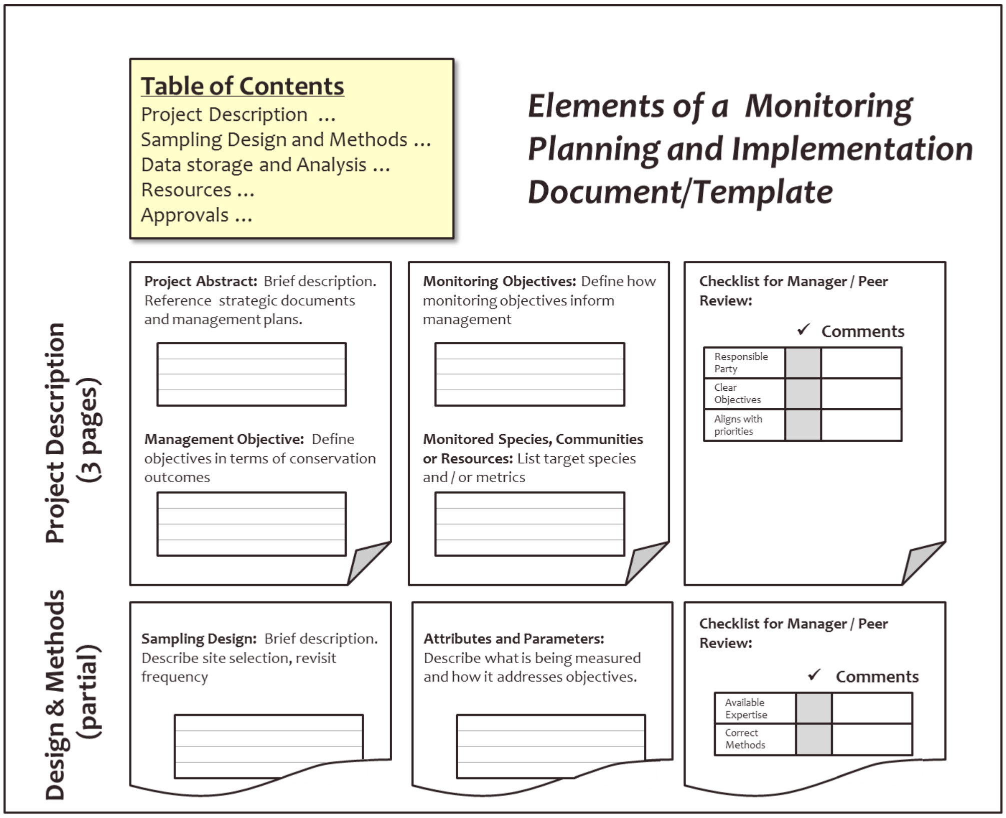


Figure 5.10: Example of pages from a monitoring plan template. Example adapted from the NZ Dept. of Conservation planning document. This template needs to be developed by, or at least vetted by, land managers, jurisdictions, and regulators from the wildlife agencies.

Chapter 5: Summary

- There are many types of monitoring and no standardized terminology. Define use of terms like “inventory”, “baseline”, and “trend” to avoid misunderstandings.
- Effective monitoring programs require clear and detailed statement of primary and secondary monitoring objectives (based on broad-scale and preserve-specific programmatic goals and objectives). Monitoring methods selected must align with the data needs to meet stated objectives
- There is no “one size fits all” approach to monitoring, but the decision trees and resource matrices provided in this chapter will support appropriate alignment between questions, methods and resources.
- Use the flowcharts and cost/benefit matrices to align monitoring methods with goals and objectives
- Evaluate potential methods based on personnel and equipment cots.

Checklist:

√	Task / Activity
☐	Goals and Objectives have been identified that align with MSCP-wide priorities and complement activities at nearby preserves (MUs)
☐	Key objectives and current understanding of the system is documented in a conceptual model that supports the choice of monitoring methods
☐	A monitoring method is selected that meets the data needs to satisfy monitoring objectives. Use the methods flowchart to identify a method that aligns with data needs and objectives.
☐	Evaluate resources and expertise to confirm proposed monitoring is feasible (resource matrix). If not, modify objectives and revisit decision tree.
☐	Create a timeline and plan for managing the monitoring program: Key aspects of oversight include (1) data Q_AQ_C and statistical analysis, (2) regular updates of management objectives and conceptual models, and (3) Planning for the future (short-term and long-term) including needed resources like adequate funding, personnel, and expertise.

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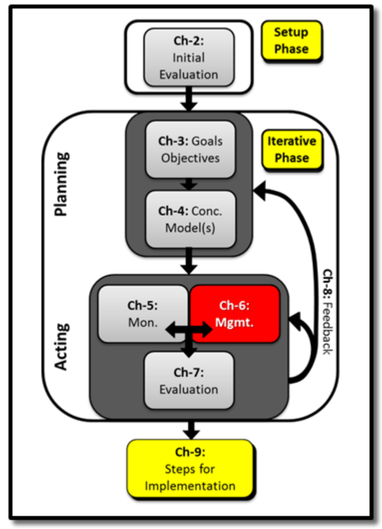
Chapter 6:

Effective Management: Using available expertise and existing information to maximize learning



Chapter guide

Management includes a broad array of activities, some that reflect known, best practices and others that are more experimental. In this chapter we discuss management in several contexts, from routine activities to natural experiments. In all cases, management must be aligned with local and regional goals and objectives (method used aligns with the question of interest or objective). In addition, management should be based on strong monitoring data and should contribute to improved understanding and/or increased capacity to manage. This chapter focuses on the important issue of linking monitoring data to management action. Common problems with this stage of the adaptive management process include poor design of management experiments, lack of consistent data collection through time, and inadequate use of data (from both monitoring and experiments) to inform management. In this chapter, we provide a framework for how monitoring and experimental data can be used to direct and improve management actions.

Introduction: Linking monitoring data to management action

The terms "Management", "Adaptive Management", and "Active Adaptive Management" and "Management Experiments" are often used interchangeably. Management encompasses a much broader set of actions and ideas. Management can include activities that are well understood and supported by an abundance of data or experience. It can also include activities designed to test novel strategies in the absence of an effective standard method. Adaptive management is the iterative learning process that improves the effectiveness and efficiency of management over time[1]. As such, adaptive management provides a structured process for managing resources in the present while reducing uncertainty for management in the future through controlled experimentation[2]

Prioritization and implementation of management actions at a particular site must reflect regional priorities and local needs. Regional guidance documents like the Management Strategic plan, (Hereafter, **MSP**; Management Strategic Plan for Conserved Lands in Western San Diego County, http://sdmmp.com/reports_and_products/Management_Strategic_Plan.aspx) provide a context in which local managers can decide how their needs align with others in their Management Unit or across the broader region. Implementation should be based on best practices and best available science, when available. If the required management actions are known to be effective, then there is no need for adaptive management because there is no uncertainty (Figure 6.1). If the activity is supported by some data, it will be important to monitor the efficacy of management. If there is no accepted approach, the management experiments as envisioned in the adaptive management process may be appropriate.

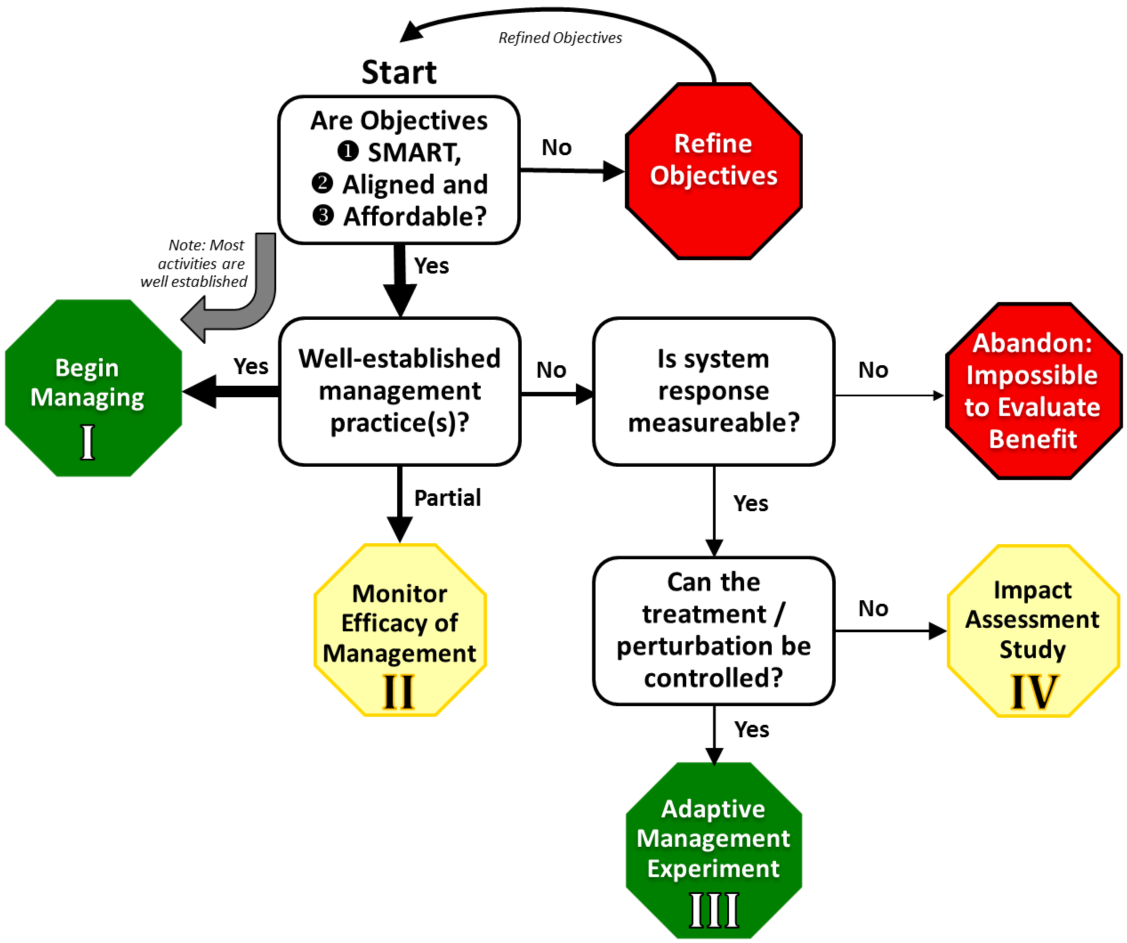


Figure 6.1: Flowchart for Management and Adaptive Management. Stop signs (red octagons) indicate that management is not adequately justified. Yellow octagons indicate that management should proceed with caution since success potentially depends on key assumptions about what is known. Green octagons indicate management that is well justified and/or supported by data.

Managers are often faced with a large list of potential actions and a limited budget. As a result, management actions can be constrained by available resources including personnel, equipment, and expertise. If the resources for an action are not available, managers must either work to procure additional resources or refocus their activities.

Planned (pro-active) management is difficult because natural systems are inherently unpredictable. Species and ecosystems can be altered due to obvious external disturbances (e.g. unauthorized trail building, drought, fire) or as the result of less obvious internal changes (e.g. invasive plants, insect pests, species shifts). As a result, managers need to be prepared to respond rapidly to a newly identified problem. Managers need to be able to quickly assess problems and re-allocate effort in a way that is similar to triage in medicine (prioritizing based on urgency).

I) Begin managing (well-established practices)

For many actions, best practices are well established and management triggers are fairly well understood. For these (weed control, maintaining signage and fencing), the main issue is simply documenting what is being done, and why because there may be several potential management actions that are possible. The initial step is to document why you chose a particular activity. For example, fencing, signage, and outreach to local stakeholders are all potential methods to control creation or use of illegal trails. The first step in the management process is to decide what approach to take and to document this for future reference.

Quantifying and recording some measure of management effectiveness is also beneficial. Since this type of management carries little uncertainty, it is important that monitoring efficacy be simple and inexpensive. It is possible that management success will vary year to year or place to place. Simple monitoring of efficacy should improve management through time by allowing more targeted activities.

The success of management may require coordination across preserves or jurisdictions. Communicating the extent and success of ongoing management is important at broader scales and over long time periods. An important part of this process is uploading activities and data to supported regional databases like SC-MTX (South Coast Multi-Taxa Database; http://mtx.sdmmp.com/), as several fields of the database are geared to document current management practices, costs and efficacy. Community forums and meetings for managers (e.g. South County Land Manager meetings) have also been a means to informally share information on management practices among preserves.

II) Managing under modest uncertainty (partial understanding)

Many situations may arise where the best management practice is not established although there may be information to support a limited range of mgmt. action options.. As a result, management decisions are being made with a modest level of uncertainty. Under this scenario, the uncertainty exists but is limited and does not warrant an expensive or time-consuming replicated experiment. On the other hand, the suitability or efficacy of a management action is variable enough that careful monitoring of the outcome is warranted[3]. The key is to define the level and type of monitoring that is consistent with the programs goals, the level of uncertainty, and the cost of monitoring[4].

Control of non-native herbs is an ongoing and difficult process. The efficacy of mechanical or chemical control can depend on the amount of thatch, the presence of a viable source of native seeds, soil type and condition, slope and aspect, as well as the weather. Monitoring regrowth of native and non-native plants is required to establish that the action met its intended target. Relatively rapid field techniques like vegetation height, cover, and description of the dominant species will provide enough information to evaluate success.

As stated above, both the management intervention and the results should be shared with important stakeholders at community meetings and other venues and uploaded into the regional database(s) like MTX. This provides some institutional memory of the activities as well as allows larger, regional analyses.

III) Managing under severe uncertainty (Adaptive Management)

One key component of active adaptive management is the use of replicated management experiments to rapidly and efficiently reduce uncertainty[1]. Thus, an important component of adaptive management is the design, execution, and analysis of management experiments.

It is important to reiterate that management and adaptive management are not the same. Many management activities are well understood and an experimental approach is not needed. Worse, using an experimental approach when established practices exist may delay critical monitoring or management while re-discovering what is already known. This section focuses on types of experiments that may be appropriate when managing in the face of significant uncertainty. Even so, the design and analysis of experiments is an enormous topic. In this section, we discuss some of the general aspects of good experimental design, illustrate common applications, and give a concrete example.

Elements of good experimental design

The distinction between a sample and an experiment hinges on the ability of a preserve team to control the process of interest. Sampling involves the selection of individuals and the measurement of one or more variables of interest from the selected individuals. Experiments are typically planned manipulations when one or more treatments are imposed on individuals in order to observe their responses. Note that the term individual is used very broadly here. Depending on the objective, individuals could be visitors to a city park, banded burrowing owls, vernal pools, seedlings of an endangered tree, or a collection of marked 1m by 1m plots of degraded grasslands.

Sampling, even very good sampling, cannot be used to determine cause and effect. This idea is easy to illustrate from real, well-sampled data (Figure 6.2). Scientists have been measuring the concentration of CO_2 in the atmosphere for decades. NOAA publishes estimates of the average global carbon dioxide concentration every year. Likewise, the CDC monitors the prevalence of obesity among adults in the US. There is an almost perfect correlation between the global concentration of CO_2 and obesity in the US. Does this extremely strong correlation suggest that elevated CO_2 is causing obesity? Or that obesity in the US is a major driver of global CO_2 concentration? Of course not. The two variables appear related because of one or more hidden factors. In this case, both obesity and CO_2 concentration have risen at nearly the same pace since 1985. As a result, there is an apparent relationship between the variables, even though they are not directly related. This amusing example illustrates that it is often dangerous to conclude cause and effect from observational (monitoring) data. Indeed, the role of experiments is to document cause and effect relationships.

Experiments are the only fully convincing way to demonstrate cause and effect. In an experiment, the researcher deliberately imposes some treatment on individuals in order to observe their responses[5]. Ideally, experiments can eliminate or control extraneous (hidden) factors. Experiments are most effective when they adhere to four critical principles, **control**, **comparisons**, **randomization**, and **replication**[6].

An experiment is well controlled when the experimenter has tight control of the planned treatments and has been able to eliminate or reduce potential sources of bias and variability. For example, in weed control experiments, the timing, concentration, and application of an herbicide needs to be identical in all plots receiving the same treatment. In contrast, it is harder to control fire intensity in a series of prescribed fires because of potential differences in slope and aspect, fuel load, wind speed, humidity and other variables.

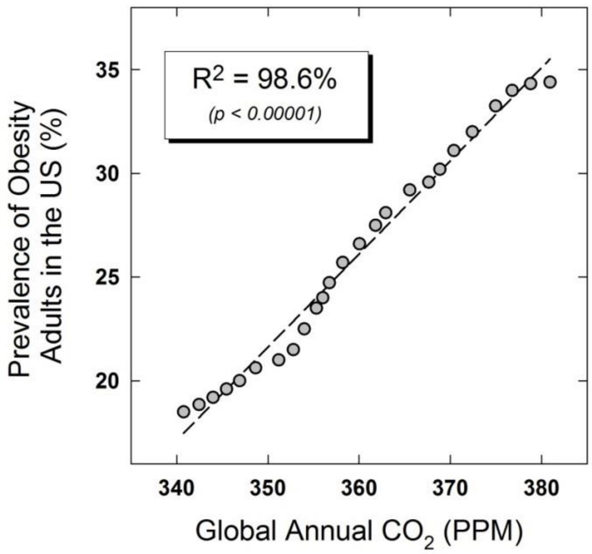


Figure 6.2: There is a nearly perfect linear relationship between global annual CO_2 concentration and the prevalence of obesity (BMI > 30) in adults in the US. The graph is based on very rigorous monitoring data collected from 1982 to 2006 by NOAA and the CDC.

When we strive to control all aspects of an experiment, we run the risk of creating an artificial environment. For example, a restoration experiment might include supplemental watering to improve the success of seedlings. This additional water may make the results less realistic and therefore less relevant to management where watering is impossible. Experiments which compare multiple treatments, including a control treatment, allow strong inference despite potential experimental artifacts. Together, tight control coupled with relevant comparisons provide strong evidence for cause and effect.

Randomization and replication go hand in hand and are necessary to separate the true response of the system to the experimental manipulation from chance effects and pre-existing differences among individuals. Replication simply means imposing the same treatment on multiple individuals or experimental units. Weed control experiments should use chemical control methods on several plots. Plots will differ in the relative composition of species, soil conditions, and seed bank. The use of replicated treatments will allow the experimenter to evaluate whether there is a consistent response greater than the natural variability observed among plots.

Randomization refers to the random allocation of treatments to individual replicates. It is often difficult to have the self-discipline to implement random allocation of treatments in the field. We often tend to want to implement what we hope is the most effective treatment on the individuals/plots that will be of greatest benefit. It is important to avoid this seemingly innocuous decision. Choosing which units receive particular treatments increases the likelihood that the treatment groups differ in ways that have nothing to do with the treatment and instead reflect pre-existing differences. Random allocation removes subjective decision making from the process of deciding which replicates receive which treatments. The random allocation minimizes the risk of bias in the experiment which can lead to an incorrect result.

Common experimental designs

The design of a management experiment may be far more involved and complicated than the standard designs presented here[7,8]. It is important to realize that some experiments may require specialized expertise and experience. Individual scientists and managers need to acknowledge their own limits and seek support or build collaborations for large and/or complex projects.

The simplest design is the <u>completely randomized,</u> <u>1-factor</u> experiment. In some ways this is analogous to the simple random sample described in the previous chapter. In particular, completely randomized implies that the individuals (e.g. experimental units, plots) are assigned to treatments at random (Figure 6.3, left panel). The experimenter makes no attempt to restrict allocation of treatments which reduces the potential for bias. In a single-factor design, there is only 1 variable of interest although there can be multiple levels within a factor. For example, an experiment on watering to improve the success of a restoration experiment may include 3 levels: Control (no watering), low watering (e.g. once a month), and high watering (e.g. once a week). The only factor being manipulated is the amount of water (1-factor) but at several levels (in this case, three levels).

Often experiments need to tease apart the potential impacts of several different factors. In a restoration experiment, watering and the addition of native seed mixtures can both be vital to success. In a translocation project for small mammals, it may be important to evaluate the importance of moving related individuals (family groups or neighbors) as well as habitat enhancement at the release site. In both examples, 2 different factors are being manipulated simultaneously. The strongest approach to understanding the relative importance of each factor is a <u>fully-factorial</u> experiment.

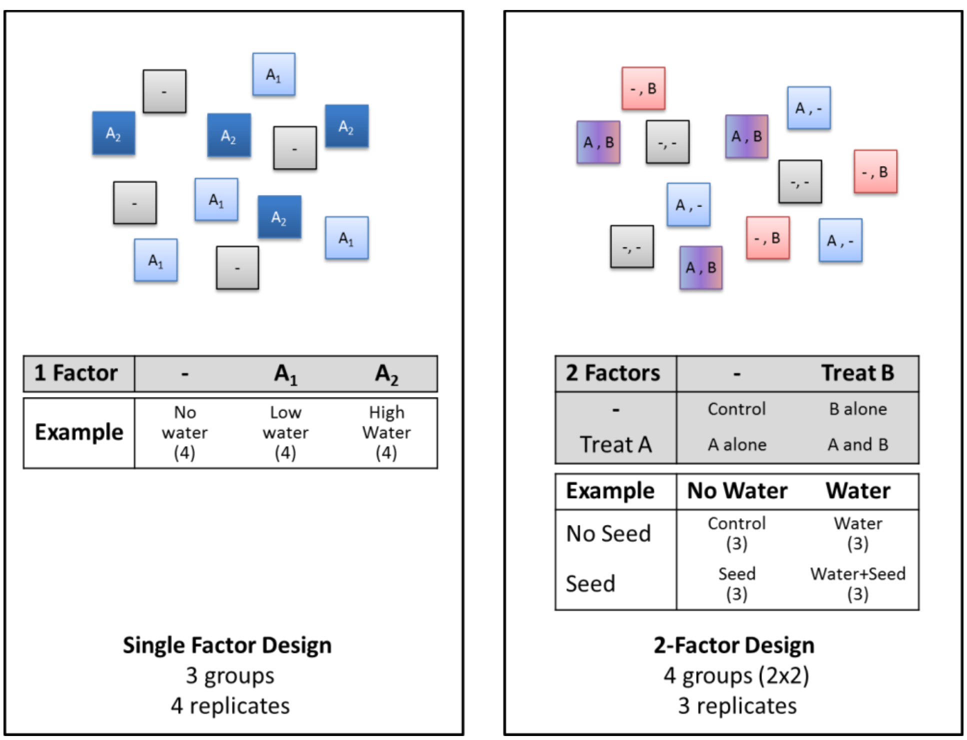


Figure 6.3: Two common experimental designs: 1-factor and 2-factors. In a 1-factor design (Left), a single variable is manipulated. In a 2-factor design (Right), two different variables are manipulated.

Factorial experiments are designs in which all combinations of both factors are used in the experiment (Figure 6.3, right panel). If an experimenter wanted to use two levels of watering (none, watering) and two levels of seed addition (none, seeds added), he/she would need four treatment combinations: ❶ control (no water or seeds), ❷ water alone, ❸ seed alone, and ❹ both water and seed addition. This allows the experimenter to separate the effects of watering and seeding as well as evaluate whether the effect of seed addition differs depending on the amount of watering.

Fully factorial designs can be very expensive if there are many factors or many levels within each factor. For example, a factorial experiment testing three levels of waters (none, 1 x month, 1 x week) and five seed mixtures (e.g. none plus four different native seed mixes) would require 15 treatment combinations in total (notice that this is simply 3 x 5 = 15). If each treatment was replicated three times (a typical minimum), then 45 experimental units would be needed.

It is possible to design experiments that test 3 or more factors. Following the restoration experiment theme again, an experimenter may wish to test the effects of watering (three amounts), seed mixtures (five combinations), thatch removal (two levels, unmanipulated or removed), and weed control (4 levels, none, chemical, mechanical, and hand weeding). This ambitious 4-way factorial experiment would require 120 treatment combinations (3 x 5 x 2 x 4 = 120) and 360 plots if three replicates were planned. Clearly, factorial designs become cumbersome as the number of factors or levels within each factor becomes large.

The implementation of a fully-factorial design still requires the experimenter to decide how to assign treatments to individual units/plots. Again, a simple and robust strategy is to allocate experimental units to individual treatments at random (Figure 6.3, right panel). This approach reduces potential bias, but can be difficult to implement in the field.

Management experiments are often improved by carefully controlling the allocation of treatments to experimental units. It is important that this process still involve some random element to avoid potential bias. Instead, we restrict the randomization in order to account for local variability. One such experiment is the complete-block, 1-factor design. When planning a complete block design, experimental units are divided into natural groups called “blocks” (usually adjacent plots or related individuals etc.). Within each block, one of each of the planned treatment is assigned randomly to an experimental unit (Figure 6.4, left panel).

The rationale for the complete-block design is fairly intuitive. The natural world is highly variable. By restricting the randomization of treatments into blocks, the analysis restricts the comparison of treatments within each block. This reduces the natural variability and increases power. The statistical analysis of a complete-block design is slightly more complicated than the analysis for a completely random design but the potential improvement in precision often provides a large net benefit.

In management, processes often occur at vastly different scales. This presents important challenges to the effective design of experiments. Evaluating post-fire restoration is a good example. Managers may use prescribed burns as one of the factors in their experiment. These prescribed burns may cover tens or hundreds of acres in a single planned event. The other factors (often watering, seeding, or weed control) are implemented on much finer scales. As a result, the size of the experimental units for all other treatments may be small relative to the burn area. Designs in which smaller units are allocated within these larger areas or impacts can be called split-plot designs (Figure 6.4, right panel).

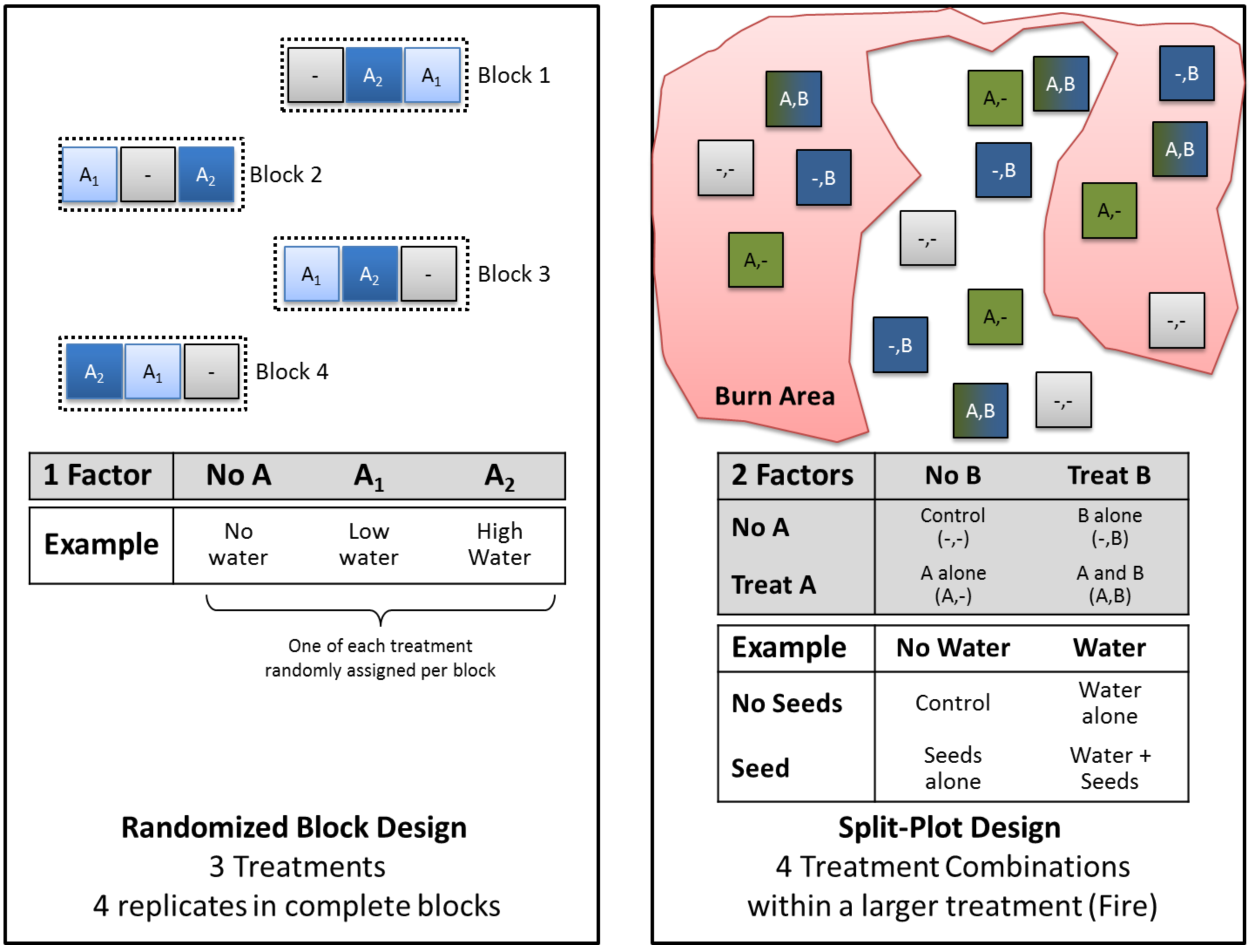


Figure 6.4: Randomized block and split-plot designs. The complete block experiment is designed to account for natural spatial variability by grouping treatments near each other into blocks. The split-plot design manipulates three factors, two that can be controlled in small areas (adding water and/or seeds). The third factor, fire from a prescribed burn, can only be implemented over a single large area.

Split-plot designs (partially) solve these scale problems by allowing the allocation of smaller experimental units within these larger treatments. In some ways, this is analogous to the randomized-block design because statistical comparisons are made among units within the same larger treatment. Like the block designs, split-plot designs are more complicated to analyze but can offer important logistical advantages over completely random designs. One important concern about split-plot designs is the fact that the large treatment is often unreplicated (as in the example). It is possible that the large treatment is unusual which may impact the validity or generality of conclusions drawn from the experiment.

Complete-block and split-plot designs are focused on accounting for the high degree of spatial variability inherent in ecological systems. Most ecological systems are also highly variable through time. Thus, no discussion of experimental design for management would be complete without discussing the length of experiments. The effectiveness of a given management action often varies through time because of factors that are uncontrollable and unpredictable (weather, drought, fire, pathogen outbreaks). Experiments should be long enough that the results can be evaluated across a range of natural conditions. In restoration of native herbs, this may require that the experiment is maintained through a complete el niño, la niña cycle (5 to 10 years?). This is true even though many of the species being tracked in the experiment are annuals. For long-lived organisms (e.g. shrubs, trees, some birds, carnivores), the experiments may take many years or even decades to evaluate.

Example: Controlling the non-native grass *Brachypodium distachyon*

The general concepts of experimental design are easier to understand within the framework of a concrete example. The following description and analysis is based on a well-designed and well-executed experiment performed at Crestridge Ecological Reserve (ER) by Patricia Gordon-Reedy (CBI). The experiment evaluated ways to remove or control the non-native grass *Brachypodium distachyon* (hereafter BrDi) and enhance native plant richness and cover. The experiment was targeted at BrDi, but managers expected that reduced BrDi cover would be associated with increased cover and species richness of native plants. This expectation is based on a widely held conceptual model of the system. This model characterizes the ecosystem as having two principal components, native herbs and non-native herbs. Reduction of non-native herbs, particularly the dominant grasses like BrDi, *Bromus spp., Avena spp.* allow many species of native herbs to grow.

The experiment used a 2-factor, complete-block design (Figure 6.5). The two factors were BrDi removal (none, mechanical removal, chemical (herbicide) removal) and thatch removal (none, thatch removed). Each of the 6 treatments was implemented in several replicated blocks across the landscape. The experiment is ongoing, but data from the first 2 years are already available.

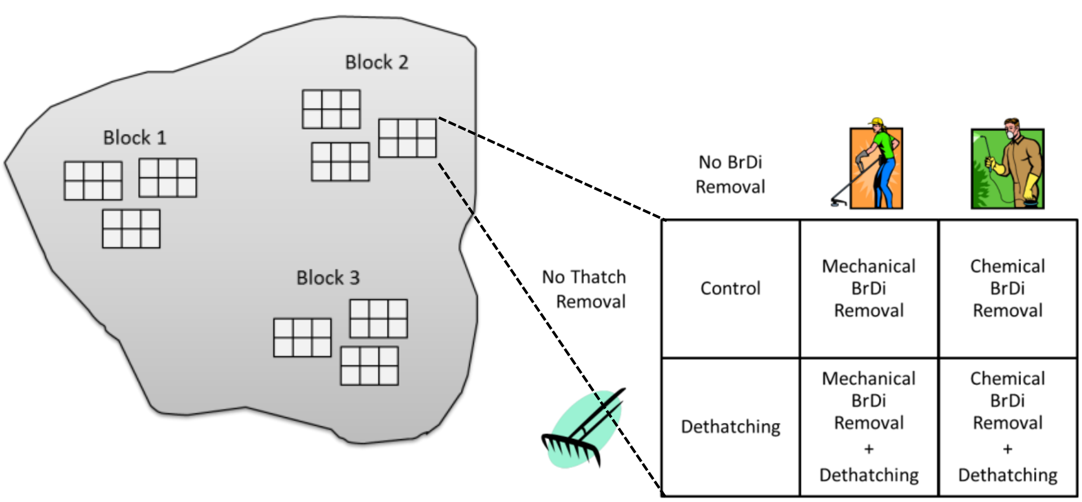


Figure 6.5: 2-factor, randomized-block design of the experiment at Crestridge ER. (Example courtesy of Patricia Gordon-Reedy, CBI)

After one year of treatment, the experiment suggested that mechanical and chemical control (herbicide) methods reduced BrDi relative to controls and that thatch removal had no important effect across the three treatments (Figure 6.6, left panel). Furthermore, the herbicide treatment was substantially better than the mechanical treatment at controlling BrDi. The results were quite different in the second year of the experiment. Mechanical removal was not effective at controlling BrDi.

Herbicide application reduced BrDi but to a lesser degree. The second year of the experiment suggests that BrDi control efforts are less effective than observed in the first year. More data is needed to understand why methods vary in their effectiveness.

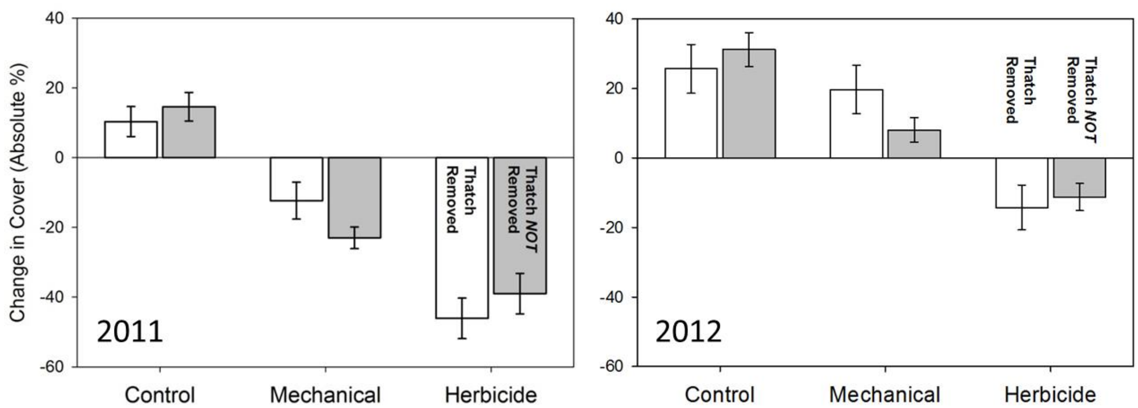


Figure 6.6: Change in cover of the non-native grass *Brachypodium distachyon* at Crestridge ER. Response after one year of treatment (Left) and after two years (Right).
(data courtesy of Patricia Gordon-Reedy, CBI)

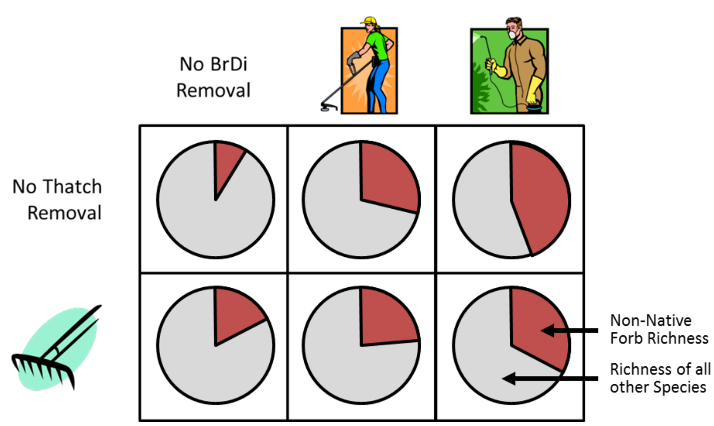


Figure 6.7: Change in the species richness of non-native forbs at Crestridge ER. The richness of non-native forbs increased significantly following BrDi removal.
(Data courtesy of Patricia Gordon-Reedy, CBI).

As mentioned earlier, managers expected that removal of BrDi would allow increased native plant cover and species richness. As a result, data was collected on several metrics in addition to the cover of BrDi. One important measure is the richness (number) of species in different functional groups. In particular, it is important to evaluate the species richness of non-native grasses and forbs. In the second year of the experiment, non-native forb richness increased significantly with the BrDi removal treatments (Figure 6.7). This suggests that as the non-native grass BrDi is removed, the species most likely to respond are also non-native. This is contrary to our expectations based on a simple conceptual model and suggests that the fundamental model may need to be revised.

The unfortunate response of non-native forbs in the second year of the experiment underscores the importance of monitoring a suite of variables in a management experiment. Although the experiment was focused on BrDi removal, there may be a myriad of direct and indirect effects on the vegetation community, soil properties, and nutrient cycling. Good experiments will anticipate these potential differences and track a suite of response variables that will capture broad changes in the system.

IV) Managing under severe uncertainty and with limited control: (Impact Assessment)

Many important management actions will be in response large impacts (disturbances) to the ecosystem. Often the magnitude and timing of these impacts are impossible to predict (e.g. fire, pest outbreak). In addition, many of the impacts cannot be controlled experimentally (e.g. climate change). In these situations, managers can take a quasi-experimental approach to evaluating the consequences of these impacts and developing an effective response[5]. Impact Assessment is a term that refers to a broad collection of methods used to evaluate these impacts.

Impact assessment uses a series of observations to provide insight into cause and effect. Since the impacts are typically uncontrolled and unreplicated, the inferences made may be confounded by processes that are poorly measured or misunderstood. The goal of impact assessment is to minimize the potential for confounding through the careful design of an observational study of the impact. The strength of an assessment study depends, in part, on three factors. (1) Impact assessments will be strongest when high-quality pre-impact data is available. (2) Inference is further improved by comparing data from the impact area to a non-impacted (reference) site. (3) The strongest inference will be based on multiple (replicated) impact and reference sites (Figure 6.8) with pre-impact and post-impact data.

The value of pre-impact data illustrates another potential benefit of baseline surveys and regular (omnibus) monitoring (See Figure 5-2 in Chapter 5). Since many impacts are unpredictable, it is difficult to plan for pre-impact data. The existence of baseline or surveillance data increases the likelihood that post-impact data can be compared to relevant pre-impact data.

Impact assessments can be studied by simply collecting data at a site following the impact or disturbance (Figure 6.8. "After Only"). Inference based on this design is limited since the data is only available from the impact site after the impact has occurred. Strong inference based on the data alone is impossible. Instead, strong conclusions hinge on our understanding about the pre-impact system. For example, the composition and structure of CSS vegetation communities are well described. Measurement of post-fire recovery is likely to be very useful even without pre-fire data. If recovery by native shrubs is absent or very slow and non-native forbs and grasses are dominant, we can conclude the site is degraded. If the local biologist or land manager knew that native shrubs were present, we can conclude the site was probably impacted by the fire.

Impact designs are stronger if there is a reference site and/or pre-fire data. Comparison to a reference group helps demonstrate that any change observed at the impact site was likely due to the impact (Figure 6.8. "Reference Site"). Inference is stronger when a well-matched reference site is stable while the impact site is changing. The use of a reference site is only a partial fix since it is possible that the reference site was different from the impact site even before the impact. Thus, the difference observed post-impact would be incorrectly attributed to the impact rather than a pre-existing condition.

Pre-fire data (Figure 6.8: "Pre/Post") allows a quantitative measure of change. Continuing the example of fire in CSS vegetation, pre-fire native shrub diversity, cover, and structure could be compared to post-fire data using the same metrics at the impact site. Large declines would suggest an impact. Again, this interpretation should be made with caution. Without a reference site, it is possible that this large change could be happening in other non-impacted systems. For example, shrub cover could be changing throughout the region to due drought or disease. Thus, the change through time would be incorrectly attributed to the impact rather than a process that is happening throughout the region.

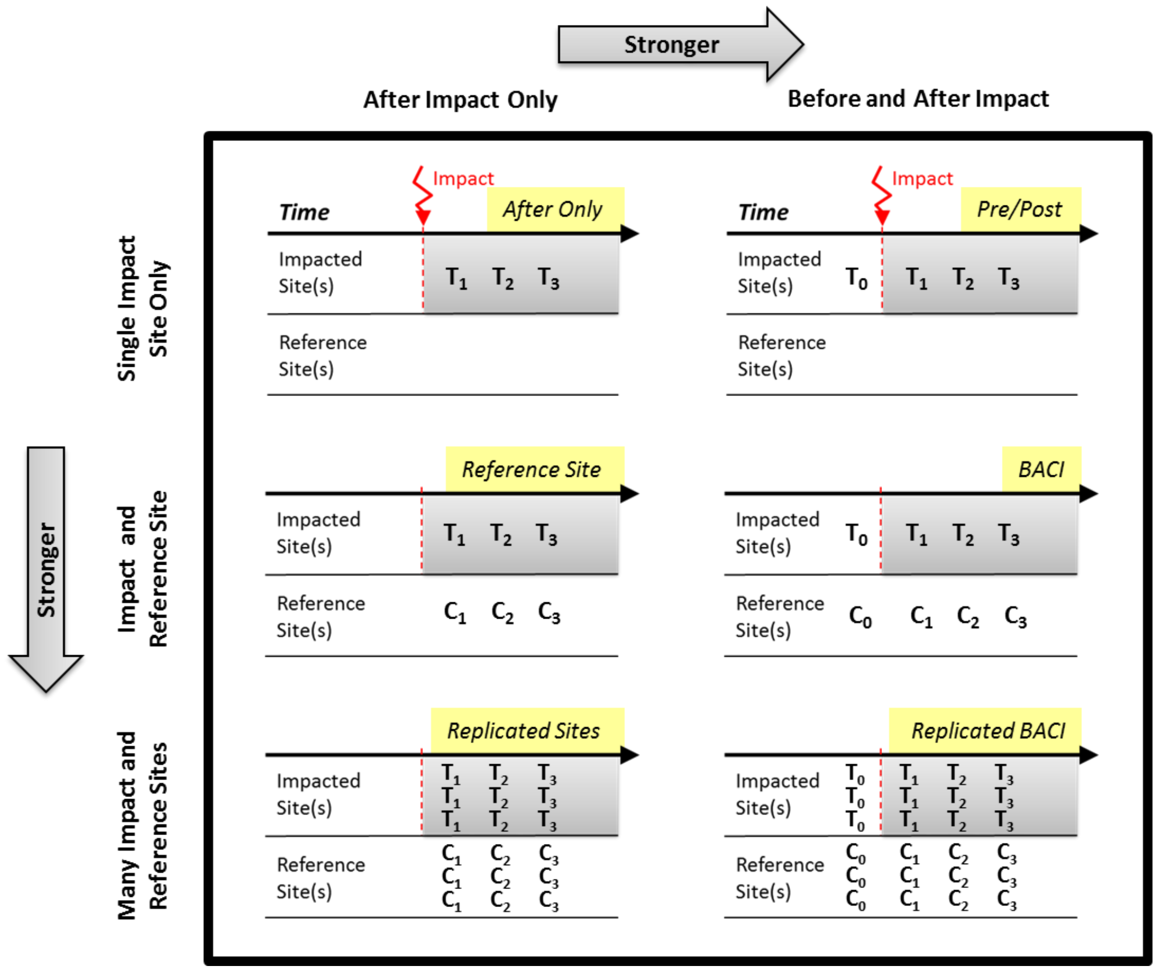


Figure 6.8: Examples of impact assessment study designs. The strongest designs have three features: (1) pre-impact data, (2) a non-impact reference, and (3) multiple sites/plots. The replicated BACI (Before After, Control Impact) design incorporates all three elements.

The simultaneous use of a reference site combined with pre-post data strengthens a study. This design is often called a BACI design[7]. BACI stands for Before-After-Control-Impact study. BACI designs have both a reference site (Control) and an impact site for which there is both pre and post-impact data (Figure 6.8: "BACI"). This design allows a manager to determine whether the change at the impact site is different from the change observed at the reference (control) site. This eliminates the problems mentioned above about pre-existing site differences and broad-scale changes across the region. BACI designs can still lead to erroneous conclusions since it is possible that the change at the impact site is not truly being caused by the impact itself. The strongest inference can be made when several different reference and impact sites are monitored (Figure 6.8: "Replicated BACI"). Inference is very strong if similar changes are observed at all impact sites but none of the reference sites.

Example: Post-fire response of carnivores

The strength and potential weaknesses of impact assessment can be illustrated with an example evaluating post-fire recovery/re-colonization and habitat use of carnivores after the 2003 Cedar fire. The example is loosely based on the MS thesis work of Paul Schuette at San Diego State University. The study compared carnivore activity at multiple sites inside the burn perimeter and at reference sites just outside the burn (Figure 6.9). Sites within the burn area were further divided into those that were near the perimeter and those in interior areas. More than 30 sites were monitored over an 18 month period.

The classification of sites into three categories was based on the *a priori* assumption that carnivore activity patterns near the fire edge would be similar (or recover faster) than those in the center of the large burn. Sites were also classified based on other characteristics like the density of housing and distance to road. These factors are potentially influence the presence of gray foxes, coyote and other carnivores. Monitoring was conducted seasonally for more than a year to ensure that observed patterns would not be an artifact of season or short term changes in carnivore activity.

Results from this impact assessment study were surprising. The presence of common carnivores was not strongly related to burn status (interior, edge, unburned). On the other hand, there was some evidence that the density of housing was an important predictor. Moreover, in some areas fire-fighting was concentrated near housing developments, so housing density was confounded with the burn perimeter. Finally, there was some evidence that the presence of coyote was negatively correlated with the presence of gray fox. This could be the result of different habitat preferences, differing responses to urbanization, or simply that gray fox avoid coyotes (a known predator). Despite the careful design of the study, it was not possible to tease apart these conflicting interpretations. Since impact assessments are not planned manipulations, some ambiguity in interpretation of causality is common.

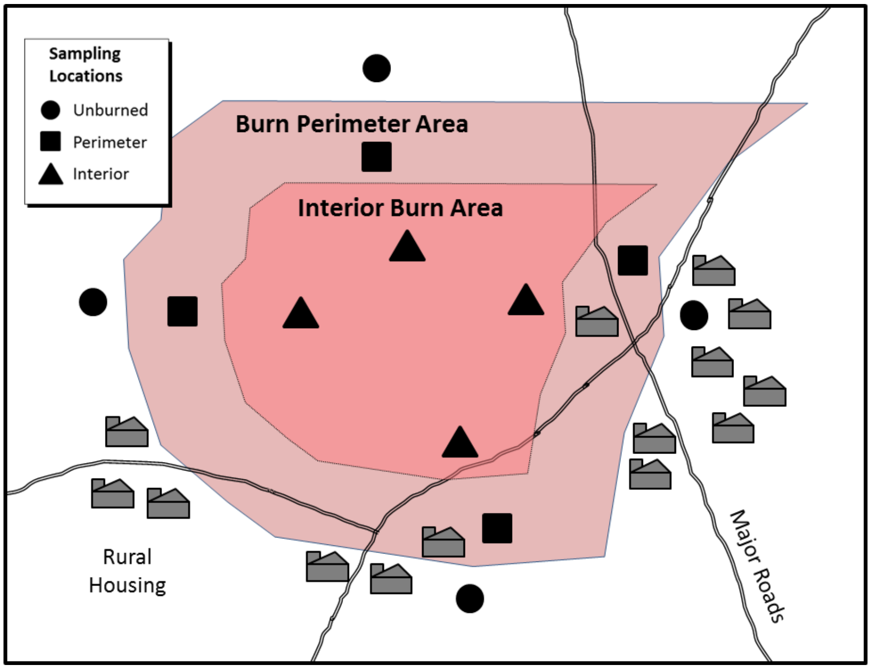


Figure 6.9: Impact study of carnivores following the Cedar Fire in San Diego. The example is based on Paul Schuette's MS thesis at SDSU. The design incorporates two strong elements, reference sites and replication. Pre-fire data was not available.

Chapter 6: Summary

- Management includes a broad array of activities from well-established practices to testing novel approaches.
- Prioritization and implementation of management actions at a particular site must reflect regional priorities and local needs.
- Adaptive management uses experiments to improve efficacy and efficiency by reducing uncertainty.
- Management experiments vary from simple treatment comparisons to complex designs testing multiple strategies over a heterogeneous landscape.
- Impact assessment studies are used when managers have limited or no control over an impact but are evaluating impacts and testing management responses.

Checklist

√	Task / Activity
☐	Management activity/activities are targeted to address high priority objectives that align with regional and local needs.
☐	Management activity is appropriate given the level of uncertainty and experimental control over the system (see flowchart in Figure 6.1).
☐	Data are collected on all management activities to allow evaluation of cost/benefits.
☐	Adaptive management experiments are replicated. Compare one or more strategies to an appropriate control.
☐	Impact assessment studies incorporate pre-impact data and multiple sites whenever possible.

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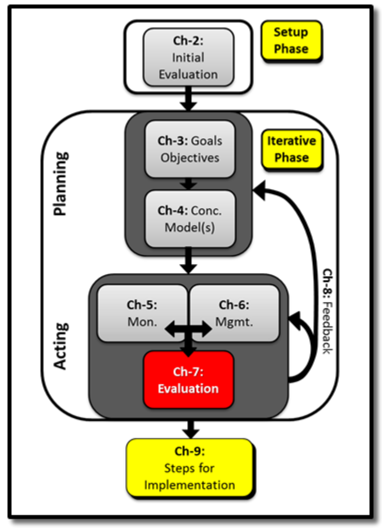
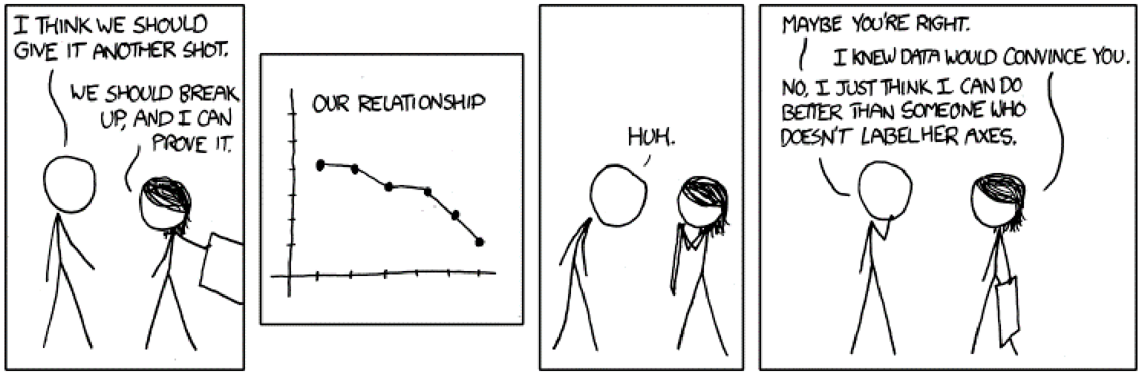
Chapter 7:
Evaluating data: Analysis, interpretation and synthesis





From the Web Comic XKCD. It reminds us that even a simple graphic requires some minimum standard of detail and completeness (labeling axes in this case).
Source: http://xkcd.com/833/

Chapter guide

The information and improved understanding from monitoring and management is the engine that powers adaptive management. To learn from monitoring and management activities requires that the data collected is analyzed, interpreted, and used to update goals/objectives, refine conceptual models and to improve future monitoring and management. Data analysis is not easily summarized since there are many techniques, each with unique strengths and potential weaknesses. Effective data analysis starts with informative graphics and robust summaries of the data. More complex inferential techniques should be used when required to understand the data. These techniques often require scientists with specialized training in statistics and thus often require broader consultation and collaboration.

Introduction

To complete the adaptive management feedback loop, data must be analyzed and interpreted within the broader context of monitoring and management. Some aspects of data analysis are simple and routine while others require substantial expertise (Figure 7.1) and there are many texts written expressly to cover this topic. In this chapter, we provide a structured approach to familiarize preserve teams with some basic terms and analytical approaches. Most importantly, the chapter outlines a decision tree to help guide management teams towards the type of data analysis that is (and is not) aligned with the data, the questions and expertise at hand. Analysis typically involves several steps including graphics and simple statistical summaries, common forms of estimation and hypothesis testing, and more sophisticated statistical analyses. Not all questions will require formal hypothesis testing, but all questions benefit from good data visualization and appropriate statistical summaries.

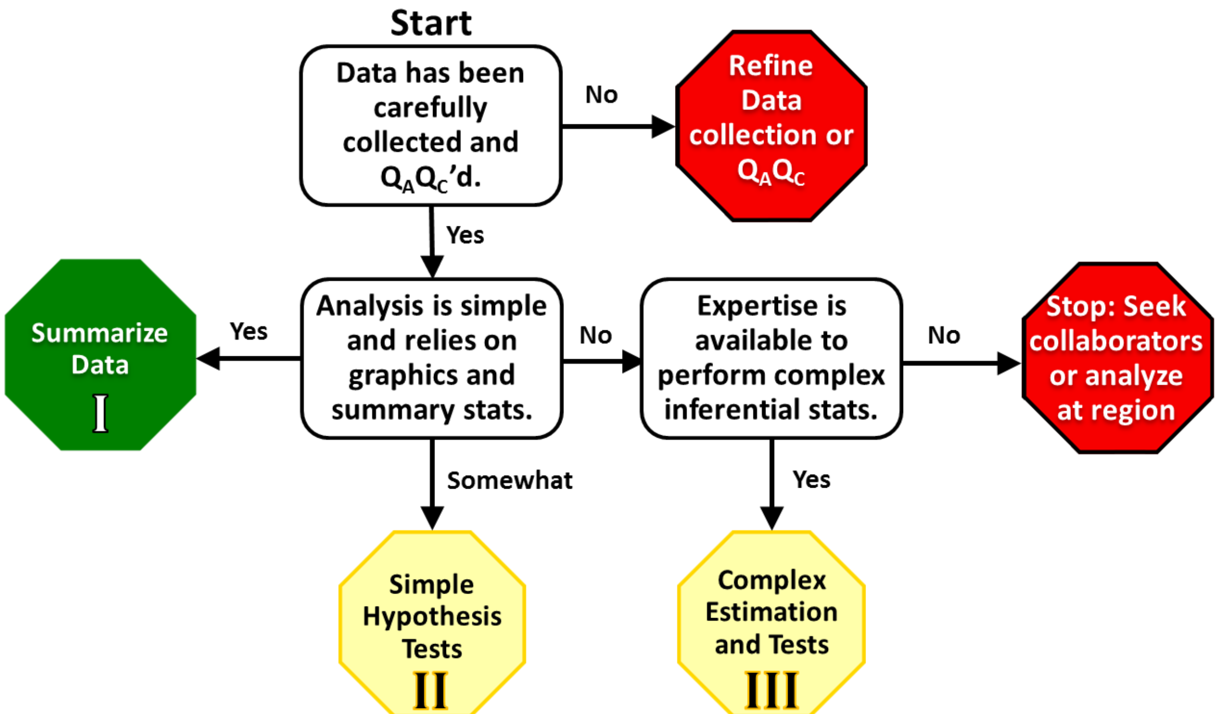


Figure 7.1: Flowchart for data analysis and interpretation. Stop signs (red octagons) indicate that data is not appropriate for analysis (e.g. poor experimental design or lack of Q_AQ_C) or that the analysis requires additional expertise. Yellow octagons indicate that data analysis management should proceed with caution since the interpretation of statistical analyses depends on satisfying their key assumptions. The green octagon indicates that all projects should include graphics and summary statistics.

I) Summarize data: Graphing and statistics

Visualizing and summarizing data are key elements of the analysis of biological data. Visualizing data is important because human beings are masters at processing visual information. A good graph is truly worth a thousand words. Yet despite this (or indeed because of this) graphics can also mislead.

The pair of graphs in Figure 7.2 illustrates this issue. Both depict the mean annual concentration of CO_2 over a 25-year span from 1982 to 2006. The top graphic uses a scale that includes zero, as is often recommended. This gives an impression that CO_2 levels have not changed much in the last quarter century. This impression is reinforced by plotting the average concentration as a reference line. The bottom panel shows the same data but uses a more appropriate scale to communicate that there has been a large increase in CO_2 levels. Technically, both graphics are correct. The top graph shows that the proportional change in CO_2 levels have increased only modestly (~12%). The bottom graph shows that the absolute change is around 40 ppm. Climate change scientists have determined that the rapid and recent increase in atmospheric CO_2 far exceed natural changes observed in the last 650,000 years[1]. It is important that data graphics are consistent with the scientific interpretation of the information as in the bottom panel.

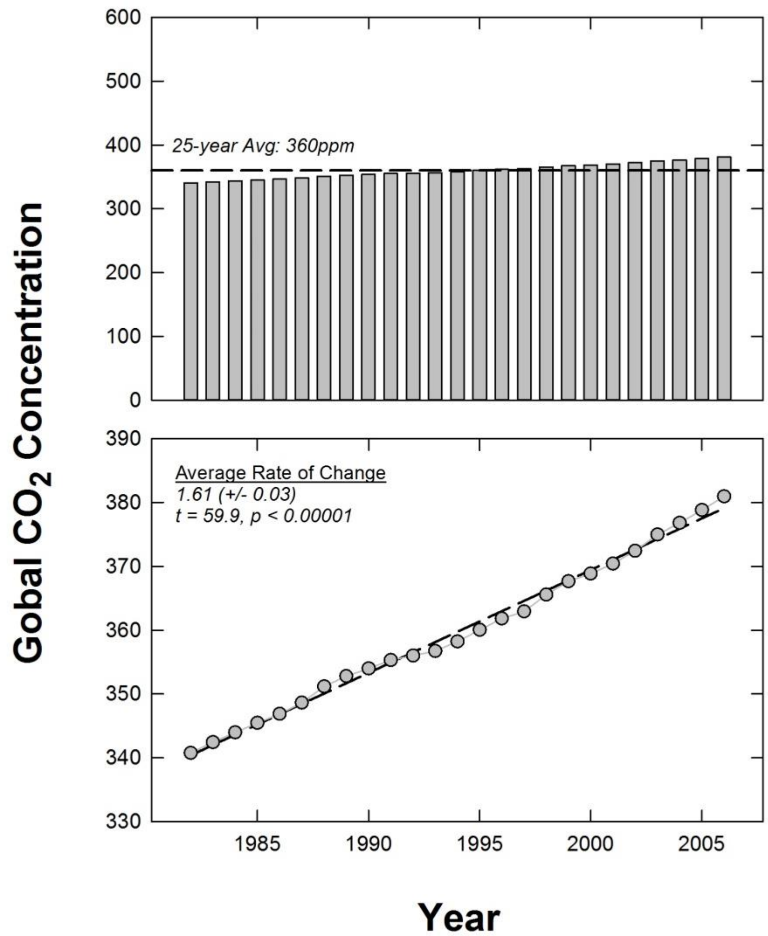


Figure 7.2: Two graphs of the same data on CO_2 concentrations through time. **(Top)** The bar chart includes the value of 0 on the y axis giving the overall impression that CO_2 is increasing little, it at all. **(Bottom)** The line and scatter plot uses a more appropriate scale and communicates that that CO_2 is increasing rapidly.

Elements of good graphics

The overriding goal in developing good graphics is maintaining fidelity to the data. Good graphics should not overstate or understate the patterns in the data. In addition, good graphics should be easy to interpret. That is not to say that all graphics should be simple, but that complex graphics need to carefully justified and rendered. Finally, graphics should be efficient, meaning that graphics should use the minimum detail necessary to accurately reflect the data. One mnemonic for good graphics is the ACCENT principles[2] (Table 7.1). The accent principles aim to improve graphics by emphasizing the pattern(s) while removing or de-emphasizing elements that mislead or clutter a graph. In addition, scientists have studied how accurately graphic elements are perceived by humans. This has led to a ranking or hierarchy of graphical elements based on the ease and accuracy on interpretation[3]. Recently guidance documents and how-to manuals have been developed for biologists and land managers[4].

Table 7.1: Components of effective graphics. The ACCENT principles.

A	Apprehension: Easy to understand and interpret.	*Does the graph maximize apprehension of the relations among variables?*
C	Clarity: Elements are easy to Distinguish	*Are the most important elements or relations visually most prominent?*
C	Consistency: Consistency with previous graphs	*Are the elements, symbol shapes and colors consistent with their use in previous graphs?*
E	Efficiency: Portray complex relations as simply as possible.	*Are the elements of the graph economically used?*
N	Necessity: The need for the graph, and the graphical elements.	*Are all the graph elements necessary to convey the relations?*
T	Truthfulness: Ability to represent the data accurately	*Are the graph elements accurately positioned and scaled?*

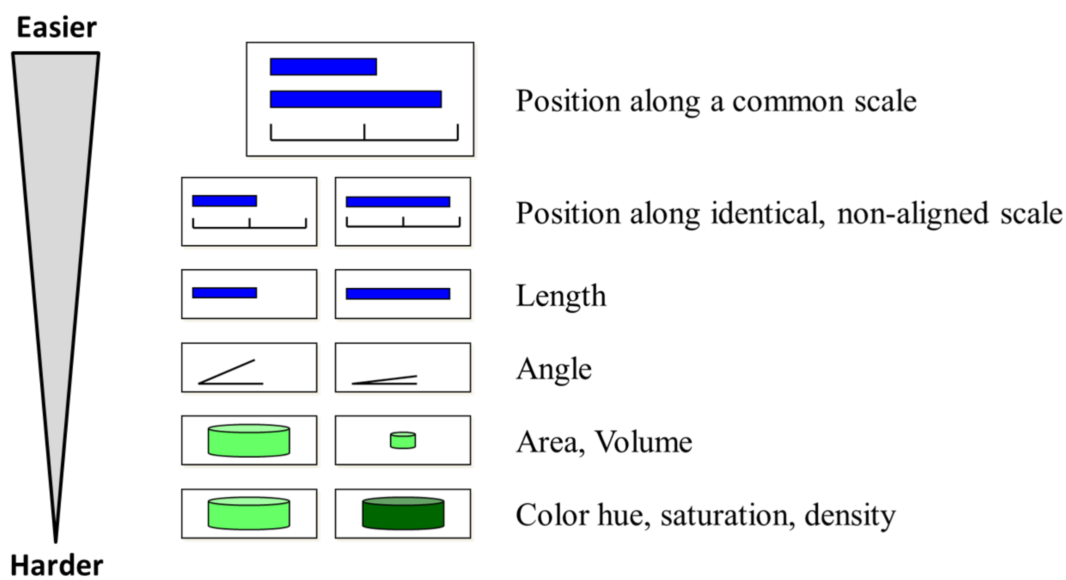


Figure 7.3: Ranking of graphic elements based on the ease and accuracy of interpretation. Adapted from Cleveland, 1994, The Elements of Graphing Data (2^{nd} ed).

Good graphics: Two examples

Effective graphics can be developed with little experience and software that is commonly available. The key is to develop graphics to simply and effectively illustrate patterns in the data. A good example comes from rare-plant monitoring being done by the City of San Diego Department of Parks and Recreation (Figure 7.4). This graph plots the cover on non-native plants at 7 sites being monitoring for San Diego thorn-mint (*Acanthomintha ilicifolia*). The graph depicts increasing cover on non-native plants over a 5-year period from 2006 to 2010. The graphic includes the observed values and best-fit regression line at each site. It is easy to see that non-native cover has increased dramatically and at about the same rate across all monitored sites. The graph is well executed as its axes are well labeled, sites are fairly easy to distinguish, and they are graphed at the appropriate scale.

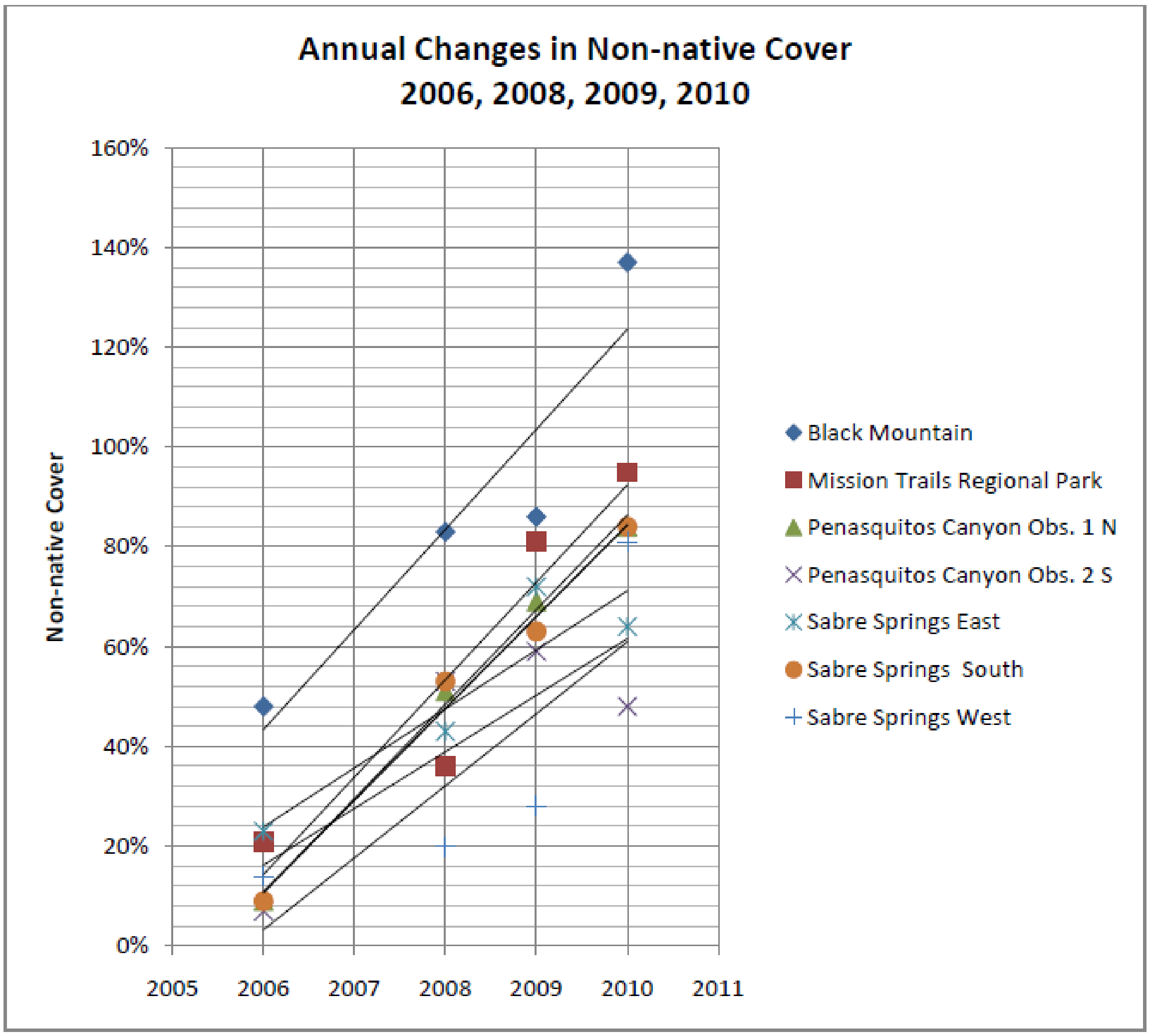


Figure 7.4: Observed changes in the cover of non-native plants at sites being monitoring for *Acanthomintha ilicifolia* (San Diego thorn-mint). Graphic courtesy of Betsy Miller, City of San Diego, Department of Parks and Recreation

The second example presents data from a large vegetation monitoring program. The graphic (Figure 7.5) contains 8 panels and allows the reader to compare between the two dominant vegetation communities (CSS and Chaparral) as well as across different response variables. Interpretation of the graph is facilitated by the use of common scales for all six panels depicting cover. In addition the scale for species richness is the same for chaparral and CSS. The wider space between richness and cover panels helps differentiate the two types of variables.

Several important patterns are clear from this graph. Species richness jumped between 2007 and 2008 (likely because 2007 was very dry and few forbs germinated). Native shrub cover dominates chaparral and CSS communities and is about 50% higher in chaparral. Non-native grass cover is higher than non-native forb cover in both chaparral and CSS. Moreover, non-native cover is higher in CSS communities than in chaparral communities. Finally, the changes in cover were incremental with the notable exception of non-native grass cover. Non-native grass cover increased dramatically from 2007 to 2010 but then leveled off or dropped slightly. These differences and trends are well supported by more complex statistical tests and are easy to discern from this graph.

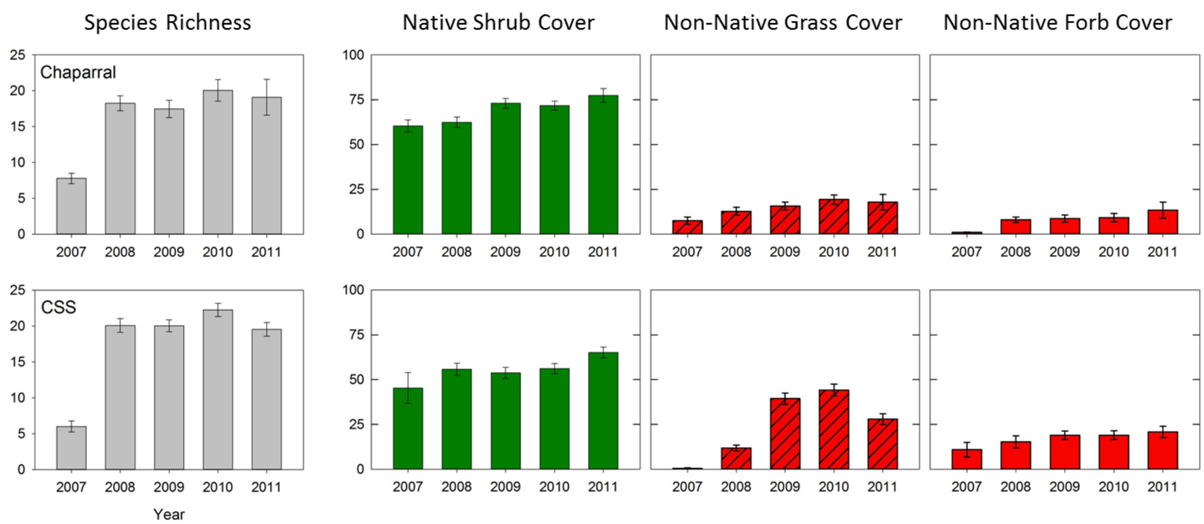


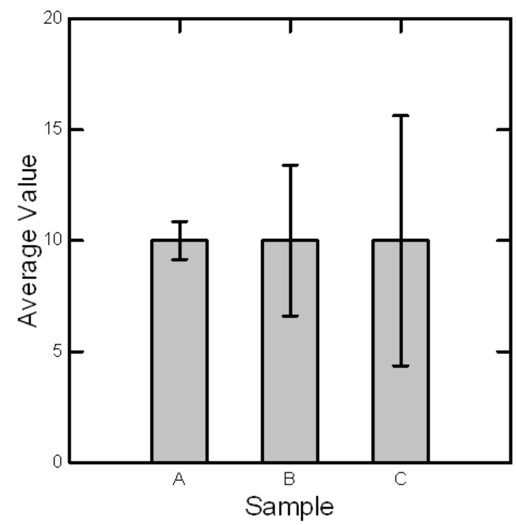
Figure 7.5: Observed changes in the richness cover of Chaparral and CSS vegetation communities throughout San Diego. This graphic has 8 panels representing 272 visits to 97 plots sampled across 14 sites. Data from Strahm and Deutschman, San Diego State University

Summary statistics:

Simple statistics like the sample mean (average) and standard deviation are important tools to characterize patterns in data. The concise description (or summarization) of patterns in the data should be linked to the process of visualizing the data. This is best illustrated with an example using hypothetical data (Figure 7.6). For this example, three datasets are constructed that have identical sample means although the sample standard deviations differ.

The reliance on the mean and standard deviation would miss the most important differences among the samples. In sample A, all the values are clustered tightly around the mean value of 10. In Sample B, the simple statistical summaries suggest that the data are more variable but centered on 10. Instead, most of the data are tightly clustered around the value of 9 except for 1 outlier. Finally, the third sample have two distinct clusters of data, one centered on 5 the other on 15. The important differences between the samples have to do with the potential outlier in sample B and the two distinct modes in sample C. Both of these features are missed when reporting the sample mean.

	Sample		
	A	**B**	**C**
	9.9	9.0	4.5
	10.1	10.0	15.5
	10.5	8.0	6.0
	12.1	9.0	14.0
	9.5	9.3	5.0
	9.4	8.8	16.0
	9.6	9.0	14.5
	9.7	19.0	5.5
	9.7	8.5	4.0
	9.6	9.5	15.0
Mean	**10.00**	**10.00**	**10.00**



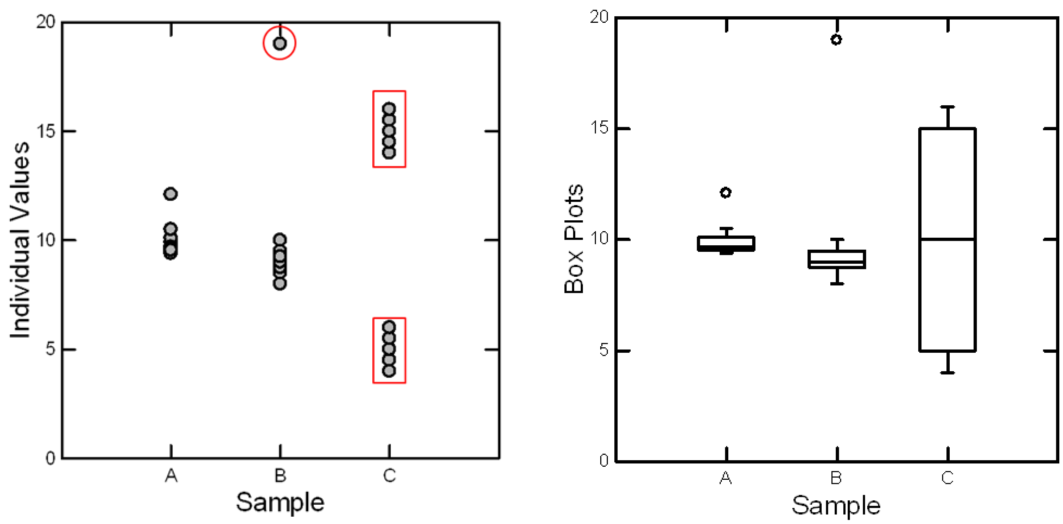


Figure 7.6: Three graphs of the same hypothetical data. The top right panel graphs the sample mean and standard deviation which is typical. The bottom panels are alternative graphics that reveal more information. In the dot plot (bottom left), the outlier in sample B and the two distinct groups in sample C are highlighted in red. The mean and standard deviation do not capture these important differences between the samples.

This simple example serves as a reminder that simple statistical summaries can be misleading. Summaries of the data should be paired with visualization of the data to avoid misinterpretation. In addition, robust measures like the median and inter-quartile range should be explored as possible alternatives to the mean and standard deviation. These measures are less familiar to biologists but are often less sensitive to unusual points or uneven statistical distributions.

II) Analysis: Simple hypothesis tests

Drawing strong conclusions from monitoring and management data often require formal statistical tests to separate signal from noise. Ecological data are notoriously noisy (variable) and detecting significant trends or differences among groups is difficult. There are many types of hypothesis tests that may be useful and appropriate in monitoring and management. This complexity also increases the chance that a poorly conceived or executed analysis will be misleading. Common problems include inappropriate choice of statistical test, failing to meet the assumptions of the test, extrapolation beyond the observed data, or misinterpretation of the test statistics themselves. In this section, we describe several common approaches and describe a strategy for using hypothesis tests monitoring and management data.

The first challenge is to choose the test that is appropriate for the question being asked and the nature of the data that was collected (Table 7.2). It is important to understand the fundamental difference between measurement data and count data. It is also important to understand the distinction between averages, proportions as point estimates and relationships between variables (e.g. slopes). There are several good textbooks and manuals on choosing and using statistics for biologists. These may make useful reference materials for biologists and land managers[5-7].

Table 7.2: Choosing the correct statistical approach based on question and type of data.

Measurement data (Continuous)	Means	Inference about the mean from 1 sample or treatment	**Confidence Intervals or 1-sample t-test**
		Inference about the mean from 2 samples or treatments. Determine whether they are paired.	**Paired t-test or 2-sample t-test**
		Inference about the mean from 3 or more samples or treatments	**ANOVA** *(Analysis of Variance)*
	Relationships	Linear relationship between 2 variables	**Correlation and Regression**
		Linear relationship between 2 or more explanatory variables and 1 response	**Multiple Regression**
Categorical Data (Discrete)	1 variable	Inference about proportions relative to an a priori hypothesis	**Goodness of Fit Chi-Square**
	2 variables	Inference about whether rates/proportions are associated	**Contingency Table Chi-Square**

Example of hypothesis testing: Non-native cover in San Diego.

We will revisit the data on non-native cover at sites managed for San Diego thorn-mint as an example of the role of that hypothesis testing can play in making inferences (Figure 7.7). The data are graphed with the best-fit regression line. This is an appropriate measure of linear change through time, an idea well supported by the graph. Regression can be used to compare the slopes (rate of change) at thorn-mint sites (Figure 7.7, left panel) relative to a broader sample of CSS and chaparral sites throughout San Diego (Figure 7.7, right panel). The average slope observed at thorn-mint sites was +14.9 (+/- 2.9) per year which is similar to the 19.7 (+/- 4.7) observed throughout the region. T

These estimates and their standard errors were used to construct an approximate t-test. The resulting t-value of 0.87 (p = 0.42) suggests that the slope estimates are not significantly different. This provides an important context for interpreting the data at the thorn-mint sites. Although the increase is notable, it is similar to increases observed throughout the region. The reference data indicate that this change is likely part of a larger cycle driven by weather (rainfall) or other broad-scale factors.

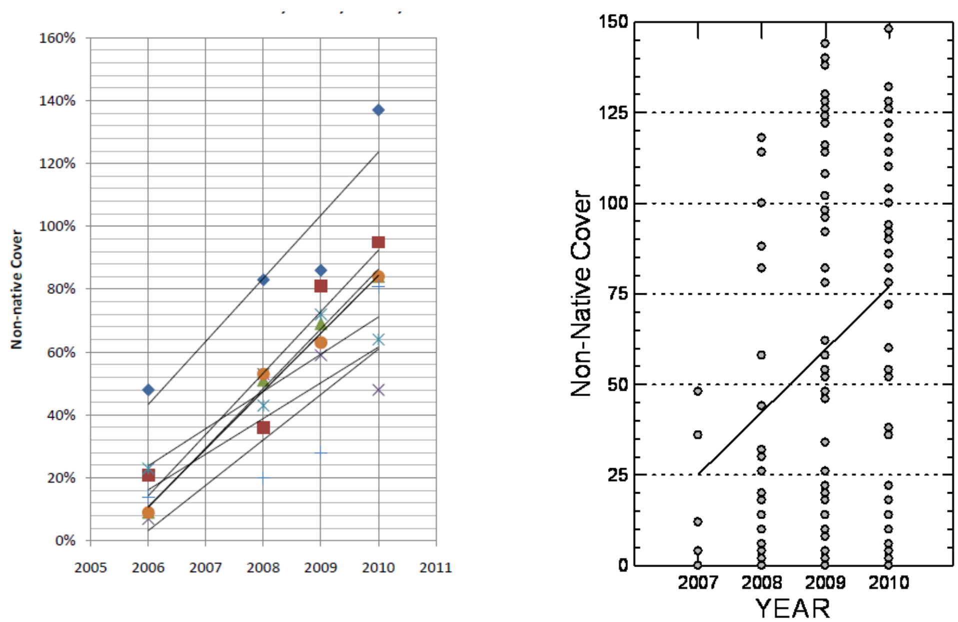


Figure 7.7: Two graphs depicting the change in non-native cover over a 4 year period. (LEFT) Data from Betsy Miller, City of San Diego, Department of Parks and Recreation (RIGHT). The rates of change (increase in non-native cover per year) were not significantly different between the two studies. Data from Strahm and Deutschman, San Diego State University.

The comparison of regression lines assumes that the true relationship is linear (e.g. straight line). This is an important assumption and one that should be tested, or at least evaluated. When a quadratic relationship is fit to the broad scale data, there is some evidence that the relationship is non-linear. Fitting a quadratic curve to the data changes the interpretation substantially (Figure 7.8, middle panel). The new curve suggests a leveling off or even a slight decrease in non-native cover. Adding the next year's data demonstrates that the quadratic model was superior to the linear model.

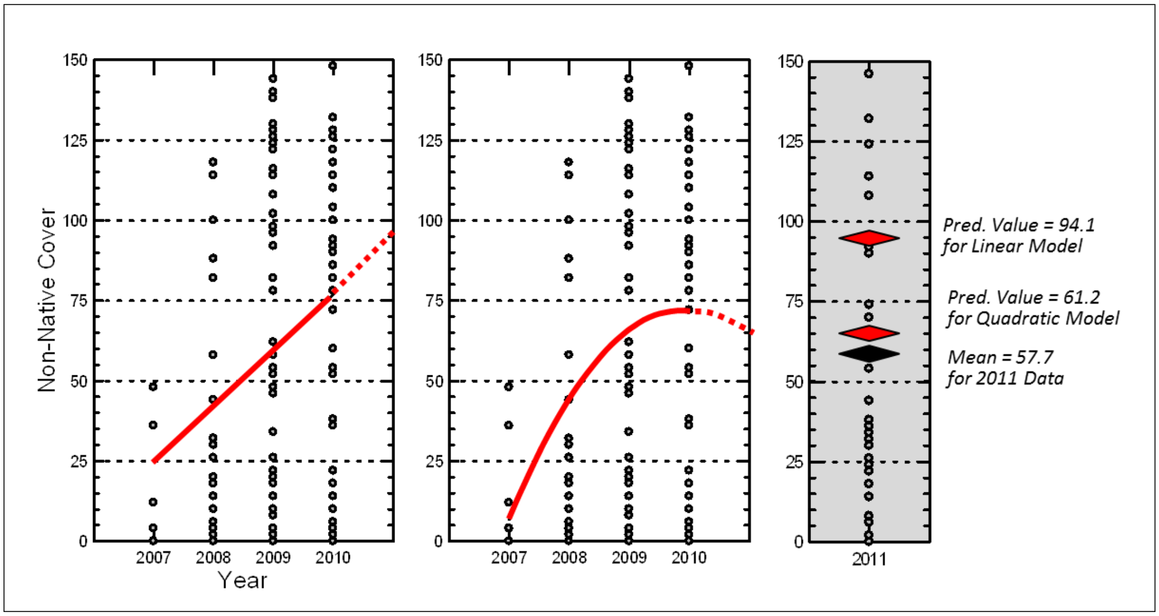


Figure 7.8: Graph depicting the change in non-native cover fit with a quadratic model instead of a linear model above. The quadratic model provides strong evidence that the rate of increase in non-native cover is slowing. In fact, the quadratic model does a much better job predicting the non-native cover for the next year (in this case, 2011). This insight was masked by the use of a straight-line fit. Data from Strahm and Deutschman, San Diego State University.

This example also provides insight into how the choice of statistical tests can obscure important changes. The inclusion of a straight line on the graph leads the reader to see a linear relationship, even if there is some evidence that the relationship is curvilinear. This example also reinforces the importance of longer-term studies for management. The inclusion of 2011 data demonstrated conclusively that the increase in non-native cover had slowed and even dropped slightly.

III) Analysis: Complex estimation and tests

Many datasets from monitoring programs and management experiments will be complex and require substantial expertise to analyze. Examples from monitoring include data from 2-stage or cluster sampling, adaptive sampling, or panel designs where different groups are sampled over several time periods. Using mark-recapture techniques to estimate changes in population density over time is another example where substantial expertise is needed. Management experiments with blocked, split-plot and repeated measures elements are also challenging. In addition, many impact assessment studies lack experimental control and as a result the identification and elimination of confounding variables is done in the analysis phase. In most of these cases, the analysis will likely be conducted in collaboration with experienced statisticians at the wildlife agencies, state and federal organizations (e.g. USGS) or at universities.

We illustrate the challenge of a complex analysis using the weed-control experiment introduced in the previous chapter. This experiment evaluated ways to remove or control the non-native grass *Brachypodium distachyon* (hereafter BrDi) and enhance native plant richness and cover. The experiment used a 2-factor experimental design. The two factors were BrDi removal [none, mechanical removal, chemical (herbicide) removal] and thatch removal [none, thatch removed]. Each of the 6 treatments was implemented in three replicates within three blocks across the landscape. Thus, there were a total of 9 sets of each treatment combination. Each plot was measured before and after the experimental manipulation. This study has elements of complete block, split-plot, and repeated measures combined the 2x3 factorial design.

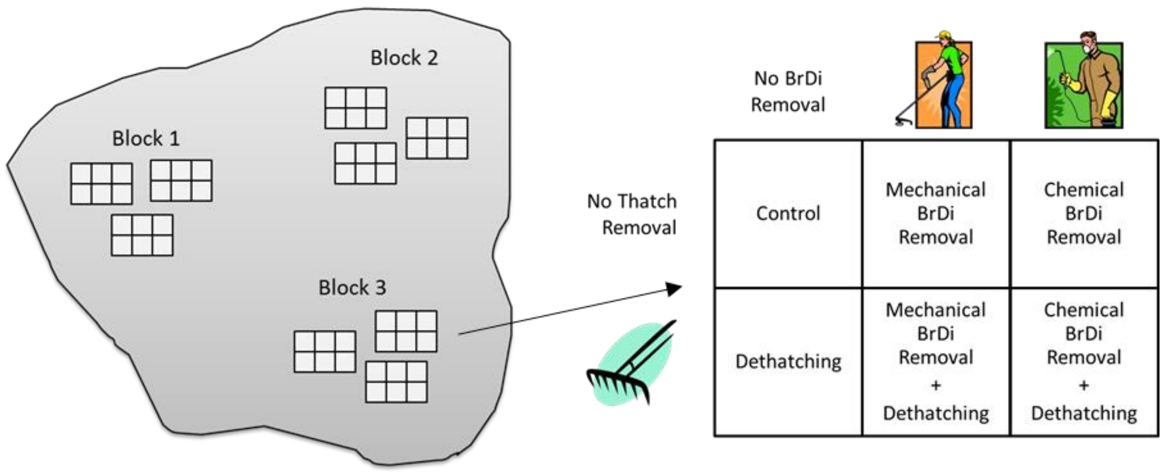


Figure 7.9: Design of the experiment to control *Brachypodium distachyon*.
(Example courtesy of Patricia Gordon-Reedy, CBI)

Data visualization is always an important first step in analyzing complex data like those from this experiment. In Figure 7.10, we graph the change in BrDi cover for each of the 9 replicates. Positive values indicate increased BrDi cover, negative values indicate a reduction in BrDi cover, and 0 is no change. The graph suggests that chemical control is more effective than mechanical, that BrDi cover was more variable in the thatch removal treatment, and that the Block 1 (green) tended to have higher BrDi cover.

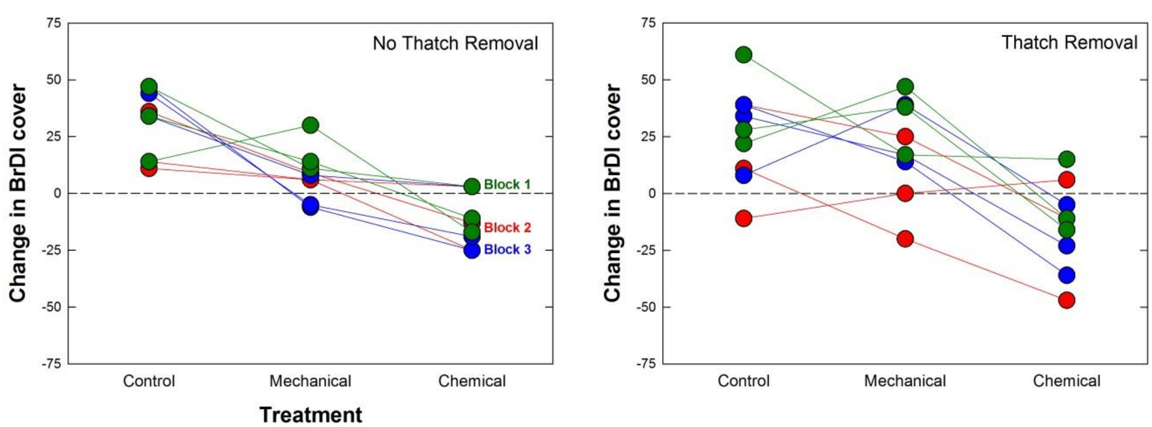


Figure 7.10: Results from an experiment to control *Brachypodium distachyon*. Each circle represents a single value. Lines connect the values from within a replicate. Colors identify the blocks used in the field. (Data courtesy of Patricia Gordon-Reedy, CBI)

The analysis for these data involves a split-plot ANOVA with 3 blocks based on the pre-post differences (Table 7.3). The resulting ANOVA table contains seven different F tests in four groupings or stanzas, each with its own estimate of error (natural variability). The first stanza estimates the differences among the three blocks and treats each of the 9 experimental replicates as a unit. The F-ratio of 4.67 provides some modest evidence that the blocks differ. The remaining stanzas are “within subjects” which means that treatment effects are gauged relative to the local control plot. Among these three stanzas, the only strong and significant result is the main effect of treatment. This F-ratio off 30.4 tests for a difference among the three treatments but does not indicate which treatments differ. Follow-up tests demonstrate that the largest contributor to this result is the difference between control and chemical treatment. This makes sense since Figure 7.10 clearly illustrates that plots treated with an herbicide (chemical) are different from the control (untreated) plots.

Table 7.3: Complex ANOVA table for the *Brachypodium* experiment. This analysis is difficult to interpret and makes important assumptions about the distribution of the residuals. Complex analyses like this should be analyzed by experienced scientists/statisticians.

Between Subjects						
Source	SS	df	MS	F-ratio	p-Value	
Block	2296	2	1148	4.671	0.06	
Error A	1474	6	245.7			

Within Subjects						
Source	SS	df	MS	F-ratio	p-Value	
Thatch Removal	13.5	1	13.5	0.052	0.828	
Thatch * Block	477.4	2	238.7	0.914	0.45	
Error B	1568	6	261.3			
						Huynh-Feldt
Source	SS	df	MS	F-ratio	p-Value	p-Value
Treatment	15688	2	7844	30.4	<.001	<.001
Treat * Block	863.2	4	215.8	0.836	0.528	0.528
Error C	3097	12	258.1			
						Huynh-Feldt
Source	SS	df	MS	F-ratio	p-Value	p-Value
Thatch * Treat	766.8	2	383.4	1.39	0.287	0.287
Thatch * Treat * Block	651.8	4	162.9	0.59	0.676	0.676
Error D	3314	12	276.2			

Analyses from regional monitoring efforts and broad-scale impact assessments are an important complement to the very controlled experiment described above. The analyses are also likely to be complicated. Often times, these analyses require specialized approaches like bootstrapping and randomization methods, meta-analyses or mixed models. These broad analyses are often hampered by differences in methods, data recording, and sample design. Even when methods are standardized, inter-observer variability often introduces significant uncertainty.

Where to go from here?

Data analysis and interpretation involves the graphical presentation of data, statistical summaries of observed patterns, and formal estimation and/or hypothesis testing. There are many texts written on data analysis and we haven't attempted to duplicate those here. What you are now familiar with a decision tree to help guide your teams towards the type of data analyses that are (and are not) aligned with the data, questions and expertise at your preserve.

Biologists and managers working at the preserve-level can graph and summarize data from uncomplicated experiments or monitoring programs. Keeping these tasks in house should facilitate the rapid analysis of data so that it can be used to update management and monitoring strategies. Ideally, data collected from these simpler projects are coordinated and standardized so that data collected at individual preserves can be entered into regional databases. The synthesis of data from multiple preserves can be harnessed to provide new insights across the region. in these larger efforts.

More complicated designs will likely require collaborative efforts to analyze. The more complicated the data, the greater the risk of misinterpretation. As such, they will benefit from collaboration with experts at all levels. It is important to remember that poor or improper data analysis can destroy our ability to interpret biological data from well-designed studies. On the other hand, no amount of clever data analysis can provide insight in a deeply flawed experiment or poorly executed monitoring program.

Data analysis, like other steps in the adaptive management process, should improve understanding and facilitate meeting a programs goals and objectives. Data analysis is mathematically and computationally challenging and many scientists and managers lack the expertise (and often the interest) to tackle complex analyses. This is perfectly reasonable. Stakeholders should strive to be educated (and skeptical) consumers of statistical information.

Chapter 7: Summary

- Monitoring and management data must be analyzed and interpreted in order to support the learning and, thus, the adaptive management process.

- Some interpretation can be straightforward. Visualizing and summarizing data are key elements of the analysis of biological data. Even simple graphics and data summaries have the potential to mislead.

- Complicated analyses from management experiments or monitoring programs often require specialized expertise and experience. Individuals working at the preserve-level should seek partners or collaborators whenever appropriate.

- Individuals not need to be statisticians to analyze and interpret biological data. Instead, biologists and managers need to be skeptical consumers of statistical graphics and tests and need to seek experts and expertise when needed. .

Checklist

√	Task / Activity
☐	Data have been collected in a careful and consistent fashion that will support analysis and interpretation.
☐	Data have been through a careful Q_A/Q_C process to ensure that the information is correct.
☐	Data have been visualized and summarized with appropriate statistics
☐	Determine whether further analyses (like formal hypothesis tests) are needed. If so, evaluate whether they require specialized expertise. Seek collaborators for complex surveys and experiments.
☐	Input data and results into regional databases to institutionalize information and facilitate broader-scale analyses.

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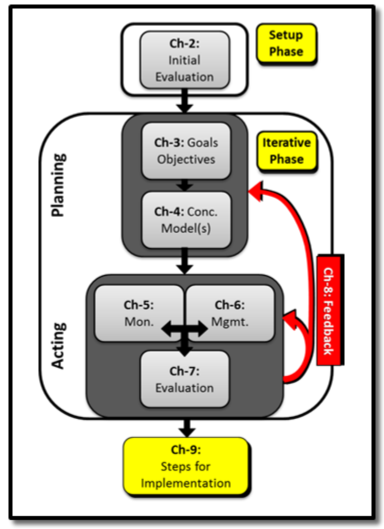
Chapter 8:
The feedback loops



Chapter guide

In this chapter, we discuss the importance of feedback processes that "*close the loop*" that links monitoring and management activities on a preserve to its goals and objectives. This guidance document has walked through the individual steps in this process, providing detailed explanation and concrete examples of the critical elements. In this chapter, we suggest that feedback must occur at several levels and on different spatial and temporal scales. New information should be used to update preserve-level monitoring and management activities frequently (often annually). Regional updates to goals and objectives (e.g. the Management Strategic Plan) should occur regularly, but on a longer return interval (often 5-10 years). The key is that successful adaptive management requires this dynamic and iterative cycle to be employed.

Introduction: The feedback loop

Adaptive management rests on the idea that knowledge of natural systems is incomplete, but despite data gaps and uncertainty, managers are required to act. As we've discussed in previous chapters, managers engage in management actions designed to meet specific goals based on documented knowledge and their understanding of how a system works. These management actions are monitored to evaluate their effectiveness. Monitoring results are interpreted to update our understanding of species or system dynamics and to continue or modify management activities[1]. This stepwise process yields information, filling in the knowledge gaps and identifying new ones that must be answered. We refer to this iterative process as ***closing the loop***. One of the central criticisms of the adaptive management process is that it often lacks this evolution of knowledge. This occurs when data aren't collected/analyzed/interpreted appropriately in order to evaluate how well management actions are achieving their objectives.

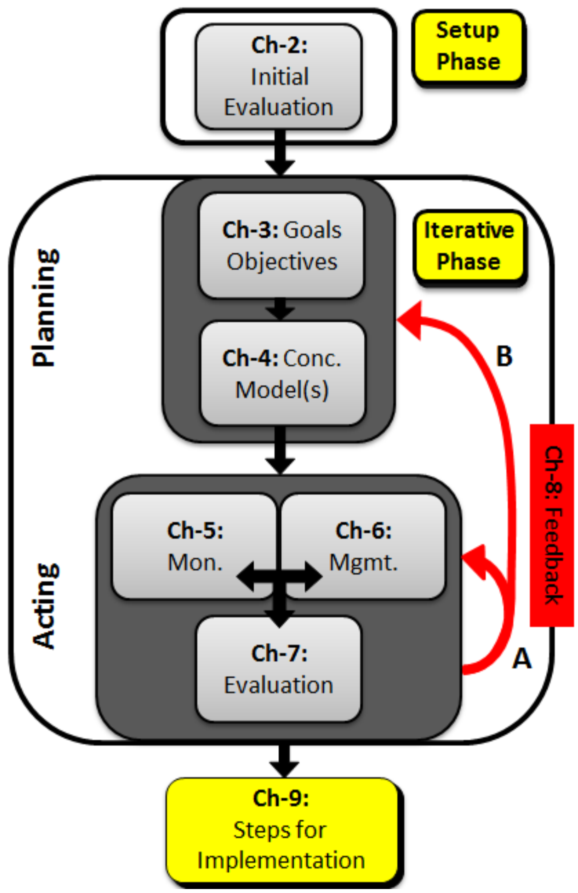


Figure 8.1: There are two distinct feedback loops. One loop (Line A) represents frequent updates to management and monitoring efforts by individual preserves. The second loop (Line B) represents a regional process of synthesis and refinement that occurs periodically.

To be precise, there are multiple loops that need to be closed and these occur at different scales. One iterative process or loop occurs at the preserve-level or local scale (line A in Figure 8.1.). In this loop, new information is used to refine and update monitoring and management activities. A second iterative process occurs primarily at the regional scale (line B in Figure 8.1). At this scale, information from multiple preserves over several years is evaluated and integrated and used to update regional goals and objectives.

There is an important distinction between these two processes. At a preserve, there needs to be a process that connects monitoring, management and evaluation (Ch. 5-7). This integration of management actions, monitoring data and the analysis and interpretation of the data should occur annually to evaluate site-specific management goals and the data collected to evaluate those actions. At the regional scale, the feedback loop occurs far less frequently. These periodic evaluations will allow for a compilation of preserve-level and Management Unit data to evaluate regional trends, regional performance metrics and assessment. Preserves-level activities can support this process of regional evaluation of management units and overall network, and help inform strategic planning and funding. Although preserves can support and play an important role in the regional evaluations (line B), in this chapter, we'll focus on the loop that must be closed at the preserve-level (line A).

Closing the loop: three features

To be able to *close the loop* requires that a preserve has three key features in place: efficient data entry and storage, analytical capacity, and a review structure. Two of these features were discussed in Chapters 2 and 7, but we'll briefly revisit these topics in the context of the feedback loop as well.

1. Efficient data entry and management

Data entry and storage may be the least glamorous aspect of adaptive management, but it is also one of the most important. Without a strong data management infrastructure, a preserve will have limited ability to evaluate its progress towards meetings its stated goals and objective. Fortunately, MSCP preserve managers do not have to develop their own databases. The South Coast Multi-Taxa database (SC-MTX) has been developed to serve as the data storage and access platform for the MSCP preserves. As a result, Individual preserves do not need to re-create or re-invent database storage structures. More importantly, a regional database provides standardization so that data can be input and extracted quickly and easily. The SC-MTX database can accommodate species, natural community, and management-relevant data.

As was discussed in Chapter 5 in the context of monitoring, data entry and management requires resources. The lack of resources allocation to data entry and management is a common problem within the context of adaptive management. It is commonly discussed in scientific literature[2] and in other adaptive management guideline documents[3]. As a general rule, data entry, quality assurance, and management costs are about 15-20% of total project costs[4-7]. Fortunately, this cost may be lower for MSCP preserves since SC-MTX has already been developed and is currently being supported.

It may be seem counterintuitive to redirect resources from management action or monitoring activities to data entry and management. However, without data, a preserve manager's ability to evaluate monitoring and management is severely limited. Application of field computers has been shown to greatly reduce input time of data collected in the field. Of course, this requires more resources in terms of software and hardware, but is worthy of consideration as resource allocation is considered.

2. Evaluating and interpreting analytical results

With data in hand, the next step is analysis and interpretation. As mentioned in Chapter 7, this step may be relatively simple or it may require expertise and resources that exist outside of the preserve. That said, expertise from the preserve is essential to an effective evaluation process. The challenge for preserve staff is to integrate results from analyses and use that information to evaluate current practices and inform and update the conceptual model/working understanding of the systems and species of interest.

The level of expertise needed to interpret results will be guided by and based on the level of complexity of the management actions (well-established to experimental), and the complexity of analyses (simple to complex). Working closely with preserve staff will ensure that data are correctly interpreted.

3. A review structure

One of the key ingredients to *closing the loop* is having an evaluation mechanism in place. An effective annual review is one that allows planners or managers to meet with field staff to review current activities in the context of available data and analyses. The goal of this review is to assess the efficacy monitoring and management activities.

Annual reviews are needed to:

- Critically review monitoring and management efficacy.
  - *Is monitoring data helping meet your goals and objectives?*
  - *Are your management actions helping meet your goals and objectives?*
- Update formal or informal conceptual models of the systems of species of interest.
  - *Have you learned new factors or relationships that add to your understanding of the species, systems or processes you are managing?*
- Allow confirmation that your preserve is aligned with MU and regional directives and priorities.
  - *Do you need to revise or re-define a specific goal or objective to align with MU or regional directives and priorities?*

Goals of the evaluation process

What are the specific goals of this evaluation process and why is it necessary to close the adaptive management loop at the preserve level? There are three basic goals of this evaluation process:

<u>1) Evaluating management practices</u>

One of the central reasons for this review process is to evaluate the efficacy and efficiency of management actions. Asking the questions “What evidence do I have that management action A met its intended goal?”, “Is this action cost effective based on existing information on alternatives?”, “Does data collected suggest that changes need to be made in the form or time frame of this management action?” will allow the preserve team to identify where and what management actions need revision or adjustment.

<u>2) Evaluating monitoring activities/programs</u>

Monitoring data is what fuels the process of allowing a preserve to consider performance of the management actions, both in terms of the management actions themselves as well as providing data on the species or systems of interest.

<u>3) Updating models (formal or informal)</u>

As a final step, the annual review gives the preserve team an opportunity to update their conceptual models, whether informal or formal. In general, do the management and monitoring results revise the preserve teams understanding of species or system of interest? Are there certain assumptions, presumed linkages or drivers that were not supported or need to be modified based on the data yielded? This updating process need not be lengthy but is a critical element of *closing the loop* because it specifically captures and documents the evolution of knowledge that is central to effective adaptive management.

Sharing the knowledge

Once an internal review has been conducted and internal actions and activities have been evaluated and revised and adjusted as necessary, it would be beneficial to share the lessons learned with other preserves within and outside of the management units. There are a number of peer groups that can facilitate this knowledge sharing process, e.g. North and South County Land Managers groups, SDMMP meeting. This knowledge sharing supports adaptive management in two critical ways. First, it serves as an informal external review process to provide the management team at the preserve with feedback from other managers and other experts. Second, knowledge sharing also serves to support the process of meeting a common goal (as set by MU or regional priorities) across different preserves.

Chapter 8: Summary

- Adaptive management is an iterative decision-making and learning process. To *close the loop* between monitoring, management an evaluation process is required.
- There are three components needed to *close the loop* at the preserve level: ❶ data entry/storage, ❷ data analysis and interpretation, and ❸ a regular review or evaluation process. As part of these steps, management teams need to update of conceptual models (informal or formal). These steps are critical as they are the foundation to the <u>learning</u> or <u>evolution of knowledge</u> that is central to successful adaptive management.
- The evaluation process is an opportunity for the preserve planners, managers and field staff to evaluate the management and monitoring activities in terms of efficacy, efficiency and overall performance. Sharing knowledge with other management teams and experts within a Management Unit and across the MSCP is part of this evaluation process.

Checklist

√	Task / Activity
☐	Ensure your preserve has the ability to enter, review data collected
☐	Evaluate and analyze data. This may require support from outside experts
☐	With the results from these analyses in hand, engage in an evaluation process to review monitoring and management efficacy, and update formal or informal conceptual models
☐	Use evaluation process to confirm that preserve activities are aligned with MU and regional directives and priorities
☐	Share knowledge gained with other preserves within and outside of the management units

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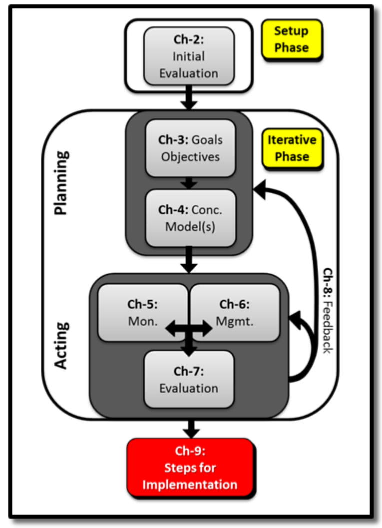

Chapter 9:
Implementation: how this document can support preserve-level monitoring and management

Chapter Guide

Even the best guidance document can only be as good as the effort and energy put towards implementation. In this final chapter, we discuss how this stepwise approach can best be implemented to improve and strengthen preserve-level monitoring and management.

Introduction: how this document can support monitoring and management

Even if there could be a perfect monitoring and management plan that outlines a flawless step-wise approach to meet the management goals at a particular preserve (and in reality, this perfect, flawless plan does not exist), there is still the need to translate the plan into activities in the field and to interpret field results to inform future planning. To translate a robust preserve-level monitoring and management plan into robust monitoring and management actions requires the collaborative work of strong preserve-level team of planners and doers. This was discussed in Chapter 8 in the context of closing the adaptive management loop. While planners have expertise to guide the management process, doers (rangers, biologists, environmental scientists, consultants) have the expertise needed to identify how different management objectives can feasibly be carried out and are tasked with devising a field plan to best align available personnel resources and expertise with monitoring and management methods and approaches. Effective land management requires a combination of on-the-ground knowledge of the preserve with a management team that can align the preserve priorities with MU and regional priorities and provide guidance on preserve-level management goals and objectives.

Managing with uncertainty

As discussed throughout this document, a central tenet of adaptive management is that managers are required to manage with uncertainty. Adaptive management is a process that acknowledges uncertainty and recognizes the importance of an evolution of knowledge: learning through doing, actively observing, and, as a result, evaluating and revising management approaches and actions as new information is gathered. Managers can't know it all, and they need to monitor and manage as they gather new information that can inform future actions.

There are three key elements to support this process of knowledge evolution, and to translate robust plans into action. These echo some of the same elements outlined in Chapter 8.

- Clear and frequent collaboration and communication between planners and the doers
- Annual reviews of on-the-ground management (what worked, what didn't and why?)
- A document that directly translates plans into action – we call that a punch list and discuss what this is and how it serves this evolutionary process.

Active collaboration and clear communication

To connect management plans to preserve-level action requires a strong collaborative relationship between the management and field staff. Without that relationship, even the best monitoring and management plan will fail. The preserve team together can translate the goals into SMART objectives and tasks, identify measurable metrics of success (based on the language in the objectives), and troubleshoot the implementation process.

As discussed in several chapters of this document, because adaptive management is a scientific process, it requires some basic familiarity and training in the scientific method and elements of adaptive management. That said, adaptive management requires expertise and experience from a wide range of backgrounds. A collaborative team of managers/planners and rangers/consultants with their different area of expertise are needed to work together and support this process.

Annual reviews: what worked, what didn't and why?

A central mechanism of clear communication and collaboration for the preserve team is the review process. As outlined in Chapter 8, collecting monitoring data that is aligned with goals and objectives is necessary *but not sufficient*. Monitoring data must be analyzed and interpreted to evaluate and assess how well management actions are meeting the preserve-level goals. Data analysis and interpretation are needed to provide a data-based assessment of what worked and what didn't. Analyses of these data are non-trivial because data from natural systems is inherently messy and will require a variable level of statistical experience and expertise (see Chapter 7 for more information).

An annual review serves as a report card for the preserve, determining areas of success as well as identifying areas for improvement. Having a document that serves as a report card, that captures the knowledge acquired, the accomplishments, and the ongoing challenges provides an important institutional history and record of monitoring and management. This is the process that directly captures the evolution of knowledge so its importance cannot be overstated.

It is important to note that many of the tasks tackled at the preserve are focused on routine maintenance and enforcement. These may seem incongruous with some of the other more species or system-focused goals discussed in previous chapters. However, all management action whether it relates to maintaining fences, signage or protecting a rare plant, can benefit from the approach outlined in this guidance document. If a management objective is to limit off-trail movement in a particular area within a preserve, being able to evaluate and assess the success of different management alternatives (e.g. signs, rail fence, roping) at meeting that objective is exactly what the adaptive management is designed to do.

With results from these analyses in hand, the preserve team can

- Help answer questions of why a particular outcome occurred
- Evaluate the efficacy of a management outcome and determine whether any changes are required
- Assess the strength of the monitoring program. Is it yielding the data needed to inform management and evaluate management efficacy and performance?
- Update the conceptual models (whether informal or formal) to reflect knowledge gained about a species or system

Translating plans into action: creating a punch list

One part of the annual review and team collaboration process is to develop a punch list. What is a punch list and why is it needed? A punch list is the document that serves to take the prescriptions and guidance from management documents (e.g. Resource Management Plan (RMP), annual management documents) and translates them into a prioritized list of specific and detailed tasks for preserve staff (Figure 9.1). This translations requires collaboration and communication (see section above) between planners and doers. It is also the stage at which the alignment between the management goals and field activities will occur.

January 2013	**Resources Required** **($$, equipment)**	**Personnel Needed**	**Notes**
Objective:			
Task 1:			
Task 2:			
February 2013	**Resources Required** **($$, equipment)**	**Personnel Needed**	**Notes**
Objective:			
Task 1:			
Task 2:			

Figure 9.1: General structure of a punch list. The key is to create a master schedule that relates specific tasks to each objective. Information on resources and personnel are listed by task.

The actual process of creating a punch list is as important product as the punch list itself. To create a useful punch list, the preserve team will need to both prioritize management and monitoring needs and evaluate proposed measures in terms of feasibility and resources. This prioritization versus feasibility/resources generates a strong framework for long-term management and monitoring planning.

We've included a template for a punch list (Figures 9.1) as well as an example (Figure 9.2) to illustrate this process. The punch list is designed to provide a timeline for activities, a direct link to specific objectives the tasks associated with those objectives. The punch list also allows the preserve team to identify the resource and personnel needs as well as any critical documentation associated with each task. Tasks should designate the *who*, *when*, *where*, *what* as another way of evaluating feasibility of the objective relative to expertise and resources of field staff. Again, this review process need not be time consuming. However, it is important to do as it provides another critical bridge between the management vision and the on the ground activities.

January - February	**Resources required**	**Personnel**	**Notes**
Objective: Decrease activity of off-trail hikers and mountain bikes			
Task 1: Inspect and repair fences and barriers at 5 main access points	Fencing materials	Ranger	
Task 2: Increase outreach by posting flyers, updating signage, and contacts with local recreation groups	Signs and brochures	Ranger	
Objective: Improve our understanding of the egg phase of Hermes copper: Locate10 eggs on redberry plants and following them through emergence.			
Task 1: Egg Searches at sentinel sites	Field truck	Biologist	
Task 2: GPS location of eggs and photograph egg appearance through time	GPS, Camera	Biologist, Photographer	
Task 3: Create database and GIS layer	GIS software and expertise	Biologist	Upload data to MTX
March – April	**Resources required**	**Personnel**	**Notes**
Objective: Increase distribution of thread-leaved *Brodiaea* using herbicides to control *Brachypodium*.			
Task 1: Mark experimental plots with flagging	Flagging, GPS	Biologist	
Task 2: Monitor contractor while herbicide is applied		Biologist, Contractor	
Objective: Reduce coverage of A. donax to less than 50% coverage of riparian area			
Task 1: Mechanical removal	Removal equipment	Biologist and field crew	

Figure 9.2: Example of a punch list for monitoring and management.

May	Resources required	Personnel	Notes
Objective: Support volunteer program and outreach			
Task 1: Have each docent (n=6) give 1 tour a month	e-flyers and paper flyers	Docent	Create email distribution list
Objective: Monitor Hermes abundance and distribution: Follow females after mating to determine oviposition preferences and validate habitat model			
Task 1: Capture and ID females based on swollen abdomen. Mark and release.	Pin Flags	Biologist	Difficult in sites with uneven terrain.
June	**Resources required**	**Personnel**	**Notes**
Objective: Monitor thread-leaved *Brodiaea* extent			
Task 1: Fine-scale field mapping of distribution. Estimate cover and flower density.	Quadrats frame, Robel Pole	Biologist	

Figure 9.2 (continued): Example of a punch list for monitoring and management.

Chapter 9: Summary

- Implementation of the process outlined in this document requires active collaboration and clear communication between preserve managers and field staff.
- Annual reviews can further support the collaborative relationship between management and field staff.
- A punch list can serve as a document that translates management goals and objectives into specific tasks. Creating a punch list requires prioritization and an evaluation of feasibility and is central to long-term planning

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APPENDIX 1.1

Detailed list of meetings with stakeholders and steering committee

Meeting	Dates
Development (and Revision) of SOW	12/2009 - 8/2010
Coordination Meeting: IEMM, SDMMP, SANDAG	3/2011
Coordination Meeting: IEMM, SDMMP, CDFW, and USFWS	5/2011
Coordination Meeting: IEMM, SDMMP	7/2011
Steering Committee Meeting`	9/2011
Preserve-Level Meetings (9 meetings with ~25 scientists/regulators/managers)	10/2011 - 12/2011
Coordination Meeting: IEMM, SDMMP, CDFW, and USFWS	12/2011
Coordination Meeting: IEMM, SDMMP, USGS	5/2012
Feedback on Outline of FMP: IEMM, SDMMP, CDFW, and USFWS	7/2012
Presentation to EMP Working Group (SANDAG)	7/2012
Discussion of FMP: IEMM, SDMMP, CDFW, and USFWS	11/2012
Presentation to EMP Working Group (SANDAG)	5/2013
Draft sent to Reviewers (Local and External)	6/2013
Comments back from Reviewers (Local and External)	9/2013

APPENDIX 2.1

POTENTIAL SOURCES OF INFORMATION FOR INITIAL SITE CHARACTERIZATION (NOTE ALL LINKS ACCESSED MAR 16, 2014)

Data Source		*Note: Some URL's wrap to the next line. Remove the space before pasting in your browser*
Key Resources	**South Coast Multi-Taxa Database**	**http://mtx.sdmmp.com/**
	Conserved Lands DB: Master Occurrence Matrix (MOM)	**http://www.sdmmp.com/Libraries/ GIS_and_Maps/MOM_kml_022014.sflb.ashx**
	Conserved Lands Database: Map Review BETA	**http://gis2.sandag.org/ConservedLands/** (Note: Access is restricted, contact SANDAG for access)
Other Important Resources	**Biogeographic Information and Observation System**	**bios.dfg.ca.gov/** Direct link to public Bios Map Viewer: **https://map.dfg.ca.gov/bios/**
	California Natural Diversity Database	Several links and interfaces. Some public, other restricted to state or subscribers. **www.dfg.ca.gov/biogeodata/cnddb/mapsanddata.asp**
	CEQAnet Database	**http://www.ceqanet.ca.gov/** Queries can be submitted at: **http://www.ceqanet.ca.gov/QueryForm.asp**
	SanGIS / SANDAG GIS Data Warehouse	GIS and Regional Data Warehouse Jump Page **http://rdw.sandag.org/Default.aspx**
	San Diego Bird Atlas	**http://www.sdnhm.org/science/birds-and-mammals/ projects/san-diego-county-bird-atlas/**
	San Diego Mammal Atlas	**http://www.sdnhm.org/science/birds-and-mammals/ projects/mammal-atlas/**
	San Diego Plant Atlas	**http://www.sdnhm.org/science/botany/projects/plant-atlas/**
	San Diego Management and Monitoring Program	**http://www.sdmmp.com/Home.aspx** Reports and Products Jump Page **http://www.sdmmp.com/reports_and_products/ Reports_Products_MainPage.aspx**

Key Resources

South Coast Multi-Taxa Database (SC-MTX)

The SC-MTX is a publically accessible database that houses both land management and biological monitoring data. The database stores more than just species observational data. Information regarding vegetation, site condition, survey protocol, goals and objectives of the study, success criteria, funding source, unit effort, reports, and photographs is also available. There are two ways to search the database: a query tool and a map viewer. Users can query the database by keyword, project, species, county, or reserve. Results are displayed in tabular format, but don't give exact coordinates, only the name of a reserve, open-space, or park where the observation was recorded. The map viewer can be searched by region or preserve. Results are displayed in a tabular format that can be downloaded in MS Excel format.

Conserved Lands Database: Master Occurrence Matrix (MOM)

Description excerpted from the MSP (Vol 1 Page 4-2, 403). The purpose of the MSP Species Master Occurrence Matrix (MSP-MOM) is to track the status and management of known occurrences of MSP species. MSP-MOM was used in the MSP to designate management categories, identify occurrences important for management, develop management goals and objectives, and prioritize implementation of management actions. MSP-MOM includes only records of MSP species in which occurrences are known to be extant (verified data collected since 2000) or likely to be extant after the year 2000. Each record includes information on land owner, land manager, conservation status, management status, and spatial coordinates.

Conserved Lands Database: Map Review BETA:

General description": The SANDAG's Conserved Lands data is used to develop and maintain a comprehensive inventory of land in the region that is conserved for the purpose of protecting open space and natural habitats. The viewer displays the regional conserved lands by generalized ownership and is used to support stakeholder engagement. From: *http://gis1.sandag.org/sdgis/rest/services/Land/Conserved_Land/MapServer* and *http://www.sdrgc.org/Minutes/Docs/20131009minutes.pdf* (Accessed Mar 16, 2104)

Other Important Resources

Biogeographic Information and Observation System (BIOS)

BIOS is a system designed to enable the management, visualization, and analysis of biogeographic data collected by the Department of Fish and Game (DFG) and its partner organizations. This includes observational data for rare and sensitive species and critical habitat areas. There is also a variety of reference data, such as lakes, stream, watersheds, parks, and refuges. BIOS integrates GIS, relational database management, and ESRI's ArcIMS and ArcGIS Server technologies to create a statewide, integrated information management tool that can be used on any computer with access to the Internet. BIOS includes both public and private data map viewers. The public viewer is free and open to anyone, but contains no sensitive data. The private viewer is only open to DFG personnel and affiliated organizations. Aside from simply searching for and viewing data, the map viewer has query tools, and the option to print maps.

California Natural Diversity Database (CNDDB)

The CNDDB is a program that inventories the status and locations of rare plants and animals in California. CNDDB staff work with partners to maintain current lists of rare species and maintain a database of GIS-mapped locations for these species. There are two ways to access the CNDDB database: a query tool and a map viewer. The query tool is called RareFind, which allows complex querying and reporting through an internet browser. RareFind requires a annual subscription fee. There are two map viewers, both of which use ESRI's ArcIMS and ArcGIS Server technologies. One requires an annual subscription fee, while the other is free and accessible to the public. The free version provides access to CNDDB observational data at the quadrangle level, and the pay version provides data at the XY coordinate level.

CEQAnet Database

CEQAnet contains key information from all California Environmental Quality Act (CEQA) documents submitted to the State Clearinghouse for state review since 1990. This includes summaries of Environmental Impact Reports (EIRs), Negative Declarations, Environmental Impact Statements, and other types of CEQA and NEPA documents. The summaries include the project title, project location, lead agency name, contact information, and project description. At this time, CEQAnet does not provide the full text of any environmental documents. If additional information is needed, contact information for each document is provided.

San Diego Association of Governments Regional GIS Data Warehouse

San Diego Association of Governments Regional GIS Data Warehouse is the single authoritative San Diego County regional GIS data source. It provides data for everything from addresses to zoning, including: roads, property, parks, lakes, topography, census, and dozens of other layers - over 270 layers in 29 different categories. GIS layers that may be of particular importance include environmentally sensitive areas, conservation areas, geology, and vegetation. Other useful datasets include land use, rivers, lakes, streams, and groundwater data.

San Diego County Bird Atlas

The San Diego County Bird Atlas contains observational data for approximately 492 natives, migrants, and well-established exotic bird species. Each species account covers breeding distribution, nesting habits and schedule, migration, winter distribution, conservation outlook, and taxonomy, if relevant. The San Diego County Bird Atlas is available through Google™ Earth. This interactive application enables you to generate a list of birds recorded in atlas square, as well as see population distributions overlaid over satellite images of San Diego County. The atlas is also available as a hardcopy book.

San Diego County Plant Atlas

The San Diego Plant Atlas is a database that contains over 55,000 specimens of native and naturalized plants in San Diego County. The specimens are mostly collected by volunteers, and then certified by trained botanists. Users can search that plant atlas by using a query tool or map viewer. For the query tool, specimens can be searched by family, genus, specific epithet, and date. The results of a search can be downloaded to the user's computer in either MS Excel or MS Word. Each result location can also be viewed in Google Maps. For the map viewer, up to two species can be mapped together. A plant can be selected by either scientific or common name, and the locations of all collected specimens will be plotted on one of five maps: atlas grid square, vegetation types, topographical, county, and ecoregions.

San Diego County Mammal Atlas

The goal of the San Diego Mammal Atlas is to create a comprehensive database of mammal population distributions. There are over 30,000 mammal observations for about 100 species, collected from numerous existing information sources, including museum collections, existing GIS databases, and past publications and reports. Mammal observation data can be accessed through an online map viewer.

San Diego Management and Monitoring Program (SDMMP)

The SDMMP is a science based program seeking to provide a coordinated approach to management and biological monitoring of lands in San Diego County. Although the goal of the SDMMP is not primarily to provide data or information for management efforts, there are a number of documents, maps, reports, literature, and presentations from previous projects available to the public using a reports and product browser. There are no query functions, however. Instead the user can search through documents based on a number of categories, such as management reports, literature, maps, grants, meeting material, and monitoring reports.

APPENDIX 2.2

SEVERAL METHODS FOR RAPID ASSESSMENT

Rapid Ecological Assessment and the Rapid Assessment Program:

The Rapid Ecological Assessment (REA) and The Rapid Assessment Program (RAP) program involve characterization of the landscape by vegetation type. Species inventories are then completed by specialized surveyors/ biologists using field methods appropriate for each target taxonomic group. In addition to these field methods, REA uses Remote Sensing (RS) technology and Geographic Information Systems (GIS) to create vegetation maps that are verified by targeted field surveys. Reports of vegetation classification, species lists and identified threats and stressors are generated from both the REA and RAP.

Primary citations in Table 2.2:

1. Groves, CR, DB Jensen, LL Valutis, KH Redford, ML Shaffer, JM Scott, JV Baumgartner, JV Higgins, MW Beck, and MG Anderson. 2002. BioScience 52(6):499-512.

2. Noss, RF. 1987. From plant communities to landscapes in conservation inventories: A look at The Nature Conservancy (USA). Biological Conservation 41 (1987) 11-37.

3. Sayre R, E Roca, G Sedaghatkish, B Young, S Keel, R Roca, S Sheppard. 1999. Nature in Focus: Rapid Ecological Assessment. Island Press. 202 pages. ISBN: 978-1559637541

Other Resources:

For More Information:	**Source**
Bureau of Land Management Website on Rapid Ecological Assessment	http://www.blm.gov/wo/st/en/prog/more/Landscape_Approach/reas.html
Conservation International: Rapid Assessment Program Website	https://learning.conservation.org/biosurvey/RAP/Pages/default.aspx#
Still Counting...: Biodiversity Exploration for Conservation – The First 20 Years of the Rapid Assessment Program.	Alonso, L.E., J.L. Deichmann, S.A. McKenna, P. Naskrecki and S.J. Richards. (Editors). 2011. Conservation International, 316 pp.

New Zealand's Department of Conservation Reconnaissance (Recce)

The Reconnaissance (Recce) description is a rapid initial landscape characterization method extensively described and utilized in New Zealand. Recce descriptions map and inventory vegetation communities and provide quantitative baseline data. Using random or systematic sampling methodologies, Recce's measure composition and structure of vegetation. This technique is described in Hurst and Allen (2007) and is very similar to quadrat / transect survey methods widely utilized elsewhere. As with other rapid assessment methods, the utility of the Recce method is described as a rapid survey technique useful for filling information gaps and establishing future long term monitoring objectives and priorities where needed. Unlike REA and RAP, Recce is strictly vegetation focused.

For More Information:	Source
New Zealand's Department of Conservation: Standard Operating Procedures: RECCE plots	http://doc.govt.nz/Documents/ science-and-technical/inventory-monitoring/ im-toolbox-vegetation-reece-plots.pdf
JM Hurst and RB Allen. 2007. The Recce Method for Describing New Zealand Vegetation - Expanded Manual (Version 4)	http://nvs.landcareresearch.co.nz/html/ Recce_ExpandedManual.pdf
JM Hurst and RB Allen. The Recce method for describing New Zealand vegetation: Field protocols. ISBN 978-0-478-09393-3	http://nvs.landcareresearch.co.nz/html/ Recce_FieldProtocols.pdf

California Native Plant Society: Relevé and Rapid Assessment Techniques

This protocol describes the methodology for both the relevé and rapid assessment vegetation sampling techniques. The relevé sample is plot-based whereas the rapid assessment sample is based not on a plot but on the entire stand. *http://cnps.org/cnps/vegetation/pdf/protocol-combined.pdf* and *http://cnps.org/cnps/vegetation/pdf/field_form-combined.pdf.*

British Columbia's Biodiversity: Resources Inventory Standards Committee:

The Components of British Columbia's Biodiversity (CBCB) series is a comprehensive guide compiled by the Resources Inventory Standards Committee (RISC) as a "methodological standard for species inventory and assessment" and provides a guideline for effective land management. The RIC has described three levels of inventory surveys based on the project objectives where the term inventory doesn't necessarily mean rapid. However, the manual series provides specific species inventory methods that the few previously mentioned "rapid ecological assessments" require. The simplest level is determining presence / not detected where the presence of a species can only be confirmed. Surveys at this level include generating species lists and species to habitat associations. The next two levels including relative and absolute abundance survey require a longer term investment.

<u>British Columbia's Biodiversity: Resources Inventory Standards Committee *(Cont):*</u>

For More Information:	**Source**
British Columbia (Canada) Integrated Land Management Bureau: Resources Information Standards Committee	http://www.ilmb.gov.bc.ca/risc/pubs/index.html
British Columbia (Canada) Ministry of the Environment. Conservation Data Centre.	http://www.env.gov.bc.ca/cdc/ecology/index.html

APPENDIX 4.1

NARRATIVE FOR: HERMES COPPER CONCEPTUAL MODEL

Goals:		
Management	To preserve Hermes copper populations at currently occupied sites, and to research critical uncertainties key to management.	
Monitoring	To monitor long-term site occupancy, discover new populations in San Diego County, and to resolve questions relevant to management options, including a fire response plan, in vitro rearing techniques and possible reintroduction of individuals to previously occupied sites extirpated by fire.	
Anthropogenic Threats:		
Fire	Wild fires cause direct mortality of Hermes copper. Frequent "megafires" (fires of unusually large extent) are especially problematic due to Hermes copper dispersal limitation and the low rate at which the species recolonizes areas.	USFWS, 2011, Marschalek and Klein, 2010
Development	A large number of historical Hermes copper population centers are now developed, diminishing available habitat and increasing fragmentation.	USFWS, 2011
Fragmentation	Male Hermes copper do not disperse long distances, and generally do not cross large patches of unsuitable habitat. Although females may have the capacity for long distance dispersal, habitat fragmentation (including that caused by type conversion of shrub lands into grasslands) may exacerbate problems associated with dispersal limited species.	Marschalek and Klein, 2010; Marschalek and Deutschman, 2008; Deutschman et al. 2010;
Road Kill	It is unclear if road kill is a substantial issue for Hermes copper. Given their short dispersal distances and relatively low-flying habit it could potentially be a problem. Marschalek has observed at least one individual that appeared to have been killed in a collision; however the relative importance of this threat is unknown and at this time seems to be far less important than that of fire. This threat may be better addressed as an uncertainty.	Marschalek and Klein 2010

Natural Drivers:		
Vegetation Community	Hermes copper occur in coastal sage scrub and southern mixed chaparral. Hermes copper utilize spiny redberry (*Rhamnus crocea*) as a host plant for eggs, larvae and pupation. Adult Hermes copper show a strong preference for nectaring on California Buckwheat (*Eriogonum fasciculatum*), however may utilize other plants occasionally, including chamise (*Adenostoma fasciculatum*) and tarplants (*Deinandra sp.*).	Marschalek and Deutschman, 2009; Marschalek and Deutschman, 2008; Klein Pers.Com.; USFWS, 2011; Thorne, 1963; Marschalek pers. obs.
Species Range	Although the appropriate vegetation communities extend as far north as San Francisco, Hermes copper has never been documented north of San Diego county. The species also occurs in northern Baja California; however the status of these populations is unknown. They have never been reported along the coast, having occurred as far west as the community of Kearny Mesa, and have not been reported east of the community of Pine Valley.	Marschalek and Klein, 2010; Thorne 1963; USFWS 2011
Predators	It is unclear if predators or parasitoids on adult butterflies play a significant role in Hermes copper dynamics. A single observation of a jumping spider feeding on an adult was made by Marschalek in 2010. Other potential predators or parasitoids are unknown.	Marschalek pers. com.
Temperature	The timing of emergence and the single annual flight season of Hermes copper appears to be influenced by weather conditions and elevation, although the specifics of this relationship are as yet unknown. In addition, activity on a given day in the flight season is strongly influenced by temperature and cloud cover, with Hermes copper remaining inactive and generally unseen until a temperature of 72 degrees F. Furthermore, Hermes copper tend to prefer the north and west sides of roads and trails for what seem to be purposes of thermoregulation.	Marschalek and Deutschman, 2008, Marschalek and Klein, 2010, Deutschman et al., 2010, USFWS, 2011
Species Variables:		
Population Structure	Genetic analysis indicates that Hermes copper dispersal is complex. While individuals sampled near one another may be unrelated, suggesting that small scale landscape barriers play a role in the population structure, individuals at two different sites may be genetically similar suggesting that occasional long-distance dispersal is possible under the right conditions. At this time genetic analysis suggests that the largest population centers in the south-eastern part of the county may be mixing at higher rates, but that there is differentiation from this area and populations located at more northerly portions of the county.	Deutschman et al. 2010, Deutschman et al. 2011

Species Variables:		
Female Behavior	Female Hermes copper may be found in the same open spaces occupied by males, however, upon flushing they fly quickly away into the brush and do not generally return. Based on genetic information some long distance dispersal events do occur, however field studies suggest that male Hermes copper typically do not exhibit such movements. Given that other *Lycaena* show different behavior between the sexes it seems probable that females disperse longer distances than males.	Deutschman et al., 2010; USFWS 2011
Reproduction	Most of the Hermes copper life cycle is achieved on spiny redberry, including egg-laying, larval feeding, and pupation. Eggs are approximately 0.5mm in diameter, generally laid on the underside of relatively new growth, often near an intersection with another branch or leaf. Sources and rates of mortality for non-adults are unknown.	Thorne 1963; Marschalek and Deutschman, 2009
Dispersal	Male Hermes copper appear to be extremely dispersal limited. Evidence suggests that some long-distance dispersal may occur within the core population centers in the south-east of San Diego County, but that more northern populations are relatively disconnected. Long-distance dispersal seems to be attributable to females.	Marschalek and Deutschman 2008; Marschalek and Klein 2010; Deutschman et al., 2010m Deutschman et al. 2011; USFWS 2011

Monitoring / Research Targets:	
Adult Male Population	The adult male abundance can be used to identify new population centers and the relative size of that population. Larger populations tend to be robust, occurring at the same sites year after year, and may not need to be monitored frequently once presence is established. Smaller populations should be monitored yearly until it is determined if they are stable or not.
Female Behavior	Female behavior is a key uncertainty and needs more research. Female behavior could potentially hold the key to making determinations about what constitutes connected populations, and high habitat quality.
Reproduction/ Ovaposition	Where females choose to oviposition eggs could be crucial to identifying what constitutes high quality habitat. This information could be used to determine if unoccupied sites with redberry are simply unoccupied, or if there is some crucial factor that makes them unsuitable. In addition reproductive success is the crux of maintaining the species, and it is unclear if eggs are subject to predation or other stressors.
Larval Biology	Very little is known about the biology of Hermes copper larvae. This stage could be sensitive to a number of environmental stressors, predation and parasitism. In addition the transition from egg to larvae appears to be the stage that limits our ability to culture Hermes copper in a laboratory setting.

Critical Uncertainties:	
A	Differential habitat use and dispersal by males and females, as it pertains to reproduction and connectivity
B	The relative importance of Allee effects, isolation, genetic bottleneck, and genetic pollution as they pertain to species vigor, the need for connectivity and reintroduction
C	Larval biology, secondary diapause and parasitoids: Very little is known about larval biology and behavior. We have no information on if this species can undergo a secondary diapause, but given wild annual fluctuations in adult population size it seems possible. In addition because larvae can be difficult to find we have no information on potential parasitoids of Hermes copper or rates of parasitism which can be substantial in other *Lycaena* species
D	Small Scale Disturbance: do trails, dirt roads, and other disturbances associated with human recreational and other use impact Hermes copper habitat choices or behavior, especially surrounding reproduction?
E	Vegetation community structure: in areas with redberry, what determines when and where Hermes copper will occur? Are all stands of CSS or chaparral with redberry potential habitat that is unoccupied, or are other factors at work?
F	Climatic Conditions: spring rainfall, temperature regimes and other factors that could be affected by climate change.
Management Actions:	
G	Fire suppression, fuel manipulation or other measures to protect redberry stands from fire in the short term.
H	Reintroduction to previously occupied sites extirpated by fire
I	In vitro rearing/ farming of Hermes copper for release and preservation of genetic diversity
J	Enforcement of poaching regulations: Specimens of Hermes copper butterfly have been for sale on-line previously, but have not appeared since 2004 (USFWS, 2011). Collection does not, therefore seem to be a threat to the species, however this should be monitored and followed up on periodically.

KEY LITERATURE FOR: HERMES COPPER CONCEPTUAL MODEL

References	Annotation
United States Fish and Wildlife Service 2011 *Endangered and threatened wildlife and plants; 12-month finding on a petition to list Hermes copper butterfly as endangered or threatened* The Federal Register 50 CFR(17): 20918-20939. http://federalregister.gov/a/ 2011-9028	• Hermes copper added to the candidate species list for the Federal Lists of Threatened and Endangered Wildlife and Plants. • Hermes copper has been **extirpated at more sites than it is currently found**. As of 2011, of the 57 known historical populations, 17 populations are extant, 28 populations are believed to have been extirpated, and 12 populations are of unknown status. • Identifies the primary threats to Hermes copper as development, fire, and habitat fragmentation
Marschalek and Klein 2010 *Distribution, ecology, and conservation of Hermes copper (Lycaenidae:* Lycaena [Hermelycaena] hermes) Journal of Insect Conservation 14:721-730	• **Male dispersal is very limited** • **Wildfires in 2003 and 2007 extirpated many populations and is a major threat to the species' survival** • Current distribution is reduced from historic ranges, specifically in extreme southern and northern San Diego County • Results underscore need to better understand habitat requirements and connectivity of populations
Deutschman et al 2011 *Two-year evaluation of Hermes copper* (Lycaena hermes) *on conserved lands in San Diego County* SANDAG Final Report MOU # 5001442.	• In 139 site visits during the six week flight season, a total of 252 adults were counted across 14 occupied sites. Of those 14 sites, only five sites were occupied by relatively large populations. • The populations are relatively stable through time, although numbers may vary dramatically based on temporal influences, such as rainfall and temperature. The fate of smaller populations is unclear and should be studied. • Used AFLP markers to examine genetic differentiation (and dispersal). **Occupied patches of redberry in the eastern part of the range are relatively well connected by dispersal. Movement is restricted in parts of the landscape, particularly along the edges of the species distribution.** • Provides a conceptual model for the species

Marschalek and Deutschman 2008 *Hermes copper (*Lycaena [Hermelycaena] hermes: *Lycaenidae): life history and population estimation of a rate butterfly* Journal of Insect Conservation 12:97-105	• Description of **life history traits**, including temperature thresholds, timing of flight season, and habitat preferences, such as preference for openings in habitat like those created by trails and roads • Within suitable habitat, California buckwheat was the strongest predictor of the presence of Hermes Copper. Adults used California buckwheat almost exclusively as nectaring source. • Densities and flight season varied greatly among sites • Evaluated 3 methods for indirect population size estimate. In absence of mark-release-recapture estimate, population sizes need to be estimated from observational data, like standardized Pollard Walk surveys.
Thorne 1963 *The distribution of an endemic butterfly Lycaena hermes* Journal of Research on the Lepidoptera 2(2): 143-150	• The initial description of Hermes copper biology and life history • Identified the species range as • Describes **vegetation associations**. Hermes copper uses spiny redberry as larval host and California buckwheat as nectar source.

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Deutschman, D.H., Berres, M.E., Marschalek, D.A., and Strahm, S.L. 2010. Initial Evaluation of the Status of Hermes copper (*Lycaena hermes*)on conserved lands in San Diego County. Report prepared for San Diego Association of Governments, MOU # 5001442.

Deutschman, D.H., Berres, M.E., Marschalek, D.A., and Strahm, S.L 2011. Two-year evaluation of Hermes copper (*Lycaena hermes*) on conserved lands in San Diego County. Report prepared for San Diego Association of Governments, MOU # 5001442.

Marschalek D. A. and M. Klein 2010. Distribution, ecology, and conservation of Hermes copper (Lycaenidae: *Lycaena* [*Hermelycaena*] *hermes*). Journal of Insect Conservation 14:721-730

Marschalek D.A. and D. H. Deutschman 2008. Hermes copper (*Lycaena* [*Hermelycaena*] *hermes*: Lycaenidae): life history and population estimation of a rate butterfly Journal of Insect Conservation 12:97-105

Marschalek, D.A. and D.H. Deutschman. 2009. Larvae and oviposition of Hermes Copper *(*Lepidoptera*:* Lycaenidae). Journal of Entomological Science 44(4): 400-401

Thorne, F. 1963. The distribution of an endemic butterfly *Lycaena hermes.* Journal of Research on the Lepidoptera 2(2): 143-150

US Fish and Wildlife Service 2011. Endangered and threatened wildlife and plants; 12-month finding on a petition to list Hermes copper butterfly as endangered or threatened. The Federal Register 50 CFR(17): 20918-20939.

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Faulkner D. and M. Klein. 2004. San Diego's sensitive butterflies: a workshop focusing on nine local species, San Diego, CA.

Marschalek, DA. 2004. Factors influencing population viability of Hermes copper (*Lycaena hermes*). Master's Thesis. San Diego State University.

US Fish and Wildlife Service. 1989. Endangered and threatened wildlife and plants; Animal notice review. Federal Register 50 (CFR 17 54): 554-579.

US Fish and Wildlife Service. 1993. Endangered and threatened wildlife and plants; 90-day finding for a petition to list four California butterflies as endangered and continuation of status reviews. Federal Register 50 CFR (17 56): 58804-58836.

US Fish and Wildlife Service. 2006. Endangered and threatened wildlife and plants; 90-day finding on a petition to list Hermes copper butterfly as endangered. Federal Register 50 CFR(17 71): 44966-44976.

Appendix 4.2

Narrative for: Recreational Trails and Access Control Conceptual Model

Goals:		
Management	Balance the protection of biological and cultural resources with recreational use	
Monitoring	Monitor the impacts of recreational use	
Anthropogenic Threats:		
Off-Road Vehicles	Vegetation Disturbance: Creates destruction and loss of vegetation	Fang et al. 2010; Groom et al. 2007; Li et al. 2007; Sampson 2007; Rickard et al. 1994; Griggs & Walsh 1981; Brodhead & Godfrey 1977
	Soil Disturbance: Soil erosion and compaction; sediment discharge; creates dust	Fang et al. 2010; Goosens & Buck 2009; Schlacher & Thompson 2008; Li et al. 2007; Pickering & Hill 2007; Sack & da Luz 2003; Griggs & Walsh 1981
	Wildlife Disturbance: Direct mortality (crushing animals); changes in behavior; decreases in survival and reproduction	Previtali et al. 2010; Tarr et al. 2010; Sheppard et al. 2009; Sampson 2007; Schlacher & Thompson 2007; Schlacher et al. 2007; Preisler et al. 2006; Pomerantz et al. 1988
	Non-native Plants: Introduce and spread non-native plants	Pickering & Hill 2007
	Cultural Resource Disturbance: deflation of cultural deposits; displacement and damage to artifacts; providing access to remote archaeological sites, making them more vulnerable to looters and vandals	Jarvis 2008; Sampson 2007

Anthropogenic Threats:		
Horses	Vegetation Disturbance: Trampling vegetation	Pickering et al. 2010; Törn et al. 2009; Cole & Spildie 1998
	Soil Disturbance: Soil erosion and compaction; nitrification of soils from urine and dung	Pickering et al 2010; Quinn et al. 2010; Deluca et al. 1998
	Non-native Plants: Introduce and spread non-native plants, primarily via dung	Pickering et al 2010; Quinn et al. 2010; Törn et al. 2009; Quinn et al 2008; Pickering & Hill 2007; Campbell & Gibson 2001
	Cultural Resource Disturbance: looting and vandalism	No literature found
Mountain Bikers	Vegetation Disturbance: Trampling vegetation	Lathrop 2003
	Soil Disturbance: Soil erosion and compaction	Pickering et al. 2010; Pickering & Hill 2007; Lathrop 2003
	Wildlife Disturbance: Decrease in wildlife density; cause animals to flee	Lathrop 2003; Taylor & Knight 2003
	Non-native Plants: Introduce and spread non-native plants	Pickering et al. 2010; Pickering & Hill 2007
	Cultural Resource Disturbance: looting and vandalism	No literature found
Hikers	Vegetation Disturbance: Trampling vegetation	Pickering et al. 2010; Kerbiriou et al. 2007
	Soil Disturbance: Soil erosion and compaction	Pickering et al. 2010; Pickering & Hill 2007; Deluca et al. 1998
	Wildlife Disturbance	Steven et al 2011; Taylor & Knight 2003; Freddy et al. 1986
	Non-native Plants: Introduce and spread non-native plants	Pickering et al. 2010; Mount & Pickering 2009; Whinam et al. 2005
	Cultural Resource Disturbance: looting and vandalism	No literature found
Dogs	Wildlife Disturbance	Lenth et al. 2008; Miller et al. 2001
	Cultural Resource Disturbance: impacts of digging and defecation	No literature found

Natural Drivers:		
Vegetation Community	Vegetation Disturbance: Vegetation communities differ in resistance to and resilience after trampling	Pickering et al. 2010; Pickering 2010; Hill & Pickering 2009; Gallet et al. 2004; Cole 1995; West et al.1997; Leung & Marion. 1996; Cole 1995; Rickard 1994
	Non-native Plants: Vegetation communities differ in invasibility	Going et al. 2009; Burke & Grime 1996
Slope/ Topography	Soil Disturbance: Can affect degree of erosion	Pickering 2010; Leung 1996
	Vegetation Community: Can affect resistance/ resilience of vegetation community	Kuss 1986
Soil Characteristics	Soil Disturbance: Can affect degree of erosion	Pickering 2010; Leung 1996
	Vegetation Community: Can affect resistance/ resilience of vegetation community	Kuss 1986
Climatic Variables	Soil Disturbance: Precipitation can affect severity of erosion	Pickering 2010; Leung 1996
	Vegetation Community: Can affect resistance/ resilience of vegetation community	Kuss 1986
Monitoring Targets:		
This will be a key point of our discussion during the workshop		

Management Actions:	
A	Vehicle Barriers
B	Fencing
C	Trail Rerouting
D	Trail Closure
E	Increased enforcement
F	Signage
G	Environmental Outreach Programs
Critical Uncertainties:	
H	Impacts on cultural resources
I	Relationship between authorized and unauthorized user impacts
J	How recreation user attitude/ satisfaction affects recreation impacts
K	Dogs: should they be together with or separate from hikers in the model?
L	Climate change

KEY LITERATURE FOR: RECREATIONAL TRAILS AND ACCESS CONTROL CONCEPTUAL MODEL

1st Tier: Most important to read

References	Annotations
Pickering et al. 2010 *Comparing hiking, mountain biking, and horse riding impacts on vegetation and soils in Australia and the United States of America* Journal of Environmental Management 91:551-562	Review paper summarizing the impacts of hiking, horse riding, and mountain biking on vegetation, soils, and trails. Compares studies from Australia and the United States. Many impacts are similar for the three activities but can differ in severity. Impacts include damage to existing trails, soil erosion, compaction and nutrification, changes in hydrology, trail widening, exposure of roots, rocks and bedrock. Identifies current gaps in research, including the need for more research on horse and mountain bike impacts, for studies that directly compare types and severity of impacts among activities, and on the potential for each activity to contribute to the spread of non-native plants and plant pathogens.
Pickering 2010 *Ten factors that affect the severity of environmental impacts of visitors in protected areas* AMBIO 39:70-77	Identifies and explains ten factors that affect how much recreational users damage protected areas. Examples of these factors include resistance, resilience, susceptibility to erosion, timing of use, and size of area impacted.
Reed and Merenlender 2008 *Quiet, non-consumptive recreation reduces protected area effectiveness* Conservation Letters 1-9	Surveys for mammalian carnivores in protected areas with and without recreation revealed a five-fold decline in the density of native carnivores and a substantial shift from native to non-native species in the areas with recreation.

2nd Tier: Important to read

References	Annotations
Quinn et al. 2010 *Role of horses as potential vectors of non-native plant invasion: an overview* Natural Areas Journal 30:408-416	Review paper looking at the connection between horses and non-native plant invasions. Also looks at other impacts of horses, including trampling vegetation, soil disturbance, and increased soil nitrogen. Recommends development of best management practices such as weed education programs for equestrians, use of Certified Weed Free Feed, and the use of manure bunkers.
Lathrop 2003 *Ecological impacts of mountain biking: a critical literature review* Wildlands CPR June 29, 2003	Review paper looking at the impacts of mountain biking, specifically vegetation trampling, erosion, and wildlife disturbance.
Reed and Merenlender 2011 *Effects of management of domestic dogs and recreation on carnivores in protected areas in Northern California* Conservation Biology 25(3):504-513	Explores the relationship between carnivore species richness and abundance with management of domestic dogs and recreational visitation in protected areas. Found that policy on domestic dogs did not affect carnivore richness and abundance. However, the number of dogs was strongly associated with number of humans, so key factors with effects on carnivores appears to be the number of human visitors.
Sampson 2007 *Effects of off-highway vehicles on archaeological sites in Red Rock Canyon* California State Parks Report *http://www.parks.ca.gov/?page_id=24576*	Investigation of ORV impacts at Red Rock Canyon State Park, with a focus on archaeological sites. Damage from vehicles includes vehicle scars, loss of soils and vegetation, gullying, deflation of cultural deposits, displacement and damage to artifacts and geologic features. Management options include installation of vehicle barriers, route closures, public education, increased patrol, erosion-control measures, and restoration of damaged terrain.

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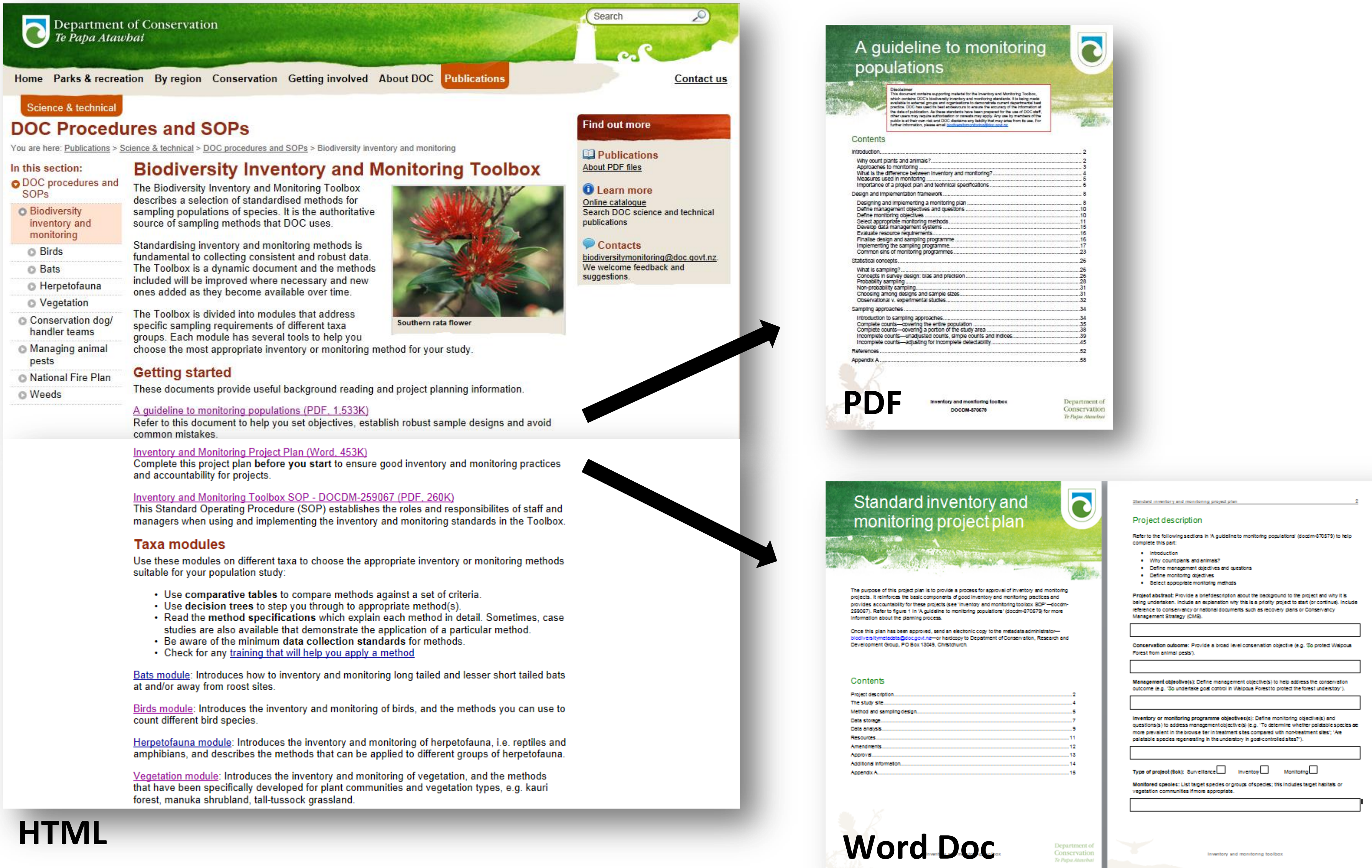
APPENDIX 5.1

NEW ZEALAND DEPARTMENT OF CONSERVATION - STANDARD OPERATING PROCEDURES: BIODIVERSITY INVENTORY AND MONITORING TOOLBOX

New Zealand Department of Conservation Standard Operating Procedures:

Biodiversity Inventory and Monitoring Toolbox



New Zealand DOC SOP
Biodiversity Inventory and Monitoring Toolbox:
General Guidance on Monitoring and Management

Section	Link ***http://www.doc.govt.nz/***	Description
Main Jump Page for Biodiversity Toolbox.	publications/science-and-technical/doc-procedures-and-sops/biodiversity-inventory-and-monitoring/	The page describes a selection of standardised methods for sampling populations of species. It is the authoritative source of sampling methods that DOC uses. **1 Page, HTML.** ***(accessed Apr. 2013)***
Overview of Monitoring. Excellent guide and reference.	Documents/science-and-technical/inventory-monitoring/guideline-to-monitoring-populations.pdf	Overview of statistical considerations in monitoring populations and communities for conservation. *"The importance of monitoring is recognised in national and international legislation and treaties … Improved and standardised monitoring practices"* will help conservation practice. **58 pages, PDF.** ***(Sep. 2012)***
Project Planning. (Word file)Excellent example of a template	Documents/science-and-technical/inventory-monitoring/im-toolbox-standard-inventory-and-monitoring-project-plan.doc	"The purpose of this project plan is to provide a process for approval of inventory and monitoring projects. It reinforces the basic components of good inventory and monitoring practices and provides accountability for these projects." ***15 pages, DOC. (May 2012)***
Mission of Dept. of Conservation SOP's and Toolbox	http://www.doc.govt.nz/Documents/science-and-technical/inventory-monitoring/im-toolbox-sop.pdf	"The Toolbox will ultimately become the authoritative source for all inventory and monitoring methods and standards" **7 pages, PDF. (Apr. 2012)**
Taxa Specific Modules *(More details below)*	Various	The toolbox contains taxa modules for animal pests, bat, birds, herpetofauna, vegetation, freshwater systems, and freshwater fish including **7 overview documents** and **61 methods** totaling several thousand pages

New Zealand DOC SOP
Biodiversity Inventory and Monitoring Toolbox:
Taxa Modules

- Use **comparative tables** to compare methods against a set of criteria.
- Use **decision trees** to step you through to appropriate method(s).
- Read the **method specifications** which explain each method in detail.
- Be aware of the minimum **data collection standards** for methods.

BATS	Link ***http://www.doc.govt.nz/***	Description
Main Jump Page for Bats Taxa Module.	publications/science-and-technical/ doc-procedures-and-sops/ biodiversity-inventory-and-monitoring/bats/	Introduces how to inventory and monitoring bats at and/or away from roost sites. Includes links to an introduction, a best-practices guide, and 13 methods papers. **1 Page HTML.** ***(accessed Apr. 2013)***
Introduction to bat monitoring	Documents/science-and-technical/inventory-monitoring/im-toolbox-bats/im-toolbox-bats-introduction-to-bat-monitoring.pdf	Overview of statistical considerations in monitoring bat populations at roosts and away from roosts at foraging sites. **35 pages, PDF.** ***(Sep. 2012)***
DOC best practice manual of conservation techniques for bats	Documents/science-and-technical/inventory-monitoring/im-toolbox-bats/ im-toolbox-bats-doc-best-practice-manual-of-conservation-techniques-for-bats.pdf	This manual has information and resources on selecting and/or applying a inventory or monitoring method for bats. ***169 pages, PDF. (Apr. 2013)***
Links to specific methods for bats	13 different links	This manual has information on line transects, automatic detectors, roost surveys and others. ***~300 pages in 13 PDF files***

New Zealand DOC SOP
Biodiversity Inventory and Monitoring Toolbox:
Taxa Modules (continued)

BIRDS	Link *http://www.doc.govt.nz/*	Description
Main Jump Page for Birds Taxa Module.	publications/science-and-technical/ doc-procedures-and-sops/ biodiversity-inventory-and-monitoring/birds/	Introduces how to inventory and monitoring birds complete and incomplete counts as well as absolute estimates of density. Includes links to an introduction and 9 methods papers. **1 Page HTML.** ***(accessed Apr. 2013)***
Introduction to bird monitoring	Documents/science-and-technical/ inventory-monitoring/ im-toolbox-birds-introduction-to-monitoring.pdf	Overview of statistical considerations in monitoring bird populations using a detailed decision tree based on project objectives. **36 pages, PDF.** ***(Feb. 2012)***
Links to specific methods for birds	9 different links	This manual has information on a range of technique from photographic methods, incomplete counts, mist netting, distance sampling, mark-resight and others. ***~200 pages in 9 PDF files***

HERPETOFAUNA	Link *http://www.doc.govt.nz/*	Description
Main Jump Page for Herpetofauna	publications/science-and-technical/ doc-procedures-and-sops/ biodiversity-inventory-and-monitoring/herpetofauna/	This page introduces the inventory and monitoring of herpetofauna, i.e. reptiles and amphibians, **1 Page HTML.** ***(accessed Apr. 2013)***
Introduction to herpetofauna monitoring	Documents/science-and-technical/i nventory-monitoring/im-toolbox-herpetofaunda-introduction-to-monitoring.pdf f	Describes the different herpetofauna functional groups and discusses the most appropriate method(s) based on objectives **10 pages, PDF.** ***(Sep. 2012)***
Links to specific methods for herpetofauna	7 different links: 5 field methods and 2 information methods (indices and estimation)	This manual has information on a range of technique from photographic methods, pitfall traps, mark-recapture and others. ***~220 pages in 7 PDF files***

Taxa Modules (continued)

VEGETATION	Link ***http://www.doc.govt.nz/***	Description
Main Jump Page for Vegetation Module.	publications/science-and-technical/ doc-procedures-and-sops/biodiversity-inventory-and-monitoring/vegetation/	Inventory and monitoring of vegetation for plant communities and vegetation types, e.g. forest, shrubland, and grassland.. **1 Page HTML.** ***(accessed Apr. 2013)***
Introduction to vegetation monitoring	Documents/science-and-technical/ inventory-monitoring /im-toolbox-vegetation-introduction-to-monitoring.pdf	Describes methods for assessing species, community composition and structure, and ecosystem processes. **28 pages, PDF.** ***(Sep. 2012)***
Links to specific methods for vegetation	5 different links	This manual has information on a range of techniques from large permanent forest plots to methods used to assess structure in grasslands. ***~160 pages in 5 PDF files***