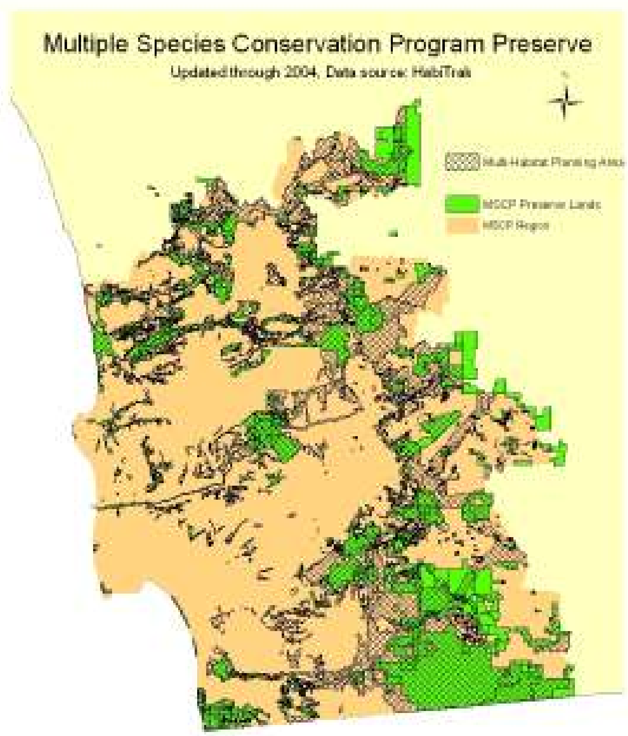
Assessment of the Biological Monitoring Plan for San Diego's Multiple Species Conservation Program

Report for Task A of Local Assistance Grant #P0450009



August 2005

Prepared for
California Department of Fish and Game
Grant Coordinator: Dr. Brenda S. Johnson

Prepared by
Department of Biology, San Diego State University
Lauren A. Hierl, Dr. Helen M. Regan,
Dr. Janet Franklin, and Dr. Douglas H. Deutschman

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

Background

This document is the first report for California Department of Fish and Game Local Assistance Grant #P0450009, which will assess and improve the San Diego Multiple Species Conservation Program Biological Monitoring Plan. This report focuses on assessing the implementation of the monitoring program to date, and reviewing information relevant to successful monitoring program design.

Multiple Species Conservation Program – San Diego's Multiple Species Conservation Program (MSCP) intends to conserve the diversity and function of the southwestern San Diego County ecosystem through preservation and adaptive management of habitat. The MSCP also aims to conserve 85 specific "covered" species. The reserve system currently includes over 127,000 acres of land. Monitoring and management responsibility for this large network of land lies with multiple jurisdictions, particularly the County and City of San Diego, and participating wildlife agencies such as U.S. Fish and Wildlife Service (USFWS), California Department of Fish and Game (CDFG), and U.S. Geological Survey (USGS).

Biological Monitoring Plan – The MSCP Biological Monitoring Plan (BMP) was issued in 1996 and included prioritized monitoring protocols for habitats, corridors, and covered plant and animal species. In 2001, the Conservation Biology Institute reviewed and refined the BMP. They concluded there was inadequate data to recommend updated protocols, though they did provide a new framework for habitat monitoring. Neither the original monitoring plan nor CBI's revisions were ever widely implemented, and debate remains on how to meet the monitoring and management needs of the MSCP.

Problem – Though the MSCP partners have made much progress in acquiring land and collecting baseline data through surveys, studies, and monitoring, it is still difficult to determine if the MSCP reserve is meeting its biological conservation goals. Implementation of the monitoring protocols has been limited, and each monitoring partner has used different methods and priorities.

In 2004, Andrea Atkinson and others published a report entitled "Designing Monitoring Programs in an Adaptive Management Context for Regional Multiple Species Conservation Plans". This report included nine steps for designing an effective BMP. By carrying out several of these steps for this Local Assistance Grant, we aim to improve the scientific robustness of the monitoring program and enhance the ability of the monitoring partners to determine if the MSCP reserve is meeting its biological goals.

Goals and Objectives

The MSCP identifies two primary biological goals: conserving diversity and function of the ecosystem, and conserving populations of specific species. The MSCP Plan and the BMP also identify specific objectives for the monitoring program, including the documentation of ecological trends and evaluation of the effectiveness of management activities. The goals and objectives of the MSCP and its monitoring plan provide a good foundation, but their effectiveness would improve if conservation targets and triggers for management were created, based on the best available data.

Review of monitoring to date

The implementation of the MSCP biological monitoring plan has been partially successful, as baseline surveys have been conducted for many MSCP parcels and for a variety of covered species. Studies have been commissioned on a diverse array of topics. However, the protocols described in the original BMP have not been adopted by most jurisdictions or agencies. An important exception is the City of San Diego's rare plant monitoring program and their additional surveys and studies on other monitoring issues. The County has surveyed many of their lands and contracted out studies on several important issues. The primary wildlife agencies USGS, USFWS, and CDFG have also surveyed MSCP lands and studied relevant questions.

Some important aspects of the monitoring program must be improved for the plan to be successful. Important areas to improve include the lack of: (1) a central repository of spatial and non-spatial data and MSCP-related documents; (2) updated and scientifically-defensible monitoring priorities; (3) management-oriented conceptual models; (4) data analysis and synthesis capacity; and (5) feedback between decision-makers and land managers.

Review of Scientific Literature

We present an examination of the MSCP monitoring plan in the context of biological monitoring principles, designs, and methodologies considered in the scientific literature. The discussions provide background for our future tasks of identifying and prioritizing attributes to monitor, developing conceptual models, identifying critical uncertainties, and determining a monitoring strategy.

One of the first tasks in the design of a biological monitoring plan is the prioritization of species, indicators/focal species, and/or habitat attributes that will shape data collection activities. Many at-risk species classification schemes have been developed to prioritize species for conservation management. The most appropriate method for the MSCP will depend on the management scenarios proposed, the available data, the assessment time frame, and the scale at which the assessment is made. Since all components of a system cannot be measured, indicator variables must be selected. Monitoring focal species is one approach, where the goal is to provide insight into the integrity of the ecosystem by monitoring particular species. Criticism about the effectiveness of this approach abounds, and these must be considered when using indicators.

Conceptual models have been identified as a critical step in developing biological monitoring plans. These models attempt to link causes or pressures with effects on the system. The models should include a link between decision-making and management actions, and formal methods of model development should be considered, including how best to use expert opinion when quantitative data are lacking.

Application of statistical sampling theory to monitoring must respect the constraints and complexities that are inherent in monitoring biological populations. These complexities make broad, synthetic monitoring programs very difficult to design and evaluate. However, there is a rich literature on statistical sampling theory and a growing one on monitoring through time that will prove useful in designing a scientifically robust sampling design for monitoring.

Initial Recommendations

We have identified a preliminary set of recommendations on how to improve the monitoring program. This Local Assistance Grant (LAG) will carry out some of these recommendations in later tasks, the Rare Plant LAG will carry out other recommendations, and the remaining issues will need to be addressed by the monitoring partners. Recommendations include:

1) Updating the conservation targets and setting management triggers based on the best available data

2) Comprehensively surveying all MSCP lands for the covered species and natural communities represented and compiling all the results

3) Mapping covered species, natural communities, and monitoring locations

4) Storing and maintaining survey, map, and monitoring databases in a single location

5) Creating a digital library of all MSCP-related materials

6) Applying an at-risk-species prioritization scheme to provide scientifically-defensible monitoring priorities

7) Developing conceptual models for prioritized components that make the link between monitoring and management explicit

CHAPTER 1: BACKGROUND

Introduction

> *It is deeply discreditable to the people of any country calling itself civilized that as regards many of the grandest or most beautiful or most interesting forms of wild life once to be found in the land we should now be limited to describing, usually in the dryest of books, the physical characteristics which when living they possessed, and the melancholy date at which they ceased to live.*
>
> Theodore Roosevelt: January 20, 1915.
> Quoted in DiNunzio (1994)

Theodore Roosevelt was the first president to champion conservation. He was motivated both by his own love of sport hunting and a deep commitment to the conservation of natural habitats (DiNunzio 1994). The Roosevelt doctrine (Leopold 1933) recognized the importance of science as a tool for conservation. In a 1915 article, Roosevelt praised William T. Hornaday for his scientific textbook on conservation urging that it "should be owned and constantly used by every man and woman alive" (DiNunzio 1994). Roosevelt embraced this scientific text because Hornaday promised to "avoid the discussion of academic questions, because the business of conservation is replete with urgent practical demands" (Hornaday 1914). This idea that conservation is driven by urgent practical demands is at least as true today as it was 90 years ago.

San Diego's Multiple Species Conservation Program (MSCP) was based on many of the principles espoused by Roosevelt and others early in the 20th Century. The MSCP is an important attempt to advance the urgent practical demands of conservation by coordinating habitat and species conservation at a regional level, instead of allowing a piecemeal approach to leave a fragmented ecosystem unable to support rare species and habitats.

This document is the first of six reports for California Department of Fish and Game Local Assistance Grant #P0450009, which will assess and improve the San Diego Multiple Species Conservation Program Biological Monitoring Plan. This report focuses on assessing the implementation of the monitoring program to date, and reviewing information relevant to successful monitoring program design.

Multiple Species Conservation Program

The MSCP aims to conserve the diversity and function of the southwestern San Diego County ecosystem through the preservation and adaptive management of large blocks of interconnected habitat and smaller areas that support rare vegetation communities such as vernal pools. The MSCP was also designed to conserve specific species at levels that meet the take authorization issuance standards of the federal Endangered Species Act and California's Natural Community Conservation Planning Act. The Multi-Habitat Planning Area was the land targeted for inclusion in the reserve, and was designed by a cooperative group of jurisdictions, wildlife agencies, property owners, developers, and environmental groups. The majority of land currently acquired by the MSCP partners falls within the boundaries of the Multi-Habitat Planning Area (Figure 1).

Eighty-five species are "covered" by the San Diego MSCP, including 39 animal species and 46 plant species (see Appendix A for a list of the covered species). The MSCP planning area includes 14 jurisdictions and special districts. Over 127,000 acres have been added to the reserve through 2004, and lands continue to be added by the participating jurisdictions and wildlife agencies (San Diego Association of Governments 2004).

Biological Monitoring Plan

The biological monitoring component of the MSCP is intended to ensure that the reserve is achieving its biological goals by collecting and analyzing data on preserved habitats and covered species.

The Biological Monitoring Plan (BMP) for San Diego's MSCP was written by Ogden Environmental in 1996, under contract to the City of San Diego, California Department of Fish and Game (CDFG), and U.S. Fish and Wildlife Service (USFWS). They were tasked with setting monitoring priorities and protocols in order to determine whether the MSCP reserve was preserving covered species and ecosystem function and integrity. The Biological Monitoring Plan describes monitoring methods for (a) habitats, (b) corridors, and (c) covered plant and animal species.

The stated objectives of the BMP (Ogden Environmental and Energy Services 1996) were to: document the protection of habitats and covered species as specified in Subarea Plans and Implementing Agreements; document changes in preserved habitats or preserved populations of covered species; describe new biological data collected, such as new species sightings and information on wildlife movement and corridors; evaluate impacts of land uses and construction activities in and adjacent to the preserve; evaluate management activities and enforcement difficulties; and evaluate funding needs and the ability to accomplish resource management goals.

In 2001, the California Department of Fish and Game and the City of San Diego contracted with the Conservation Biology Institute (CBI) to review and refine the MSCP monitoring protocols from the original Biological Monitoring Plan (Ogden Environmental and Energy Services 1996). This effort yielded several important insights. CBI emphasized that refining the protocols would require analysis of existing monitoring data, additional testing of protocols, and evaluation of the types of monitoring being implemented at individual preserves (Conservation Biology Institute 2001). They did not believe they had adequate data to recommend updated protocols at that time. CBI did recommend abandoning the "habitat value monitoring" protocols from the original BMP, and provided a new draft framework for habitat monitoring. Neither the original monitoring plan nor CBI's revisions have been widely implemented, and there is still debate about how to meet the monitoring needs of the MSCP.

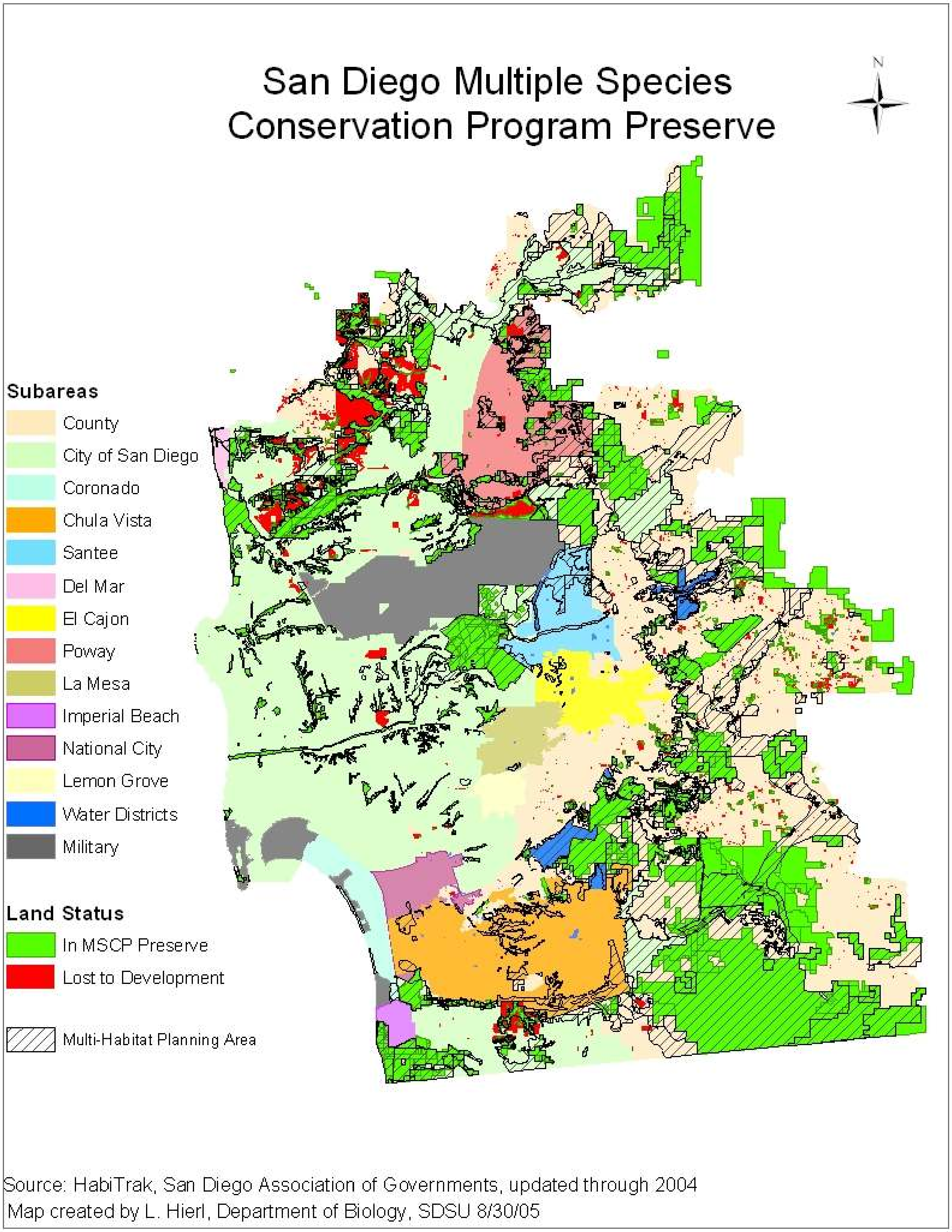


Figure 1. San Diego Multiple Species Conservation Program Preserve. Source: San Diego Association of Governments, HabiTrak, received from Sue Carnavale 5/12/05

Problem Statement

Though great strides have been made in acquiring land (Figure 2) and collecting baseline data through surveys, monitoring, and studies, it is still difficult to determine if the MSCP Preserve is meeting the goals of preserving ecosystem diversity and function and covered species populations. The initial and revised monitoring plans continue to be discussed and debated, and it is therefore not surprising that implementation of the monitoring protocols has been limited.

The BMP was written before most of the MSCP lands were preserved, so the authors did not know which habitats and species would be represented in the final reserve. At this time, the majority of MSCP lands have been acquired or are in the process of being acquired, so we are in a better position to determine which habitats and covered species are represented in the MSCP reserve, and where they are located. Over the past 10 years, our understanding of some of the covered species has improved, and advances have been made in monitoring program design and protocol development.

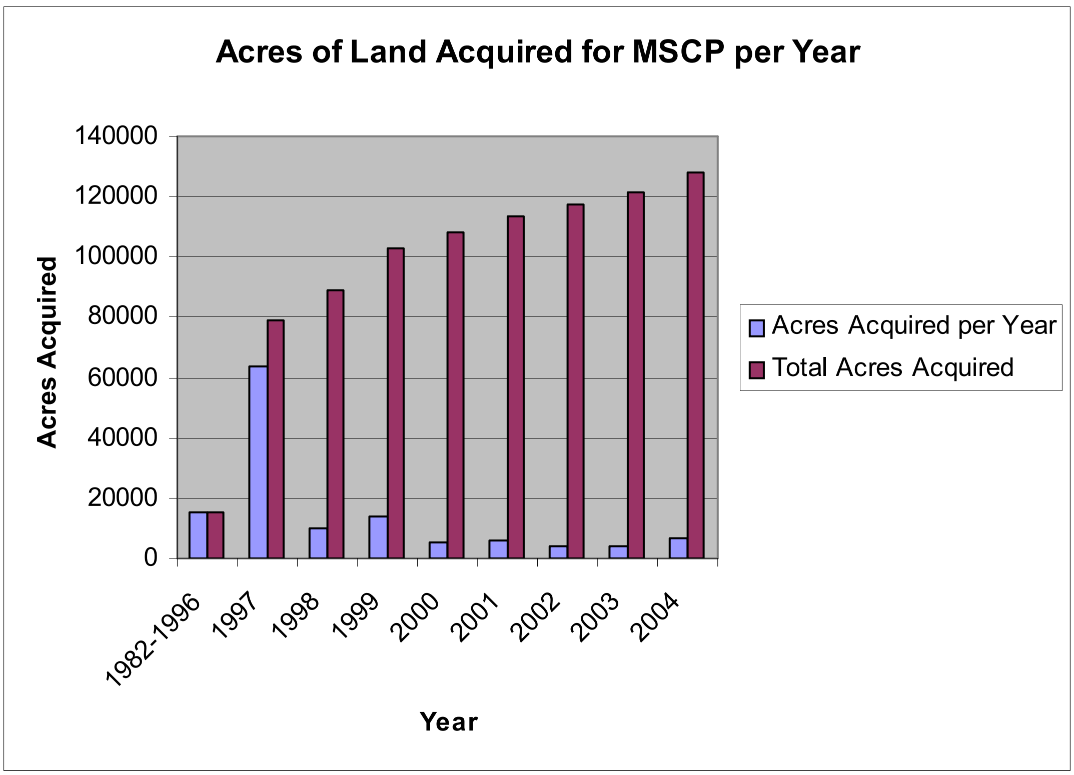


Figure 2. MSCP annual and total land acquisition from 1982-2004. Source: San Diego Association of Governments, HabiTrak, received from Sue Carnavale 5/12/05

MSCP biological monitoring has been implemented differently by each participating jurisdiction and wildlife agency since the BMP was issued in 1996. The majority of the monitoring effort to date has been focused on conducting baseline surveys, but these efforts are not completely comprehensive, nor have they been systematically compiled or synthesized for the entire MSCP Preserve. Data that have been collected by jurisdictions are sent to the wildlife agencies for annual review, analysis, and synthesis. The wildlife agencies have not had adequate resources to analyze the majority of the data, nor have they produced the Three-Year Report recommended in the original monitoring plan to summarize monitoring efforts, ecosystem status, and species status across the MSCP. Compilation and synthesis of MSCP data is difficult because of the dynamic nature of the MSCP, the complex geography of the region, and the variety of data collection methods and formats used.

In 2004, Andrea Atkinson and others compiled and critiqued the diverse literature on biological monitoring. The resulting report entitled "Designing Monitoring Programs in an Adaptive Management Context for Regional Multiple Species Conservation Plans" is an ambitious attempt to synthesize the theory behind biological monitoring and provide practical guidance on how to develop a monitoring program. Their report outlined nine steps for designing an effective monitoring program. Although these steps are similar to other published guides (e.g. Noon et al. 1999), we have structured our project around the steps as presented by Atkinson et al.:

Step 1: *Identify the goals and objectives of the regional conservation plan*
Step 2: *Identify scope of monitoring program*
Step 3: *Compile information relevant to monitoring program design*
Step 4: *Strategically divide the system and prioritize for monitoring program development*
Step 5: *Develop simple management-oriented conceptual models*
Step 6: *Identify monitoring recommendations and critical uncertainties*
Step 7: *Determine strategy for implementing monitoring*
Step 8: *Develop data quality assurance, data management, analysis, and reporting strategies*
Step 9: *Complete the adaptive management loop by ensuring effective feedback to decision-making*

To address Task A of this Local Assistance Grant this report will focus on the first three steps, particularly the compilation and assessment of information relevant to monitoring program design (Step 3).

Conclusions

San Diego's MSCP is an ambitious program to conserve species and functioning ecosystems in a region with heavy development pressure. The monitoring program aims to ensure that the covered species and habitats are preserved in perpetuity. The monitoring partners have successfully set aside large patches of land and collected data on a variety of issues and species. By carrying out the steps for designing a successful monitoring plan identified by Atkinson et al. (2004) we will improve the scientific robustness of the program and enhance the ability of the monitoring program participants to determine (1) if the Preserve is meeting its biological goals, and (2) if not, what they should do to improve the status and condition of the habitats and covered species.

In the remaining chapters, we assess the current state of the biological monitoring program for the MSCP. Chapter 2 identifies and discusses the goals and objectives of the biological monitoring plan. In Chapter 3, we present a compilation of the monitoring activities carried out by the different jurisdictions and agencies. Chapter 4 is a summary of some of the relevant scientific and policy literature on biological monitoring. Chapter 5 describes preliminary recommendations on how to proceed with developing and improving the monitoring program. These chapters break little new ground but are a necessary first step toward our future tasks under this Local Assistance Grant of grouping and prioritizing species for monitoring (Task B), developing conceptual models (Task C), identifying critical uncertainties and making monitoring recommendations (Task D), and determining a strategy for implementing the monitoring program (Task E).

CHAPTER 2:
GOALS AND OBJECTIVES

Introduction

Several monitoring partners have raised a discussion about the goals and objectives of the monitoring program so we have included a brief summary of the characteristics of effective monitoring goals and objectives, and identified the goals outlined in the MSCP planning documents, Biological Monitoring Plan, and Conservation Biology Institute revisions in 2001.

Clear and concise goals and objectives are critical components of a successful biological monitoring plan (Gibbs et al. 1999, Mulder et al. 1999, Bisbal 2001, Noon 2003). Bisbal (2001) emphasizes the importance of simple and unambiguous goals, reflective of relevant spatial and temporal scales. These goals must also be feasible to measure and assess through monitoring. Objectives should describe the desired state of the system that management intends to maintain or achieve. Such objectives help determine what should be measured, where, and how often (Gibbs et al. 1999). Clear objectives also help determine what statistical methods should be used to analyze the data (Olsen et al. 1999). Unclear goals and objectives can lead to "the wrong variables being measured in the wrong place at the wrong time with poor precision or reliability" (Noss and Cooperrider 1994). Overall, the goals should provide a clear description of what the conservation program aims to achieve, and the monitoring program should be able to determine whether or not these goals are being met (Rahn 2005).

Yoccoz (2001) distinguishes between scientific and management objectives. Scientific objectives endeavor to learn about the ***behavior*** and ***dynamics*** of the monitored system. Management objectives attempt to identify the ***state of the system*** and provide information about the system's ***response to management actions***. For the MSCP, both scientific and management objectives may be appropriate at different times, but the primary focus should be on management objectives. The idea that monitoring must support practical management echoes Hornaday's 1914 entreaty that "conservation is replete with urgent practical demands." Focusing monitoring on management goals means data must be collected on species and natural communities' status, trends, threats, and possible management responses.

Setting "triggers" for management when the system reaches a certain state is one approach for management-oriented monitoring (Mulder et al. 1999, Bisbal 2001). For example, if the goal is to detect changes in the population size and geographic range of selected wildlife species, it will be important to define what constitutes the minimum significant change in the parameter before a management action is triggered (e.g., a 20 percent decline in the species' range over 25 years) (Haufler 1999, Oregon Department Of Forestry 2000).

Management-oriented monitoring is also facilitated by the creation of species-specific and habitat-level conservation targets. Examples of conservation targets include:

(1) Target/threshold objectives; e.g., increase the population size of Species A to 5000 individuals; maintain a population of a rare plant Species B at 2500 individuals or greater; keep Site C free of invasive weeds X and Y

(2) Change/trend objectives; e.g., increase mean density of Species A by 20%; decrease frequency of invasive weed X by 30% at Site C (National Park Service 2005)

In some cases, targets may also serve to guide management trigger points. For example, if Site C becomes invaded with weeds X and Y then a management action would be triggered to counteract that event.

In order to evaluate changes in the system, baseline conditions must be established (Gibbs et al. 1999). The MSCP monitoring program aspires to link monitoring to management, so baseline conditions that must be established include where the populations of interest are located in the reserve, estimates of natural variability of the populations, and data on potential threats to species and communities. Where appropriate, the baseline conditions should be compared with management trigger points to determine if immediate management action is necessary.

The remainder of this chapter will describe and discuss the goals and objectives articulated in the MSCP planning documents and original Biological Monitoring Plan.

Goals and Objectives Identified in MSCP Planning Documents

San Diego's Multiple Species Conservation Program (Ogden Environmental and Energy Services 1998) describes two primary biological goals: [p. 1.5]

- Conserve the diversity and function of the ecosystem through the preservation and adaptive management of large blocks of interconnected habitat and smaller areas that support rare vegetation communities (e.g. vernal pools).
- Conserve specific species at levels that meet the take authorization issuance standards of the federal Endangered Species Act (ESA) and California's Natural Community Conservation Planning Act (NCCPA).

Having dual goals requires the monitoring plan to include objectives and protocols for data collection and analysis for both ecosystem and species-level components.

The MSCP also describes several objectives for the biological monitoring program:

- Document ecological trends
- Evaluate the effectiveness of management activities
- Provide new data on species populations and wildlife movement
- Evaluate the indirect impacts of land uses and construction

The Biological Monitoring Plan should be designed so the data collected and analyzed will determine whether the Multiple Species Conservation Program is meeting these biological goals and objectives.

Goals and Objectives Identified in Biological Monitoring Plan

The original Biological Monitoring Plan (Ogden Environmental and Energy Services 1996) reiterated the objectives stated in the MSCP planning documents but framed them in slightly different terms. The Conservation Biology Institute (CBI) clarified the objectives in their 2001 summary of the status of the monitoring program by adding specific questions that should be addressed for each objective. The BMP objectives and CBI questions are as follows:

- Document the protection of habitats and covered species as specified in subarea plans and implementing agreements.
  - What vegetation communities and geographic areas within the MSCP planning area are being conserved?
  - What focal species populations are being conserved at individual monitoring locations?
- Document changes in preserved habitats or preserved populations of covered species.
  - Where are the changes in vegetation community composition resulting from fire and floods within the MSCP planning area?
  - What is the change in habitat value along a preserve edge-to-interior gradient at individual monitoring locations and at the MSCP scale?
  - What are the status and trends of focal species populations or occurrences at individual monitoring locations and at the MSCP scale?
- Describe new biological data collected, such as new species sightings and information on wildlife movement and corridors.
  - What is the use of designated wildlife corridors by focal species at specific monitoring locations?
  - How do construction activities and adjacent land uses affect corridor use by focal species at individual monitoring locations and at the MSCP scale?
  - How does corridor configuration or design affect corridor use by focal species at the MSCP scale?
- Evaluate impacts of land uses and construction activities in and adjacent to the preserve.
  - What is the change in vegetation community acreage within the MSCP planning area and what areas account for these changes?
  - What is the change in habitat value along a preserve edge-to-interior gradient at individual monitoring locations and at the MSCP scale?
  - How do construction activities and adjacent land uses affect corridor use by focal species at individual monitoring locations and at the MSCP scale?
- Evaluate management activities and enforcement difficulties.
  - How do biological resources respond to management actions at the Preserve scale?
  - What are the enforcement difficulties encountered at the Preserve scale?
- Evaluate funding needs and the ability to accomplish resource management goals.

- What are the funding needs to accomplish management goals at the Preserve scale?
- What is the likelihood of achieving management goals at the Preserve scale?

The original monitoring plan also identified additional objectives for individual portions of the monitoring program. For example, the plan described a need to ensure that human-related activities do not present immediate threats to covered species nor threaten the ability of a population to persist over time.

Each jurisdiction's Subarea Plan then identified conservation targets based on the expected level of conservation of the species once the MSCP preserve lands were acquired. Appendix A summarizes the conservation targets identified in the City and County of San Diego Subarea Plans. Now that the majority of MSCP lands have been conserved or are in the acquisition process, these targets can and should be evaluated and updated.

Conclusions

The broad goals and objectives identified in the MSCP and Biological Monitoring Plan provide a good foundation for the monitoring plan, particularly identifying the need for both ecosystem and species-level monitoring objectives and protocols. The BMP's objectives failed to provide specific, measurable questions to help determine if the MSCP Preserve is meeting its biological goals, though CBI's revisions added some clarification. Since the original biological goals were determined through a political process, they are most appropriately refined by the participating wildlife agencies and jurisdictions. As scientific reviewers, we will instead provide initial recommendations in Chapter 5 of this report on steps that can be taken to refine monitoring objectives, such as by setting updated conservation targets. We stress however, that the goals of any conservation plan are defined in the policy arena and may need to be revisited and further refined in that light by the appropriate agency personnel.

We will use the goals listed below, excerpted from the MSCP and BMP documents, to inform our future analyses. Should the monitoring partners choose to alter these goals and objectives, we will work from the most updated versions available.

The monitoring program should collect and analyze data to determine whether the MSCP Preserve is meeting its goals of:

- Conserving diversity and function of ecosystems (which can and should be further defined by the monitoring participants)
- Conserving specific covered species to meet take authorization issuance standards for ESA and NCCPA (i.e. preventing jeopardy to the species)
- Identifying threats to covered species and habitats to ensure that human-related activities do not present immediate threats to populations or habitats, nor threaten the ability of populations or habitats to persist over time
- Identifying, prioritizing, and assessing management responses

CHAPTER 3:
REVIEW OF MONITORING TO DATE

Introduction

The implementation of the MSCP biological monitoring plan has been partially successful, as baseline surveys have been conducted for many MSCP parcels and for an assortment of covered species. Studies have been commissioned on a diverse array of topics, such as the effectiveness of wildlife corridors in the MSCP, the value of remote sensing technology for monitoring, and the use of herpetofaunal pitfall arrays.

However, the protocols described in the original Biological Monitoring Plan have not been adopted by most jurisdictions or agencies. The original protocols were often impractical to implement given available levels of funding, staffing, and expertise. An important exception is the City of San Diego's rare plant monitoring program. In addition to the rare plant monitoring, the City of San Diego has conducted and commissioned surveys and studies on important monitoring issues. The County of San Diego has surveyed many of its lands for rare species, and has contracted out studies on a variety of MSCP-related topics. The wildlife agencies, primarily U. S. Geological Survey, U. S. Fish and Wildlife Service, and California Department of Fish and Game have also surveyed MSCP lands, monitored a subset of covered species, and studied relevant questions. Other jurisdictions have been less actively involved in MSCP monitoring to date but may play a larger role in the future (i.e., City of Chula Vista and City of Poway).

Today we have more knowledge about the state of this system than was available to the authors of the original BMP, both because the majority of the MSCP lands have now been acquired, and because we have improved our knowledge of some of the covered species and reserves.

In this chapter we present brief summaries of the monitoring activities of the participating jurisdictions and wildlife agencies through 2004, based on reports, studies, and conversations with City, County, and agency personnel. We also provide an assessment of the monitoring activities to date in light of the nine steps described in Atkinson et al. (2004). We identify critical data gaps that must be filled to improve the monitoring program. Appendix B provides a summary by species of the monitoring, surveys, and studies for each of the covered species.

Monitoring History of Jurisdictions

The MSCP currently comprises over 127,000 acres of land managed by more than half a dozen jurisdictions and agencies (Figure 1), using 6 separate Subarea Plans and additional management plans for specific parcels.

City of San Diego

The City of San Diego has attempted to implement aspects of the monitoring protocols described in the original Biological Monitoring Plan, particularly for rare plants covered by the MSCP. Since 1999 the City has produced reports summarizing the results for the plants monitored that year. The City also maps many of their monitoring efforts, including transects that can be relocated and monitored over multiple years, covered species point locations, and population boundaries (Figure 3).

The City has monitored the following covered plant species:

- *Acanthomintha ilicifolia* (2000, 2001, 2002, 2003, 2004, 2005)
- *Ambrosia pumila* (1999, 2000, 2001, 2003)
- *Arctostaphylos glandulosa* ssp. *crassifolia* (2002)
- *Brodiaea orcuttii* (2001, 2002, 2003, 2005)
- *Cordylanthus orcuttianus* (2001, 2002, 2003, 2004, 2005)
- *Cylindropuntia californica* var. *californica* (2002, 2005)
- *Deinandra conjugens* (2003, 2004, 2005)
- *Dudleya blochmaniae* ssp. *brevifolia* (1999, 2000, 2001, 2002, 2003, 2004, 2005)
- *Dudleya variegata* (2001, 2002, 2003, 2004, 2005)
- *Lessingia filaginifolia* (2001, 2002, 2003, 2005)
- *Lotus nuttallianus* (2000, 2001, 2002, 2003, 2004, 2005)
- *Monardella linoides* ssp. *viminea* (2000, 2001, 2002, 2003, 2004, 2005)
- *Muilla clevelandii* (2000, 2001, 2002, 2003, 2004, 2005)

The City hired Dudek & Associates to conduct baseline surveys in 1998, and McMillan Biological Consulting and the Conservation Biology Institute to conduct rare plant surveys on City lands in 2000 and 2001 (McMillan Biological Consulting and Conservation Biology Institute 2002). They now have estimates of the locations and major populations of covered plant species on their lands. They also contracted out an Ambrosia Management Plan at Mission Trails Regional Park (Dudek & Associates 2000) and a study on *Ceanothus verrucosus* imaging at Lake Hodges in 2001 (Imagis and Blackhawk Helicopters 2001).

For covered animal species, the City coordinated:

- Burrowing owl surveys, conducted by Jeff Lincer (2001) and WRI (2003)
- California gnatcatcher surveys, conducted by URS (2001) and WRI (2004)
- Herpetofaunal monitoring in the MSCP region of San Diego (Rochester et al. 2001), and the continuation of USGS herpetofauna pitfall array trapping at 13 sites on City MSCP lands in 2000 and 2002
- Quino checkerspot Citywide baseline surveys from 1999-2004

  (Note: Quino checkerspot is not currently a covered species in the MSCP, but pending a decision on the proposed amendment to add the butterfly to the covered species list, we will include descriptions of Quino monitoring and surveys in this chapter of our report.)

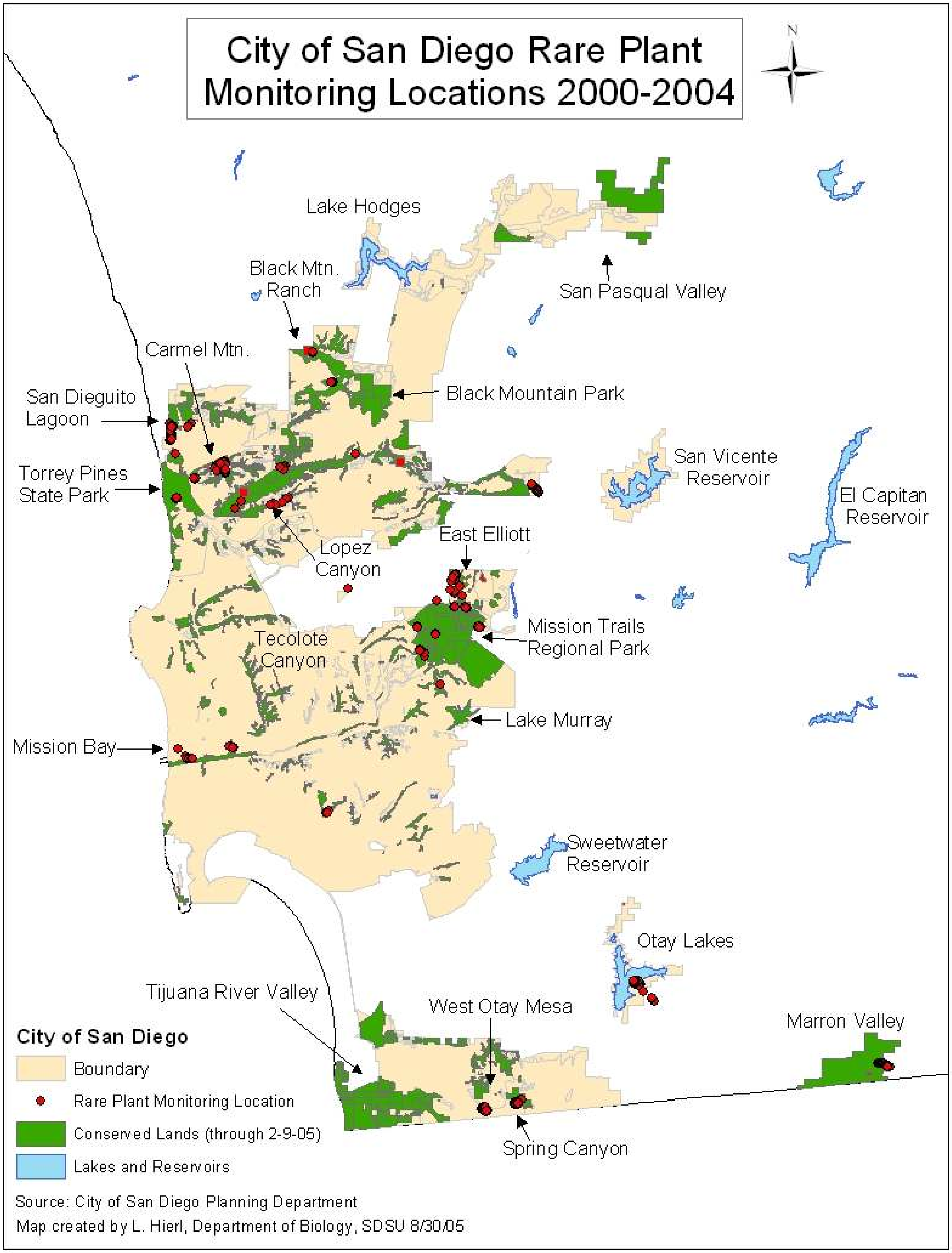


Figure 3. City of San Diego Rare Plant Monitoring Locations from 2000-2004. Source: City of San Diego Planning Department

The City has been involved in some habitat-level/vegetation monitoring, including the following studies:

- A habitat quality pilot project with San Diego State University, evaluating remote sensing methods for establishing conditions and detecting changes in habitat quality at Mission Trails Regional Park and Crestridge (Stow et al. 2001)
- Marron Valley Habitat Quality Pilot Project, attempting to implement the protocols for habitat monitoring described in the original Biological Monitoring Plan, which were subsequently deemed too costly and labor-intensive (Conservation Biology Institute 2000)
- Citywide vernal pool baseline surveys were completed in 2003, and City staff are performing a follow-up study to compare changes in vernal pool areas from 2003 to 2005
- Study: "Image-Based Detection of Changes between 2001-2003 at the Otay Mesa Vernal Pool Restoration Site" (Coulter et al. 2004)
- Study: "The Utility of High Spatial Resolution Multispectral Imagery for Mapping and Monitoring Vernal Pool Habitat in Transitional Urban Environments" (Greer et al. 2002)
- Wildlife corridor studies (Conservation Biology Institute 2002, 2003a, 2003b)

The City is working to complete management plans for Carmel Mountain, Del Mar Mesa, Tecolote Parks, Black Mountain, and a vernal pool management plan coordinated with USFWS.

Limited staffing and funding are major considerations in the City's monitoring efforts (Melanie Johnson pers. comm. 8/16/05). The City of San Diego would like to see a scientifically robust sampling design with specific, feasible protocols.

County of San Diego

The County of San Diego has conducted baseline surveys on many of their lands, and contracted out a variety of studies on covered species and other MSCP biological issues. They have not implemented the habitat-based monitoring protocols described in the original Biological Monitoring Plan but have recently started building on baseline data to establish permanent monitoring sites. The County focused the majority of their resources on land acquisition and baseline surveys following their permit approval in 1998 (Maeve Hanley from San Diego County, pers. comm. 5/10/05). In 2003, after many acres had been acquired and draft Area Specific Management Directives were being developed, wildfires forced the County, and many other agencies, to readjust their priorities and focus their resources on fire-related issues. The County is in the unique position of having some of their lands partially monitored for covered species and stewarded/managed by homeowner associations and other groups. The integration of monitoring activities on all their lands is an additional complication they must address.

Studies the County has contracted out:

- Sensitive Plant Surveys and Vegetation Communities Mapping (County of San Diego Multiple Species Conservation Program 2002) covering portions of Otay Ranch Preserve, McGinty Mountain, and Lusardi Creek

- Report of Coastal California Gnatcatcher Juvenile Dispersal across Interstate-8 at the MSCP Southern Lakeside Archipelago Lands, San Diego County, California (Campbell and Webb 2002, 2003)
- Lakeside Linkage Avian Species Surveys (Campbell 2002)
- Bat surveying of selected MSCP/NCCP reserves in the County of San Diego (Stokes et al. 2003)
- Habitat surveys and population monitoring of Arroyo southwestern toads (*Bufo californicus*) and Pacific pond turtles (*Clemmys marmorata pallida*) (Meyer et al. 2003)
- ADAR Report, analyzed aerial photo versus satellite imagery's usefulness in detecting landscape change (Batchelor and Martin 2002)
- Quino checkerspot surveys 1999, 2000, 2001, 2002, and a completed management and monitoring plan for the butterfly (Longcore et al. 2003)
- Wildlife corridor monitoring studies, conducted by CBI and the San Diego Tracking Team (Conservation Biology Institute 2002, 2003a, 2003b)
- Otay Ranch Resource Management Plan and Interim Implementation Plan (County of San Diego and City of Chula Vista Preserve Owner Manager 2004)
- Otay Valley Regional Park, Habitat Restoration Plan, conducted by HDR Engineering for the County, City of San Diego and Chula Vista. Draft circulated December 2004. This included detailed vegetation maps and locations of sensitive and invasive plant species.

The County is working to complete management plans for San Vicente Highlands and Barnett Ranch. Many "hardline" project areas (those areas with set boundaries of land to be developed and land to be included in the MSCP reserve) within the Lake Hodges segment have completed management plans, including 4S Ranch, Starwood, McCrink Ranch, Maranatha and Bernardo Lakes.

The County has other MSCP monitoring activities underway, including on-the-ground photo plots and permanent transects for sensitive plant species and avian species, and a GIS-based mapping system to keep track of covered species locations. They are working to merge their data with BIOS, the Biogeographic Information and Observation System at CDFG that stores and manages biological and spatial data. The County has also updated the vegetation maps for some of their lands. The County would like to receive guidance on habitat-level monitoring, particularly focused on the possibilities of using remote sensing and aerial photography (Jeremy Buegge and Maeve Hanley pers. comm. 5/10/05).

<u>*Other Jurisdictions*</u>

The City of Poway has an approved Subarea Plan, and has participated in limited monitoring activities, including contracting with CBI to conduct a study on road kill incidence to evaluate the effectiveness of the wildlife tunnel associated with the extension of Scripps Poway Parkway from Pomerado Road east to State Route 67.

Chula Vista, La Mesa, and Coronado's Subarea Plans have been approved by the wildlife agencies, but no MSCP monitoring has yet been conducted by these jurisdictions (NCCP 2005). Chula Vista's Implementing Agreement was signed in January 2005 and they have worked on a coordinated monitoring and management plan for the Otay Ranch property with the County and plan to begin monitoring efforts there in the near future.

Del Mar, El Cajon, and Santee have not yet submitted draft Subarea Plans to the wildlife agencies for approval. No monitoring has been conducted on MSCP lands by these cities (NCCP 2005). The cities of Imperial Beach, Lemon Grove, and National City have elected not to participate in the San Diego MSCP.

Monitoring History of Participating Agencies

The wildlife and biological resource agencies involved with the MSCP have conducted studies, surveys, and other monitoring-related activities on MSCP lands. The primary participating agencies include the U.S. Geological Survey, U.S. Fish and Wildlife Service, and California Department of Fish and Game.

U.S. Geological Survey

USGS has primarily conducted baseline surveys and studies on reptiles, amphibians, and terrestrial vertebrates including, but not limited to, MSCP covered species. They have also worked on post-fire monitoring projects that include covered species and MSCP Preserve lands.

Relevant studies and surveys include:

- Bat surveying of selected MSCP/NCCP reserves in the County of San Diego (Stokes et al. 2003)
- Habitat surveys and population monitoring of Arroyo southwestern toads (*Bufo californicus*) and Pacific pond turtles (*Clemmys marmorata pallida*) in the County of San Diego (Meyer et al. 2003)
- Coastal sage scrub amphibian and reptile autecology study (Case and Fisher 1996)
- Southern California herpetofauna research and monitoring: 1995-1999 (Fisher and Case 2000)
- Inventory and management needs study of Point Loma herpetofauna (reptiles and amphibians) with comments on mammals and invertebrates, 2001 (Brown and Fisher 2002)
- Sampling design optimization and establishment of baselines for herpetofauna arrays at the Point Loma Ecological Reserve (Atkinson et al. 2003)
- Distribution and abundance of the Least Bell's vireo (*Vireo bellii pusillus*) and the southwestern willow flycatcher (*Empidonax traillii extimus*) at selected southern California sites in 1997 (Kus and Beck 1998)
- Southwestern willow flycatcher populations in southern California: distribution, abundance, and potential for conservation (Kus et al. 2003)
- Distribution and abundance of the southwestern willow flycatcher at selected southern California sites in 2001 (Rourke et al. 2004)
- Multitaxa survey at Rancho Jamul 2001-2002 (Brown et al. 2002)

- Post-fire monitoring study to compare pre-fire data with 5 years post-fire data at Elliot Reserve, Otay Mountain, Rancho Jamul and Hollenbeck Canyon. Study included sampling for reptiles, amphibians, small mammals, bats, birds, ants, other invertebrates, and vegetation

Robert Fisher and others at USGS have also worked on developing a Multi-Taxa Database for MSCP monitoring data, coordinated with BIOS. USGS staff are also actively involved with a number of surveying and monitoring efforts in the County.

U.S. Fish and Wildlife Service

USFWS has conducted surveys, studies, and monitoring for the MSCP. Many USFWS monitoring activities occur on San Diego National Wildlife Refuge (SDNWR) lands, though USFWS biologists contribute to monitoring efforts throughout the region.

At SDNWR a variety of covered species are monitored, including the rare plants: *Acanthomintha ilicifolia, Deinandra* [*Hemizonia*] *conjugens, Ambrosia pumila, Dudleya variegata*, *Monardella linoides* ssp. *viminea (Griffin 2003)* and *Ericameria palmeri* var. *palmeri (Griffin 2002).* Covered animal species monitored on the refuge include: arroyo toad (*Bufo californicus*), southwestern willow flycatcher (*Empidonax traillii extimus*), coastal California gnatcatcher (*Polioptila californica californica*), and least Bell's vireo (*Vireo belli pusilla*) (Griffin 2003). Raptors were monitored on the refuge as part of a larger region-wide survey effort being conducted by the Wildlife Research Institute (WRI 2002). A San Diego National Wildlife Refuge Fire Management Plan has been completed, and a Comprehensive Conservation Plan is in development for the refuge.

USFWS is also involved with a County-wide coastal California gnatcatcher monitoring effort, Arroyo toad surveys, California least tern and light-footed clapper rail surveys, and additional bird monitoring using point counts. The Service is also conducting post-fire monitoring projects that include covered species and MSCP Preserve lands.

California Department of Fish and Game

BIOS – The Wildlife and Habitat Data Analysis Branch of CDFG aims to provide support and database management of monitoring data through the BIOS program (http://bios.dfg.ca.gov). Ultimately all MSCP data should end up in this statewide database, but currently only a few relevant studies have been added to the system.

RAP – The Resource Assessment Program (RAP) works on species and natural community assessment and monitoring in the southcoast ecoregion, of which the MSCP is a small portion. Although the geographic scope of RAP is quite different from that if this LAG project, the personnel involved will work together to ensure that monitoring plan design activities are complementary and synergistic wherever possible.

NCCP – The Natural Communities Conservation Program (NCCP) has provided input and oversight on many MSCP monitoring issues, and funding for Local Assistance Grants (including this one). Some of the CDFG lands in the MSCP have had baseline surveys (e.g., Hathaway et al. 2002, Madden-Smith et al. 2004), and management plans are completed or in development for

Hollenbeck Canyon, Boden Canyon, and Rancho Jamul. No long-term MSCP monitoring is currently being conducted by CDFG, though they have contributed resources to aid other monitoring partners' efforts.

Other Agencies

The National Park Service's Cabrillo National Monument is part of the MSCP Preserve, as is the Point Loma Ecological Reserve (a 640-acre reserve owned and managed by five government agencies including the Park Service, U.S. Navy, and City of San Diego). The Park Service has a nationwide biological monitoring program called Vital Signs (National Park Service 2004), and Cabrillo National Monument has been monitored for a variety of species through this program, including shorebirds, herpetofauna and small mammals. The Vital Signs monitoring program is independent from the MSCP monitoring, though USGS conducted herpetofaunal monitoring on monument lands and there may be opportunities for integration of monitoring efforts in the future.

The San Diego Association of Governments (SANDAG) maintains the HabiTrak database of habitat acquisition and losses within the MSCP jurisdictions. SANDAG is also managing the TransNet money recently approved by voters, which will provide funding for land acquisition, monitoring and management activities in the County.

Additional state and federal wildlife agencies have lands in the MSCP and are considered cooperating partners that aim to manage their lands consistent with the MSCP goals whenever possible. These include the Bureau of Land Management and California State Parks. Both partners have allowed monitoring of covered species on their land, particularly for the Tecate cypress and Torrey pine.

Non-Profit Organizations

Other groups in San Diego County have been collecting data on species of concern for a variety of purposes. Some of these data may be complementary to the MSCP monitoring efforts, though concerns about data quality and consistency of methods must be addressed. Relevant groups include, but are not limited to, the San Diego Tracking Team, California Native Plant Society, San Diego Natural History Museum, Partners in Flight and local universities (including SDSU and UCSD). Other non-profit groups have been actively involved with the MSCP in various capacities, including the Conservation Biology Institute, Wildlife Research Institute, and the Conservation Resources Network. Non-profits can provide expertise in local flora and fauna, and have the ability to locate and organize volunteers that could potentially play a larger role in future monitoring efforts.

Assessment of the monitoring plan's implementation

In this section we evaluate the status of the implementations of the MSCP's Biological Monitoring Plan in terms of the 9 steps for designing a monitoring plan (Atkinson et al. 2004).

Step 1: Identify the goals and objectives of the regional conservation plan

The biological goals and objectives of the MSCP monitoring plan are stated in the MSCP planning documents, Biological Monitoring Plan, Subarea Plans, and further refined in CBI's

2001 report. The goals provide a good basis for the monitoring program, but further work is needed on (1) updating and improving the specificity of objectives, (2) linking monitoring to the goals, and (3) linking monitoring to management to ensure the goals are met.

Step 2: Identify scope of monitoring program

The geographic scope of the MSCP has become better defined over the years as the majority of the land has been acquired. Issues of spatial scale have yet to be addressed, and in particular, a need remains to improve coordination between individual reserves and jurisdictions, and to begin synthesizing data at the MSCP-scale. Effort to analyze monitoring data at the regional scale was begun by USFWS but they did not have adequate resources to complete this task. The syntheses are also not yet coordinated with other regional species conservation programs. The monitoring program also has not determined the appropriate scale for assessing different monitoring and management needs (i.e., minimum monitoring at each reserve and appropriate levels for management responses). Temporal scale issues have also left open questions of when to monitor, how often, and when management actions should be taken.

Step 3: Compile information relevant to monitoring program design

No central repository of MSCP-related data and documents has been created. Each individual jurisdiction and wildlife agency has a unique set of monitoring reports, studies, and datasets. No entity is maintaining an updated bibliography and library of relevant studies on monitoring program design, monitoring protocols, covered species, or other related materials.

Step 4: Strategically divide the system and prioritize for monitoring program development

The original BMP divided the monitoring plan into habitat, corridor, and covered species monitoring. The covered plant species were prioritized by group, and a subset of the covered animal species were given monitoring priority. However, the plan did not provide compelling, scientifically defensible documentation of the reasoning behind the priorities set and divisions made.

Step 5: Develop simple management-oriented conceptual models

Several conceptual models have been developed for MSCP covered species and natural communities over the past decade (including for the Arroyo toad, Quino checkerspot, and the CSS/chaparral/grassland assemblage). However, these models did not make the link between monitoring and management clear.

Step 6: Identify monitoring recommendations and critical uncertainties

Data gaps have historically been addressed through a piecemeal approach in the MSCP, with individual jurisdictions or wildlife agencies commissioning a study on a topic of interest. Though these studies have helped advance our knowledge on particular issues, the uncertainties were not identified or prioritized in a way that allowed the most important issues to be studied first.

Step 7: Determine strategy for implementing monitoring

Implementation of monitoring plan protocols has been a major problem for the monitoring program. The City's rare plant monitoring has most closely followed the protocols. The City also attempted to implement the habitat value monitoring from the original BMP and found the protocol unfeasible. A fundamental issue deterring monitoring partners from implementing the monitoring protocols described in the original plan was that many of the protocols were impractical given the available staffing and funding.

Step 8: Develop data quality assurance, data management, analysis, and reporting strategies

Data quality assurance, data management, analysis, and reporting have all presented challenges over the course of the monitoring program. Data management is being addressed through BIOS and the Multi-Taxa Database, but it has been difficult in the meantime to analyze data. No Three-Year Reports synthesizing results have been produced, so no coordinated changes have been made to priorities, nor have management responses been recommended.

Step 9: Complete the adaptive management loop by ensuring effective feedback to decision-making

Decision-making on important monitoring issues has been hampered by the lack of data analysis and subsequent identification of management prescriptions that are needed. Without the necessary data to determine the state of the system and what should be done to improve it, good management and decision-making has been virtually impossible.

Conclusions

Progress has been made gathering data on covered species through baseline surveys, limited monitoring activities, and targeted studies. Improvements in sampling design and protocols should allow better coordination and implementation of protocols by the many monitoring partners, which in turn will allow the assessment of status and trends of species and habitats at the MSCP scale, and the triggering of management responses when problems are identified.

CHAPTER 4: REVIEW OF SCIENTIFIC LITERATURE RELEVANT TO BIOLOGICAL MONITORING PLANS

Introduction

The purpose of this chapter is to examine the specific case of the San Diego MSCP in the context of biological monitoring principles, designs, methodologies and implementations considered in the scientific literature. This chapter will present conceptual discussions, including literature reviews, on important issues for monitoring program design. The discussions provide background for identifying and prioritizing attributes to monitor (Atkinson et al 2004, Step 4), developing management oriented conceptual models (Step 5), identifying critical uncertainties (Step 6), and determining a monitoring strategy (Step 7; See Figure 1).

Noon et al. (1999) suggests that identifying stressors and developing conceptual models precede the selection of attributes to measure. Rahn (2005) goes one step further arguing that these steps happen simultaneously, not sequentially. These differences in the ideal order of steps used to plan a monitoring program are important. These steps, however they are described, are intimately linked and may not be separable. For example, the strategic division and prioritization of the system will influence what conceptual models are constructed (Figure 4). Conversely, these conceptual models provide insights that may lead to a revision of the prioritization of the system. Although these steps are intertwined, we follow the Atkinson et al (2004) approach in the organization of this chapter.

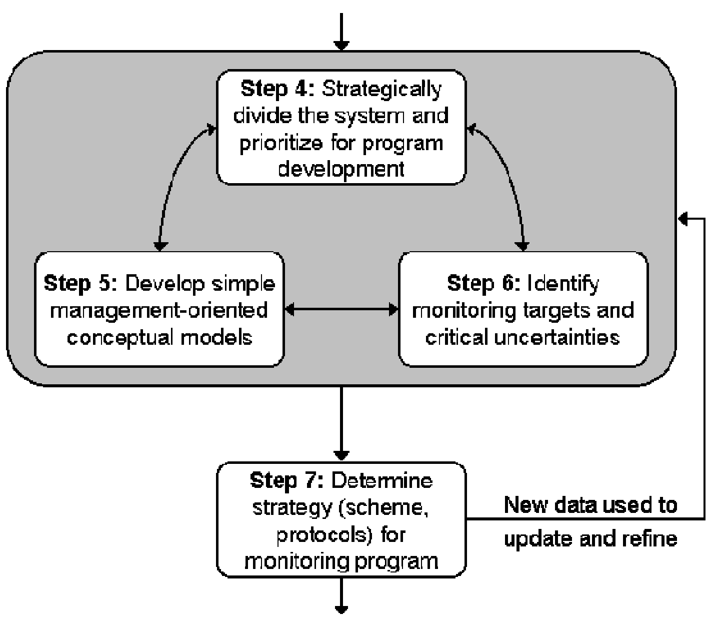


Figure 4. Revision of the steps outlined in Atkinson et al. (2004). The major difference is the emphasis on the interrelationship between steps 4, 5 and 6 and the importance of feedback loops.

This chapter serves as background for these important and difficult steps. Each of these steps will be explored in more detail in future reports that will carry out prioritization schemes and identify monitoring components (Task B), develop conceptual models (Task C), and describe important statistical issues that need to be incorporated in the monitoring program design (Tasks D and E).

Prioritization Schemes

One of the first tasks in the design and implementation of a biological monitoring plan is the prioritization of species, indicators and/or habitat attributes that will shape and inform data collection activities. The current list of covered species in the San Diego MSCP was constructed in this light. However, while the covered species are the result of prioritization for the purpose of identifying areas to be included in the MSCP (and identifying species that would be adequately protected by these lands), further prioritization will be needed for monitoring within the MSCP. Due to resource constraints, all covered species within the MSCP cannot be monitored with the same degree of effort. Hence, it will be necessary to prioritize species in relation to the overall goals of the monitoring plan.

Prioritization of species for management-oriented monitoring should have two purposes. First, the status and trend of at-risk species (those most vulnerable to threats and disturbances) should be ascertained and compared with species-specific management trigger points. This will identify those species that require immediate management action to ensure their persistence in the reserve network. Second, the status and trend of the ecological system should be ascertained and compared with broader ecosystem management trigger points. This will elucidate whether or not the MSCP goals are being met and will assist in identifying areas that need continuing management action. Hence, prioritization of species for monitoring will involve selection of at-risk species and focal species.

- At-risk species will be those deemed to be at risk of decline or extinction under current conditions or in the face of short- or long-term threats.
- Focal species will form part of a broader group of ecological indicators. At-risk species may also serve as focal species, although this will not always be the case.

Review of protocols for prioritizing species at risk of extinction

Threatened species classification schemes are increasingly used around the world for reporting on the state of the environment and for setting management priorities for endangered and vulnerable species (Possingham et al. 2002). A variety of agencies use them to assess local, regional and global levels of threat for species and for prioritizing species at risk of decline or extinction. Many protocols have been devised to address specific taxa, geographic regions, legislative requirements and degrees of acceptable extinction risk. They include subjective methods (US Fish and Wildlife Service 1983, Nicholopoulos 1999), rule-based approaches (IUCN 1994, Swaay et al. 1997, Keith 1998, Swaay and Warren 1999, IUCN 2000) and point scoring methods (Millsap et al. 1990, Master 1991, Lunney et al. 1996, Beissinger et al. 2000, Carter et al. 2000).

Most threatened species protocols provide a classification of threat based on whether or not a species (or in some cases, a population or community) satisfies various criteria, constructed to determine the degree to which species are in danger of extinction. Criteria may be based on past and projected future reduction in population size or geographic range, current geographic range and population size, and other features of populations and their habitat. Classification systems vary considerably depending on the objectives of the system, the relevant species, the data available, the form of data aggregation, and the geographical scale of consideration (Root 2002, Andelman et al. 2004). These factors need to be taken into consideration when selecting a protocol with which to prioritize at-risk species.

Root (2002) provides a review of some of these methods for ecological risk assessment while Wisdom et al. (2001) review a similar subset for forest planning contexts. Andelman et al. (2004) provide the most comprehensive review of a range of classification protocols in the context of prioritizing species for viability assessments under the U.S. National Forest Management Act (NFMA). The goals of the NFMA focus on species viability under proposed Forest Service management plans. However, since the goals of the MSCP monitoring plan are specified in terms of documenting "changes in preserved habitat or in preserved populations of covered species" (Ogden Environmental and Energy Services 1996) we believe that prioritization of at-risk species for monitoring is pertinent here. Tables 1 and 2 summarize the methods available for prioritization of at-risk species, including the data requirements and key features of each system. The following methods have all been used at some level to prioritize species at risk (Andelman et al. 2004):

The *IUCN 2001* protocol is used to prioritize species in the IUCN Red List of Threatened Species (http://www.redlist.org/). To date 3046 animal species and 384 plant species in the United States have been assessed under these protocols.

CITES. The aim of CITES is to ensure that international trade in specimens of wild animals and plants does not threaten species survival. As of 2004, 1310 species in the U.S. were listed on Appendices I and II.

NS Heritage refers to the NatureServe ranking protocols (http://www.natureserve.org/). As of 2004, these have been applied to 8164 vertebrate and selected invertebrate species and to 29579 vascular and nonvascular plant species from a broad range of taxonomic groups in the U.S. and Canada. This review refers to the classification protocol articulated in Master et al. (2000). The protocol has recently been revised to be more in line with the IUCN protocols (Regan et al. 2004). Further revisions are currently under way (Tracey Regan pers. comm. 8/15/05). Most rankings in the NatureServe database are based on the Master et al. (2000) protocol and so we restrict our review here to that version.

USFWS refers to the U.S. Fish and Wildlife Service guidelines for determining a listing priority status rank to species proposed as candidates for potential listing as either endangered or threatened under the federal Endangered Species Act. Approximately 1260 species from a broad range of taxonomic groups have been classified as endangered or threatened under the USFWS guidelines.

The *Millsap et al. (1990)* classification system was designed to categorize vertebrate species in Florida, based on their risk of extinction. As of 1990 it had been applied to 668 vertebrate species for a broad range of taxonomic groups in Florida (excluding marine fish species).

The *Lunney et al. (1996)* classification scheme is a modification of the Millsap et al. (1990) protocols for the purpose of systematically evaluating the conservation status of all mammals, birds, reptiles and amphibians in New South Wales (NSW), Australia, in accordance with the NSW National Parks and Wildlife Act of 1974. As of 1996, 883 vertebrate species have been assessed under this protocol for a broad range of taxonomic groups in NSW, Australia.

The *Partners in Flight* classification scheme was originally created to address declining populations of Neotropical migratory songbirds, but it was hoped that it could be applied consistently to any group of species in any geographic region (Carter et al. 2000). Between 100 and 300 bird species have been classified according to the PIF protocols in the US.

COSEWIC is the Committee on the Status of Endangered Wildlife in Canada. As of May 2003, 612 species had been assessed in one of the seven categories and approximately 180 species had status reports in preparation.

The *MER* is a Method for Evaluating the Risk of Extinction of Wildlife in Mexico. It is not known how many species have been assessed under this scheme or if it has yet to be implemented.

Table 1. Comparison of protocols with respect to a set of key parameters that are commonly used as surrogates of risk of extinction (after Andelman et al. 2004).

Parameters	Protocols								
	IUCN 2000	CITES	NS Heritage	USFWS	Millsap et al 1990	Lunney et al 1996	PIF	COSEWIC	MER
Population size	Y	Y	Y		Y	Y	Y	Y	
Population trend	Y	Y	Y		Y	Y	Y	Y	
Number of populations	Y	Y	Y					Y	
Abundance relative to other species							Y		
Reproductive potential					Y	Y		Y	
Population concentration		Y			Y	Y			
Area of occupancy	Y		Y					Y	
Extent of occurrence	Y	Y	Y		Y	Y	Y	Y	Y
Range trend	Y	Y	Y		Y	Y		Y	
Extreme fluctuations	Y	Y						Y	
Area importance							Y		
Habitat condition		Y						Y	Y

Table 2. Comparison of threatened and endangered species protocols based on a number of biological and data quality criteria (after Andelman et al. 2004). L = local geographical scale; N = national geographical scale; G = global geographical scale.

System	Scale	Quantity/ accessibility of information required	Current/future management	Future population trend	Ecological specialization	Range of taxonomic groups and life histories
IUCN 2000	N/G	Low	Yes	Yes	No	High
CITES	N	Low	Yes	Yes	No	High
NS Heritage	L/N/G	High	Yes	Yes	Yes	High
USFWS	N	Low	Yes	No	No	High
Millsap et al '90	L	High	Yes	Yes	Yes	Medium
Lunney et al '96	L	High	Yes	Yes	Yes	Medium
PIF	G	Medium	Yes	No	Yes	Low
COSEWIC	N	High	Yes	Yes	Yes	High
MER	N	Medium	Yes	No	Yes	High

System	Geographic distribution	Threats	Uncertainty	Reliability/ robustness (ambiguous or vague language)	Transparency
IUCN 2000	Yes	No	Yes	Yes	Yes
CITES	Yes	Yes	No	Yes	Yes
NS Heritage	Yes	Yes	Yes	No	Yes
USFWS	No	Yes	No	No	No
Millsap et al '90	Yes	No	Yes	No	Yes
Lunney et al '96	Yes	Yes	Yes	No	Yes
PIF	Yes	Yes	Yes	Yes	Yes
COSEWIC	Yes	Yes	No	No	No
MER	Yes	Yes	Yes	Yes	Yes

Discussion

None of the protocols were designed specifically for application to populations or sub-populations, the most relevant unit of management consideration for the MSCP. However, the IUCN recently developed a protocol for regional Red List assessments that is explicitly intended for use with populations (IUCN 2003) and this could be implemented for prioritization of species with distinct populations within the MSCP. Other at-risk species prioritization protocols that operate at global or national scales will address populations in the MSCP if the entire range of the species is within the MSCP. This will be the case for species endemic to San Diego County, particularly if their entire range falls within the MSCP reserve.

Seven of the methods, namely Lunney et al., MER, NatureServe Heritage, USFWS, PIF, CITES and COSEWIC, explicitly address the impact of recent or potential threats. This aspect is important for determining which species are most likely to be adversely affected by changing conditions and disturbances and would benefit from management-based monitoring. Three methods use "habitat fragmentation" to assign a risk category to a species. While this would seem extremely important for preservation of the covered species in the MSCP, it may not necessarily be a distinguishing factor for *prioritizing* species since all the covered species in the MSCP have experienced high levels of fragmentation.

Data availability is an issue for all quantitative prioritization schemes. A protocol will only provide a reliable prioritization of at-risk species if it has mechanisms for dealing with uncertainty in data and data gaps. While there exist strategies for acknowledging uncertainty in threatened species classification (in particular see IUCN, NatureServe Heritage and Millsap et al.), explicit quantitative treatment of uncertainty in such classification protocols has largely been ignored until relatively recently (Akçakaya et al. 2000). Six of the nine protocols reviewed address uncertainty, although for most of these uncertainty is merely acknowledged rather than dealt with explicitly in the protocols. The IUCN protocols allow for a comprehensive treatment of uncertainty using bounding techniques (Akçakaya et al. 2000). This treatment of uncertainty can be extended, in principle, to all quantitatively-based protocols (i.e. NatureServe Heritage, Millsap et al., Lunney et al., PIF).

Despite similarities among the protocols, each was designed for a different purpose. It is important to maintain consistency throughout any prioritization process. "The most appropriate method for prioritizing at-risk species will depend on the management scenarios proposed, the amount of data available, the time frame within which the assessment must be completed, and the scale at which the assessment is to be made" (Lehmkuhl et al. 2001, Andelman et al. 2004).

Indicators, Surrogates and Focal Species

Selecting appropriate attributes to monitor is a daunting task. The identification of indicators and/or the selection of focal species has received much attention in the monitoring literature (Landres et al. 1988, Noss 1990, Kremen 1992, Pearson 1994, Simberloff 1998, Canterbury et al. 2000, Kerr et al. 2000). A major thrust of the Environmental Protection Agency's Environmental Monitoring and Assessment Program (EMAP) was the identification and/or development of appropriate indicators. Despite many years of effort, the utility of indicators remains controversial (National Research Council 1995, Niemi et al. 1997, Lindenmeyer 1999, Andelman and Fagan 2000). Nevertheless, indicators remain an appealing idea and studies continue to be carried out to establish the utility and effectiveness of specific indicators.

Indicator species have recently been used to:

- predict species richness (Jonsson and Jonsell 1999, Fleishman et al. 2005)
- gauge species sensitivity to logging and grazing (Lesica and Hanna 2002, Hanley et al. 2005, Kavanagh and Stanton 2005)
- monitor the conservation impacts of natural resource use (Kremen et al. 1998)
- monitor the conservation status of Hawaiian seabirds (Dearborn et al. 2001)

among many other applications. Indices of Biotic Integrity (IBI) have also received much attention in the literature. These measures of ecosystem "health" combine a number of indicators into an overall index that is meant to represent relative condition of a biological unit (e.g. site, stream, ecosystem, biome, vegetation type, land-use type). They have been used fairly routinely for monitoring aquatic systems (Angermeier and Karr 1986, Moyle and Randall 1998) but have recently been developed for terrestrial systems, in particular coastal sage scrub ecosystems (Diffendorfer et al. 2004). However, these measures also receive criticism due to their obscurity—they often do not possess a direct relationship with biological processes. Nevertheless, they remain an attractive tool due to their relative simplicity and their ease of application. The State of the Nations Ecosystems effort uses an extensive list of biotic and abiotic indicators to monitor the condition and use of land, water and natural resources within the United States (The H. John Heinz III Center for Science, Economics, and the Environment 2002). Trends in these indicators have direct impacts on congressional decision-making (Committee on Science, House of Representatives 2002) and have wide-reaching influence on the perception of the state of the environment. Despite the reservations and caution expressed in the scientific literature, indicators are enthusiastically pursued because of the impossibility of monitoring all taxa in species-rich environments (Lindenmeyer 1999). Hence, it is crucial that indicators for monitoring be selected with scientific rigor and that the context and limitations of their application be made explicit. In this subsection we emphasize recent summaries by Noon et al. (1999) and Noon (2003) because they provide an overview of the application of indicators with respect to the type of monitoring relevant for the MSCP.

Indicators and Surrogates

In any research activity, attributes or variables must be selected for measurement that can address the questions asked, and in a monitoring program, ***surrogate variables*** must be identified whose ***status*** (value) and ***trend*** (change over time) can be used to determine if monitoring objectives are being met (Noon 2003). Ecosystems are complex, and so when ecosystems are monitored ***indicator variables*** must be selected from among all those that could potentially be measured. In this context, "indicator" and "surrogate" are synonymous.

Noon et al. (1999) suggest that for ecosystem monitoring, the status and trend of ***habitats and habitat elements*** (structural and compositional elements of the landscape) may be useful surrogates as an alternative to directly monitoring numerous biological populations. However, the State of Oregon's Department of Foresty proposed 67 indicators to assess whether sustainable forest management was being achieved in the state according to seven criteria – and only four of these indicators were related to the status of species (Oregon Department of Forestry 2000). Therefore, the use of indicators is not necessarily a shortcut to more cost-effective monitoring (of a smaller number of attributes, elements or variables), although it is often assumed to be so.

Suggested criteria for narrowing the list of potential indicators for field- or simulation (model)-testing (Noon et al. 1999) are fairly stringent standards that assume a high level of knowledge about the system. Those criteria are low natural variability, short-term but persistent response to change in environment (e.g. stressors), cheap and easy to measure, and can be accurately and precisely estimated. Monitoring programs will fail if the wrong indicators are selected (National Research Council 1995).

Another key point is that extrinsic environmental ***stressors*** that may compromise the goals of the plan (e.g. Forest Plan, Habitat Conservation Plan) must be identified in order to develop conceptual models (Noon 2003). Examples of stressors are drought, wildfire, habitat loss, overharvesting, altered hydrological cycles due to dams, invasive species and nitrogen deposition. Not only must stressors be identified, they must be ***monitored*** ("the status of the stressor must also be periodically estimated," Noon et al. 1999, p. 33). In statistical modeling these would be called independent or explanatory variables or covariates, and their measurement is necessary in order to infer causation from an observed change in an indicator. While this may not be mandated by the plan, it may be required in order to identify management actions.

Focal Species

Given that the objective of biological monitoring for the MSCP is to document the status of habitats and covered species (populations), it would seem that there is a legal requirement to use (some aspect of) all covered species and habitats as indicators. However, it is frequently assumed that it is not feasible to monitor everything (all biodiversity elements) in a plan, and that therefore some (protected or covered) species can be identified as ***indicator species*** (reviewed by Rahn 2005).

It may not be necessary to monitor all species in order to gauge the effectiveness of the reserve system in protecting and maintaining biodiversity, or the impacts of stressors on biodiversity. It may be sufficient to monitor a subset of species that are surrogates for a suite of life history attributes or responses to disturbances. These are also called ***focal species*** (reviewed by Andelman et al. 2004, p. 53), legally defined as surrogates that may "represent ecological conditions that provide for the viability of some other species, rather than directly representing the dynamics of those other species" (US Fish and Wildlife Service 2000). Monitoring the status and trend of focal species is intended to provide insight into the function and "integrity of the larger ecological system to which it belongs" (Andelman et al. 2001).

The focal species concept is somewhat vague and ambiguous and has been used in a variety of contexts. In the USDA Forest Service planning regulations the focal species concept has been defined very broadly as (Andelman et al. 2001):

- Surrogate measures of ecological sustainability.

- Representative of larger groups of species with similar habitat requirements or functional roles.
- Umbrella species whose area requirements include the habitat needs of many other species.
- Species that play a significant role in maintaining the structure and processes of ecological systems.
- Surrogate measures of the ecological conditions that provide for the viability of other species.

Consequently, focal species should act as an early warning of declines, and the viability of these species should allow reliable inference to the proper functioning of the system to which they belong (Andelman et al. 2001).

Lambeck (1997) uses the term focal species as any species whose functional and compositional requirements are believed to encapsulate the requirements of other species, and recognizes area, process, resource and dispersal limitations in identifying focal species. In the Committee of Scientists Report (1999) focal species were defined as "***species whose status and temporal trend provide insight to the larger ecological systems to which they belong***". While most of these definitions are relevant to the selection of focal species for MSCP monitoring, we believe this last definition fits best with the broad goals of the MSCP.

A number of practical issues related to context, sampling, and measurement need to be considered if the focal species selected are to be at all useful for monitoring purposes. Published pragmatic attributes of focal species include the following (Andelman et al. 2001):

- Their dynamics parallel those of the larger environmental component or system of ultimate interest.
- They show a short-term but persistent response to changes in the state of the environment.
- Their dynamics can be accurately and precisely estimated.
- The likelihood of detecting a change in their value is high given a deterministic change in the system (changes in their values can be distinguished from background variation).
- Differences in the status of the species is known to be able to discriminate among sites and ecological gradients.
- It is known how the species responds to the known risk factor/s.

However, we stress that as desirable as the focal species concept is for lumping species and streamlining data collection efforts, criticisms abound due to the lack of empirical evidence of their effectiveness as surrogates (Andelman and Fagan 2000, Rubinoff 2001, Lindenmeyer et al. 2002). Because of this, focal species will be only one of a range of indicators to monitor the status and trend of ecosystems.

Discussion

The current covered species list is the product of a prioritization performed at the time of the development of the MSCP. While the details of the selection criteria used to compile the covered species are largely unavailable, species were presumably selected to represent a range of life history traits, habitat associations, risk levels, home ranges, and scales of habitat use. As such, the covered species list is the result of a prior focal species prioritization. However, due to resource constraints it is likely that this list must undergo further prioritization so that time and money can be spent in the most optimal way in monitoring activities. This will be addressed in Task B of the current Local Assistance Grant.

We provide a few caveats that need to be considered in applying the focal species concept to further prioritization of the covered species list. First, since the covered species list is already the result of species prioritization, the methods reviewed here may not reduce this list much further. It may be the case that, depending on the strategy used to produce the covered species list, this is the minimal set of species with which to gauge the status and trend of biodiversity within the MSCP. Second, we assume that the methods used to compile the list of covered species are scientifically sound. That is, the set of covered species is assumed to be appropriate for monitoring purposes (all the covered species satisfy some criterion for candidature as focal species and there are no species left out of the list that obviously qualify for inclusion in the covered species list). An exception is the Quino checkerspot butterfly, which has been petitioned for inclusion as an MSCP covered species. We assume a similar petition process will be pursued if additional species are identified for inclusion in the MSCP program. In the absence of documentation on how the covered species list was compiled, we take it as a matter of faith that this is the case. Third, all focal species prioritization protocols reviewed here assume that the pool of species from which focal species are selected is large, perhaps much larger than the size of the covered species list. These issues must be taken into consideration when applying focal species prioritization protocols designed for different contexts.

Conceptual Models

Atkinson et al. (2004) consider conceptual models a critical step in the development of biological monitoring plans for regional habitat conservation plans, although they are not a formal requirement. These models can be narratives or diagrams (or tables or matrices) and they link cause or "pressures" (stressors, threats, drivers) with effect on the state of the environment (specifically to the indicator variables selected on the basis of the plan's goals or targets). The development of conceptual models for covered species, communities and landscapes is a task under this Local Assistance Grant. This section of the chapter focuses on a few key documents that have themselves reviewed the literature and made recommendations on the use of conceptual models in viability assessments under the National Forest Management Act (Andelman et al. 2001, Noon 2003) and effectiveness monitoring for habitat conservation plans (Rahn 2005).

Conceptual models have their roots in systems analysis and decision theory, and are used in theoretical ecology and ecosystem and population modeling (e.g., Manley et al. 2000). In a monitoring framework, conceptual models are useful for showing the direct and indirect relationships among stressors and biotic responses (Noon 2003). Further, while a conceptual model can describe any system, for biological monitoring the model should include a link to decision-making or management actions. Rahn (2005) points out that computer simulations are often the most explicit form of conceptual model, that quantitative models are often used to predict risk for populations, and that the literature suggests that predictions from models are less biased than subjective judgments of risk (Regan et al. 2004, Burgman 2005, Regan et al. in press). Rahn (2005) discusses a method for creating conceptual models proposed by Woodward et al. (1999) that proceeds from system description to integration of stressors, followed by description of the resulting impacts.

Noon et al. (1999) developed a template in the form of a table that can be used for each stressor in order to identify the biotic consequences at different (hierarchical) ecological scales (landscape, community, population, and/or genetic). Obviously this can only be applied once the system components and stressors have been defined. In a slightly different context, Andelman et al. (2001) reviewed methods for formally eliciting and synthesizing expert opinion for assessing population viability. They presented it as an alternative form of viability analysis when quantitative data are not adequate for mathematical or simulation modeling, or as a way of attaining best estimates for parameters in a quantitative analysis. However, the first step is, again, identifying the components of the system that connect actions (management actions, stressors) and the effects on species populations. Such models can be described verbally, mathematically, or graphically as a box and arrow diagram or flow chart, an influence diagram or conceptual diagram (terms used in decision science) – in other words, they are models that broadly synthesize known processes into a cohesive format in order to assist in the understanding of the problem context. In addition to identifying the structure of a quantitative population viability model (parameters to be estimated), or indicators to be monitored (biological monitoring program), influence diagrams can be quantified and used directly for viability analysis (by creating a decision tree or Bayesian belief network) using formal methods of eliciting expert opinion developed in decision science. These methods must be applied rigorously and not in an ad hoc way in order to produce meaningful results, and they have been applied to assess viability of terrestrial vertebrates in a major forest plan (the Interior Columbia Basin; Marcot and Heyden 2001, Raphael et al. 2001).

Finally, in addition to software applications that are available for quantifying decision trees and Bayesian belief networks, visual "brainstorming" software tools are becoming extremely popular in organizing ideas and knowledge, and are promoted for applications ranging from Web site design to global geopolitical conflict resolution. These may be useful tools for developing conceptual models for biological monitoring.

Discussion

Conceptual models are emphasized in the literature on designing biological monitoring strategies for regional habitat conservation plans (e.g., Atkinson et al. 2004, Rahn 2005). However, the formal methods of conceptual model development from systems and decision theory should also be emphasized. These include the development of quantitative models, but also formal methods for structuring expert opinion about a system when quantitative data are lacking. Both approaches will be considered under Task C with reference to the San Diego MSCP, with careful attention to the spatial scales relevant to this conservation plan and its constituent elements.

Statistical Aspects of Monitoring

The initial Ogden (1996) monitoring plan laid out a collection of loosely coordinated sampling efforts. These included habitat monitoring at 29 locations (Page 3.8) with stratification of sampling effort within locations (Page 3.10); corridor monitoring of movement of focal species (Page 4.1); monitoring rare plants using three different sized quadrats along permanent transects (Page 5.6, 5.14); and monitoring focal animals using a variety of methodologies (Page 5.22 – 5.29). The plan suffers from inadequate scientific justification of the many decisions about choice of locations, sample sizes, field protocols, planned analyses, and expected power to detect trends (Conservation Biology Institute 2001, Greer 2004). Although the criticisms of the Ogden plan are justified, it is important to acknowledge how challenging it is to develop a sound monitoring program (National Research Council 1995). The process is complex and each step is more difficult than it sounds (Fuller 1999).

Key Statistical Challenges in the Development of a Biological Monitoring Plan

Application of statistical theory and methods to monitoring is difficult. In statistical sampling theory, the units under study are usually simple and easy to define (people in an opinion poll or widgets produced by a factory). In monitoring, the units sampled can take many forms including habitat patches, points in a forest, liters of lake water, 1 m^2 quadrats, or variable-length transects flown from an aircraft. As a result, the units being sampled may not be simple, discrete entities. In addition, ecosystems comprise many interacting populations that are structured in complex ways based on genetic factors, habitat quality, environmental variability, and accidents of history. As a result, ecosystems cannot be treated as monolithic entities with a single, easily measured response value.

Monitoring biological populations is also challenging due to their inherent heterogeneity. Processes that influence population dynamics can change across space, either as smooth gradients (e.g. elevation) or in heterogeneous patches (e.g. patches of wet depression in a meadow). Similarly, population densities can change through time smoothly (e.g. a gradual decreasing trend) or erratically (e.g. a sudden, precipitous population decline). The simplest populations to monitor are likely to be spatially expansive and slow changing (e.g. forest trees). In contrast, the most recalcitrant populations are likely to be spatially localized (clustered, rare) that experience erratic boom-bust populations (e.g. insect pests with localized explosive outbreaks). Monitoring programs must respect the nature and scales of population dynamics across space and through time. As a result, the design of a biological monitoring program requires careful attention to the natural history of the population of interest.

Application of sampling theory to monitoring must respect the constraints and complexities that are inherent in monitoring biological populations. These complexities make broad, synthetic monitoring programs very difficult to design and evaluate. Despite these inherent challenges, there is a rich literature in statistical sampling theory and a growing interest in monitoring through time (see Table 3).

Statistical Sampling Theory

Statistical sampling theory is designed so that a statistic from a (carefully selected) small sample can be used to estimate the true population value. This process involves two distinct aspects: survey design and data analysis. Most statistical sampling theory is based on the notion of probability sampling. With a probability-based sample, we can evaluate the properties of a sampling scheme and its estimator in terms of two key ideas: unbiasedness and precision. The broad aim of sampling theory is to devise sampling schemes which are economical and easy to implement, which yield unbiased estimators, and which are efficient (Barnett 1986, Thompson and Seber 1996, Manly 2001, Rao 2000).

The simple random sample (SRS) is the most basic, fundamental design (Table 4). It is widely used in its own right, and, in certain cases, can be easy to implement. It also serves as the basis for more complex sampling schemes like stratified random sampling and cluster sampling. In a simple random sample, all possible samples of a given size are equally likely. The simple random sample has several important properties that make it the standard against which all other methods are measured. The SRS is unbiased, the members of the sample are independent, and the true mean and variance of the population are estimated simply by the sample average and variance (Barnett 1986, Rao 2000).

Despite its conceptual simplicity, implementation of a simple random sample is often very difficult. A SRS presupposes the existence of a complete list (the sampling frame) of all members of the population. If such a list is unavailable or inaccurate, then the SRS may be biased. Even if a complete and accurate frame is available, random sampling may be impossible because selected individuals are elusive, uncooperative or inaccessible. Finally, a SRS may be very difficult to implement due to financial or logistical constraints.

Systematic sampling can greatly ease the challenges to developing and managing a simple random sample. An example of a systematic sample would be the decision to sample every 10th individual in the population. A systematic sample will produce results that are indistinguishable from SRS provided there is no underlying periodicity in the population. If the population varies periodically, however, there is a risk that the sample will be biased.

Stratified random sampling is based on the premise that the population is comprised of several different subgroups (strata) that differ with regard to the variable of interest. A stratified random sample is a collection of simple random samples with one SRS performed within each strata. Stratified random sampling differs from SRS in the careful allocation of sampling effort to each strata. The power of a stratified sample stems from the ability to match the size of the sample within each stratum to its importance to the estimation of the overall population parameter. As a result, the performance of a stratified random sample depends on the allocation of effort to the random samples within each strata.

Stratified random sampling offers important gains in efficiency when the population can be subdivided into strata that differ in size and/or variability. Stratified sampling may also be useful when the population is naturally divided due to other factors, like jurisdictional boundaries. These potential gains, however, are not without cost. Stratified sampling depends on the quality of a priori information on the size and variability within each stratum. If these estimates are inaccurate or incomplete, then the overall estimator may be biased by an unknown amount. In addition, estimates of the population mean and variance must respect the a priori stratification.

Table 3. Literature on Statistical Monitoring.

● *Literature cited in Atkinson et al. 2004*
○ *Literature not cited in Atkinson et al. 2004*

General Texts and Edited Volumes on Ecological Monitoring

- ● Busch, D. E. and J. C. Trexler (2003). Monitoring Ecosystems: Interdisciplinary Approaches for Evaluating Ecoregional Initiatives. Washington, D.C., Island Press.
- ● Elzinga, C. L., D. W. Salzer, et al. (2001). Monitoring Plant and Animal Populations. Malden, MA, Blackwell Science Inc.
- ● Margoluis, R. and N. Salafsky (1998). Measures of Success: Designing, Managing, and Monitoring Conservation and Development Projects. Washington, D. C., Island Press.
- ● Noss, R. and A. Cooperrider (1994). Saving Nature's Legacy: Protecting and Restoring Biodiversity. Washington, D. C., Island Press.
- ● Sutherland, W. J., Ed. (1996). Ecological Census Techniques: A Handbook. Cambridge, UK, Cambridge University Press.
- ● Thompson, W. L., G. C. White and C. Gowan. (1998). Monitoring Vertebrate Populations. San Diego, CA, Academic Press, Inc.

General Texts on Environmental Statistics, Sampling and Design

- ● Thompson, S. K. (2002). Sampling. New York, John Wiley & Sons.
- ● Thompson, S. K. and G. A. F. Seber (1996). Adaptive Sampling. New York, NY, John Wiley & Sons Inc.
- ○ Barnett, V. (2004). Environmental Statistics: Methods and Applications. Chichester, England, John Wiley & Sons.
- ○ Manly, B. F. J. (2001). Statistics for Environmental Science and Management. Boca Raton, FL, Chapman and Hall/CRC.

Additional Primary Literature

Ecological Applications (1998)

- ○ Bricker, O. P. and M. A. Ruggiero (1998). "Toward a national program for monitoring environmental resources." Ecological Applications 8(2): 326-329.
- ○ Edwards, D. (1998). "Issues and themes for natural resources trend and change detection." Ecological Applications 8(2): 323-325.
- ○ Scott, C. T. (1998). "Sampling methods for estimating change in forest resources." Ecological Applications 8(2): 228-233.
- ○ Nusser, S. M., F. J. Breidt, et al. (1998). "Design and estimation for investigating the dynamics of natural resources." Ecological Applications 8(2): 234-245.
- ○ Urquhart, N. S., S. G. Paulsen, et al. (1998). "Monitoring for policy-relevent regional trends over time." Ecological Applications 8(2): 246-257.

Journal of Agricultural, Biological and Environmental Statistics (1999)

- ○ Fuller, W. A. (1999). "Environmental surveys over time." Journal of Agricultural, Biological, and Environmental Statistics 4(4): 331-345.
- ○ Urquhart, S. N. and T. M. Kincaid (1999). "Designs for detecting trend from repeated surveys of ecological resources." Journal of Agricultural, Biological, and Environmental Statisitics 4(4): 404-414.
- ○ Stevens, D. L. and A. R. Olsen (1999). "Spatially restricted surveys over time for aquatic resources." Journal of Agricultural, Biological, and Environmental Statistics 4(4): 415-428.

Other

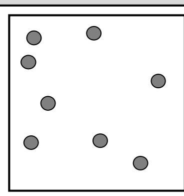
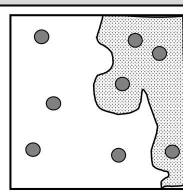
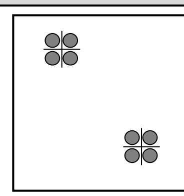
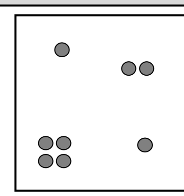
- ○ Overton, W. S. and S. V. Stehman (1996). "Desirable design characteristics for long-term monitoring of ecological variables." Environmental and Ecological Statistics 3(4): 349-361.
- ○ Vos, P., E. Meelis, et al. (2000). "A framework for the design of ecological monitoring programs as a tool for environmental and nature management." Environmental Monitoring and Assessment 61(3): 317-344.

Miscellaneous

- ○ National Research Council. (1995). Review of EPA's Environmental Monitoring and Assessment Program: Overall Evaluation. National Academy Press, Washington, D.C.

Cluster sampling usually is based on subdividing the population into many small clusters. Cluster sampling is defined by the sampling of a small number of these clusters, each of which is studied in full. Although populations can be stratified in response to administrative factors (e.g. state boundaries), the major interest in stratification is in its potential value for producing more efficient estimators of population characteristics. In contrast, cluster sampling is employed almost exclusively for administrative convenience (Barnett 1986, Rao 2000). Cluster sampling is more efficient than simple random sampling if the variation within a cluster is large, and the variation among clusters is small. This requirement is just the opposite of what is needed for high precision with stratification (Rao 2000). Developing unbiased estimates of the population mean and variance from cluster sampling designs can be quite complex and difficult. As a result, obtaining the correct estimate is non-trivial. Therefore, the use of cluster sampling needs to be carefully managed to assure that the estimates are reliable.

Table 4. Statistical Sampling Across Space. Representation of several sampling designs. Simple random sampling, stratified random sampling, and cluster sampling are traditional sampling designs for surveys. Adaptive cluster sampling is a newer technique based on the idea that the sample itself adapts to the information being collected. These ideas are presented as icons and described in more detail.

Sampling Method	Simple Random	Stratified Random	Cluster	Adaptive Cluster
Icon				
Intuition	Samples are chosen at random from a complete list of all members in the target population (the sampling frame). Simple random samples (SRS) are not uniformly spaced.	The population is divided into large groups (called strata). Each group is sampled with its own SRS. Overall estimate is a weighted averaged of the strata estimates.	The population is divided into clusters and a sample of clusters are selected. Cluster sampling is best when sampling small groups (clusters) is cheap and efficient.	The procedure for selecting the sample depends on the values observed during the study. Often, additional samples are added around successful initial samples.
Best When	• Area is homogeneous • Limited information on which to base more sophisticated sampling • A robust and unbiased estimate is more valuable than efficiency	• Area is heterogeneous • Patches are distinct • Some prior information exists about patch structure • Sampling efficiency can be optimized	• Traveling to sites is difficult or expensive • Collecting sequential samples in an area is relatively inexpensive	• Population is heterogeneous • Patches are dynamic, changing in space and time • Sampling effort and design can be flexible
Pros/ Cons	+ Simple (conceptually) + Unbiased + Robust + Variance formula is simple - May be inefficient - Difficult to implement	+ Unbiased and robust + More efficient than SRS + Variance formula is fairly simple - More complex - Vulnerable to mistakes and miscalculations	+ Can be much less expensive and thus more efficient - More complex - Unweighted average of clusters can be biased - Vulnerable to mistakes and miscalculations	+ Can be more efficient than any alternative + Best when individuals are rare and clustered - Traditional statistics are biased - Complex, very difficult to implement correctly

One recent advance in the theory of sampling is the development of adaptive sampling. Adaptive sampling is based on the powerful idea that the design of the sample can and should change throughout the sampling process. In other words, the sampling design should evolve as more information becomes available. This is a very attractive idea, but one that leads to important statistical challenges.

Adaptive sampling refers to designs in which the procedure for selecting the units may depend on the earlier members of the sample. For example, in a survey of a rare animal, sampling sites may be added near any sample where the animal is found. Thus, the sample can change (adapt) to observed patterns during the survey itself. This flexibility is impossible in the fixed sampling designs of traditional surveys. Examples of adaptive sampling include simple random sampling with a stopping rule based on observed values, adaptive stratification during a survey, adaptive allocation of effort in stratified sampling, and adaptive cluster sampling. From a theoretical basis, it can be shown that optimal strategies are often adaptive. However, adaptive procedures can be difficult to implement and challenging to analyze.

It is likely that two distinct types of adaptive sampling will prove useful in environmental monitoring; adaptive allocation in stratified sampling, and adaptive cluster sampling (Thompson and Seber 1996, Manly 2001). Estimating population parameters from adaptive cluster designs is complex. The process requires the calculation of inclusion probabilities for each unit. Unfortunately, calculation of these inclusion probabilities are not simple, and may be unknown for some units (Thompson and Seber 1996).

There is a fundamental tradeoff between sample complexity and robustness. The simplest designs are usually the most robust. Simple random sampling is often less efficient than more complex alternatives, but requires less prior information and is more forgiving to some types of mistakes. Indeed, most complex designs are built on simple random samples in a constrained or hierarchical fashion. These more complex designs, which offer gains in efficiency, are more vulnerable to mistakes in specification of the design, implementation of the sample, and calculation of the estimate. Finally, all of these traditional sampling methods assume the design is fixed prior to the beginning of the sampling period. Thus, they offer no guidance on how to adjust the sample as new (perhaps surprising) data are collected during the survey.

Monitoring Through Time

Effective monitoring requires an understanding of traditional statistical sampling theory. However, monitoring through time presents additional problems and challenges not fully addressed by traditional approaches. A principal goal of monitoring programs is to estimate rates of change (trend) in addition to measures of current status. There are many ways in which sampling designs can be extended through time (Table 5).

Questions that are specific to monitoring include whether the design of the sample should be allowed to change as information grows, whether locations should be revisited, and how should samples at different times be related. The answer to these questions lies in two things – the relative importance of description of status vs. detection of trend, and the magnitude and scale of heterogeneity (spatial and temporal). As a result, a key component of any monitoring design is the allocation of effort to describing status versus trend.

There is a continuum of monitoring designs, from designs in which sites are revisited in each sampling period to designs in which sites are never revisited and new samples are drawn each sampling period. In environmental monitoring, the most efficient strategies must reflect both the scale and magnitude of variation. For example, annual monitoring of forest stand composition is rarely necessary because of the relatively slow growth of adult trees. On the other hand, monitoring air pollution may require samples be drawn every hour.

Common designs range from revisiting every site in each sampling period to visiting new sites each period. By default, many scientists lean toward the first strategy in which sites are selected at the beginning of the monitoring process and all sites are revisited in subsequent surveys (Table 5). More careful reflection about this approach is required. Assuming that sampling effort is limited (which it always is), this approach allocates fairly large effort to site revisits, and as a direct consequence will be restricted to a very few sites. This design provides more information about trend than about regional status. This design is most effective when sites are similar, but fluctuate erratically through time. On the other hand, monitoring designs can be established in which sites are selected at random at the start of each sampling period. As a result of continual randomization, new sites are added every sampling period but sites are sampled only once. Over the course of several years, many sites will be visited leading to excellent information about status. Since sites are not revisited, change through time can only be gauged in aggregate, and the quality of information about trend depends on sites being very similar or on the assumption that all sites are changing in (approximately) the same way.

Many monitoring designs balance the relative effort allocated to estimating status and trend. One common design calls for sampling of several alternative sets of sites. Typically sites are divided into a few groups (say 3) and then each group is visited in a sequence like 1 – 2 – 3 – 1 – 2 – 3. In this design, all sites are revisited, but not during every sampling period. The alternation among different sets of sites allows for the monitoring of more sites than in a pure revisit design. This is analogous to the situation in the upper left panel of Table 5. Information about status and trend are both robust. Thus intermediate designs are optimal. The serial alternating design gives some information on both status and trend.

Discussion

Statistical theory is used to ensure that the data collected will be adequate to meet the goals of the BMP. Theory is useful to evaluate concepts of bias, variance, and power, and to improve efficiency (cost effectiveness). The monitoring literature is mixed in its treatment of key underlying statistical concepts. Although many papers discuss the pros and cons of different monitoring schemes, there has been inadequate discussion of how the multiple (competing) objectives of the MSCP impact the design of a monitoring program. There needs to be more discussion about the importance of spatial and temporal scale in determining the statistical design. There also needs to be a clearer understanding of the benefits and drawbacks of different sampling designs (random, stratified random, systematic, cluster, and adaptive) and plans for monitoring through time (new sites, revisits, rotating panel). In addition, there is inadequate attention paid to the planned analysis (or analyses) of the monitoring data and some misconceptions about the concept of power and the difference between variance and bias. Finally, there is inadequate discussion of the trade-off between efficiency and robustness. The BMP will benefit from the growing literature on sampling and monitoring if and only if these concepts can be applied to the multiple goals of the Biological Monitoring Plan.

Table 5. Common Designs for Monitoring Status and Trend. Representation of several monitoring designs. These ideas are presented as icons and described in more detail. In all three examples, total effort is equivalent (18 sites visited over a 6 year period). The designs differ radically in their allocation of effort to describing status and trend.

<table>
<tr><th>Sampling Method</th><th>Repeated Visits</th><th>New Sites</th><th>Serial Alternating</th></tr>
<tr><td>Icon</td>
<td>Year
Site (s)
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<tr><th></th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th></tr>
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<tr><td>3</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td></tr>
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<td>Year
Site (s)
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<tr><th></th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th></tr>
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<tr><td>14</td><td></td><td></td><td></td><td></td><td>X</td><td></td></tr>
<tr><td>15</td><td></td><td></td><td></td><td></td><td>X</td><td></td></tr>
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<tr><td>17</td><td></td><td></td><td></td><td></td><td></td><td>X</td></tr>
<tr><td>18</td><td></td><td></td><td></td><td></td><td></td><td>X</td></tr>
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<td>Year
Site (s)
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<tr><th></th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th></tr>
<tr><td>1</td><td>X</td><td></td><td></td><td>X</td><td></td><td></td></tr>
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<tr><td>9</td><td></td><td></td><td>X</td><td></td><td></td><td>X</td></tr>
</table></td></tr>
<tr><td>Intuition</td>
<td>Sites are revisited every year. Allows for the estimation of change for each site, every year.</td>
<td>New sites are visited in each year of the study..</td>
<td>Sites are grouped into panels. One panel is sampled each year on a fixed rotation schedule.</td></tr>
<tr><td>Best When</td>
<td>• Information on trend through time is of paramount importance
• Relatively little spatial heterogeneity
• Short-term trends at each site are of interest</td>
<td>• Information on regional status is of paramount importance
• Adding new sites is more important than consistent re-sampling of existing sites</td>
<td>• Both regional status and temporal trends are important
• Balances spatial and temporal coverage
• Interest in long-term trends through time (longer than rotation period)</td></tr>
<tr><td>Pros/Cons</td>
<td>+ Simple
+ Allows for estimation of short-term temporal change
+ Change can be detected as early as the second sampling period
- Limited spatial sampling</td>
<td>+ Maximizes the sampling of sites within the region
- Comparison of trends through time is confounded with sites
- Estimate of temporal trends can only be detected after many sampling periods</td>
<td>+ Provides estimates of long-term trends without sacrificing spatial coverage
- Fine-scale temporal change is difficult to detect
- Temporal trends can only be estimated after 2 complete rotations</td></tr>
</table>

Conclusions

In this chapter we have presented an overview of monitoring methodology relevant for the MSCP as it is presented in the scientific literature. It is clear that care needs to be taken in the selection of the entities to be monitored and in the design of data collection in order for monitoring to be effective. However, there are some established general principles and logical steps that are useful for the MSCP context. Using these as a starting point, we will develop and update formalized steps for selection of indicators and a strategy for measuring them in the context of MSCP biological monitoring.

CHAPTER 5: INITIAL RECOMMENDATIONS

Introduction

This chapter presents an initial set of recommendations based on our evaluation of the current MSCP monitoring plan and its implementation. Some of these recommendations have been made before (Conservation Biology Institute 2001, Pollak 2001) but have yet to be addressed. This project will carry out some of the recommendations (indicated by italics), and the Rare Plant Local Assistance Grant will address others. Additional issues will need to be dealt with by the participating agencies and/or jurisdictions. The initial recommendations are presented within the nine-step Atkinson et al. (2004) framework for monitoring program design. These recommendations will be revised and refined in future reports.

Initial Recommendations

Step 1: Goals and objectives of the conservation plan

To create clear, measurable monitoring objectives, the MSCP monitoring program first needs to fill in critical data gaps. Once the necessary data are collected and analyzed, updated objectives (like conservation targets) can be developed. We recommend developing species-specific and habitat level conservation targets with triggers so management actions can be taken as soon as a problem is identified. These conservation targets can be developed over time as species and habitat types have enough data available to set scientifically defensible targets and triggers. Some plant and animal species have several years of monitoring data, and targets should be developed for these species in the near term.

The following efforts will facilitate the creation of conservation targets and triggers:

1) Collect and analyze baseline data for all prioritized habitats and species so there is enough data to set scientifically-defensible conservation targets.

    a) Data requirements include: initial surveys to locate all covered species populations in the MSCP reserve, and baseline data such as population estimates over multiple years so natural variability can be estimated.

    b) *We are working with City, County, and agency personnel to compile the baseline data that have been collected to identify which species have adequate data to set targets. This process should be iterative, so targets and triggers should be revisited as knowledge of the species and systems improves.*

2) Dr. Kathryn McEachern will be working to define and clarify specific objectives for rare plants, including developing updated conservation targets where sufficient data are already available. The same effort could be pursued with a Rare Animal Local Assistance Grant.

Step 2: Scope of the monitoring program

The scope of the MSCP monitoring program is relatively well defined. The geographic scope is bound by the current configuration of the preserve, and changes as additional lands are acquired. HabiTrak is maintaining an updated system of MSCP lands.

One consideration is the upcoming availability of TransNet funding earmarked for land conservation that will occur outside the original Multi-Habitat Planning Area. If species or habitats of interest are not adequately conserved in the current preserve configuration, land managers could analyze potential conservation lands so that TransNet-funded land acquisitions complement the current MSCP reserve system.

Step 3: Compiling information relevant to monitoring program design

The MSCP monitoring program needs baseline data on existing conditions, including survey and monitoring data collected thus far for the MSCP (and additional data where available). Data and maps of species, habitats and monitoring locations will help improve the state of the monitoring program and allow for better implementation of the plan in the future. Below we outline several initial recommendations on what data need to be compiled, how this project and the Rare Plant Local Assistance Grant will contribute to these efforts, and other work underway by jurisdictions and agencies that should be continued for the monitoring program to be successful.

1) Comprehensively survey all lands in the MSCP Preserve that have not yet been surveyed to determine locations of all covered species and natural communities.

    a) Determine which lands have been surveyed and survey all remaining MSCP lands.

    b) Upon acquisition of new lands, survey and map them within a reasonable timeframe.

    c) We will work with the Rare Plant LAG, City of San Diego, County, and agency personnel on a database of surveyed lands.

2) Map all covered species locations and monitoring locations in a consistent GIS format, compiled and stored at the appropriate lead wildlife agency (using BIOS wherever possible, but an MSCP-specific collection of relevant maps would also be appropriate).

    a) The City of San Diego, County, and some agencies have begun this effort by mapping populations of species they have surveyed or monitored.

    b) We will work with the Rare Plant LAG and others to compile all available map layers of species locations and sites that have been surveyed or monitored and recommend a GIS format so future GIS layers are comparable and compatible with BIOS and other relevant database and mapping efforts.

3) Update and improve the detail or precision (resolution) of the base vegetation map in order to improve monitoring of communities.

    a) The County has updated vegetation maps for some of their lands.

b) *We will evaluate this effort and identify specific needs for updating the MSCP-scale vegetation map in Task D of this Local Assistance Grant.*

<u>*Step 4: Dividing the system and prioritizing for monitoring program development*</u>

We will set clear, scientifically-based priorities in Task B of this project. Ideally, all entities will implement the top priorities, and some entities can do more if possible. The coordination of monitoring activities will facilitate synthesis at the MSCP Preserve scale for the top priority monitoring components.

Recommendations to improve focal species selection

We echo the recommendations of Andelman et al. (2001), Wisdom et al. (2001) and Hilty and Merlender (2000) and synthesize them into the following step-down approach for selecting focal species for consideration for MSCP monitoring purposes:

1) Apply an at-risk-species based classification using the general principles of the protocols discussed in Chapter 4 above. Separate species at risk due to small population size from those at risk from other environmental factors (Caughley 1994). Environmental risk factors relevant for the MSCP include habitat loss and fragmentation due to urban expansion, decline in habitat quality, introduced species, adverse fire regime, and environmental contaminants. Note that we have subsumed human induced risk factors into environmental factors because most, if not all, risk factors have a human origin.

2) For each at-risk group, allocate species to categories based on the nature of the risk factor. Species at risk from habitat loss should be subdivided into major habitat categories (e.g., based on vegetation associations). Wisdom et al. (2001) recommend that an initial prioritization of focal species be based on macrohabitat use (including vegetation type and structural stage combinations).

3) The spatial scale of risk factors and habitat associations should be given careful consideration to ensure representation across the MSCP region. Using information on home ranges (or a surrogate such as body size (Purvis et al. 2000)) further classify species in each group according to their spatial scale of response to environmental factors.

4) Using information on life span or age at first reproduction, further classify species in each group according to their temporal scale of response to environmental risk factors.

5) Rank species in each group according to those that best satisfy the pragmatic issues of sampling and measurement outlined in Chapter 4 above.

6) Select one or more focal species from each group that best represent the rest of the group.

7) Apply a stopping rule. Examples of stopping rules are:

    a) Stop when each discrete vegetation community type is represented by at least one focal species.

b) Stop when all risk factors have been associated with at least one focal species.

In the case of the covered species list, a ranking of focal species will be important because all of the covered species may be prioritized as focal species under this step-down approach. Hence, we further recommend that species that are exposed to a higher degree of risk and species that satisfy the pragmatic criteria for sampling and measurement to a higher degree be given priority as focal species. This may mean that species whose life history and response to changes in environmental factors are well known will be given higher priority as focal species. That is, species for which there have been data collection efforts in the past will be prioritized as focal species above those that are poorly studied. Note that these recommendations rely on a thorough compilation of the ecological characteristics, responses to risk factors, distributions, and habitat associations. Hence, before any focal species prioritization can occur this information must be compiled, collated, and analyzed for each of the covered species.

Step 5: Developing conceptual models

We reemphasize the need to identify existing conditions (Rahn 2005), or establish baseline conditions, by compiling and analyzing information relevant to the monitoring program (Step 3 in Atkinson et al. 2004). Existing data on species and habitat distributions and abundances, including monitoring data collected for the MSCP, are an important key to identifying indicator variables and stressors if they are appropriately analyzed, and such data are therefore necessary for developing conceptual models.

We will develop conceptual models, focused on identifying threats and management responses in Task C of this project.

The following issues will be considered as we develop the models:

1) Conceptual models are typically developed by compiling information about a system, e.g., a literature review. Where "literature" or data are lacking, conceptual models can be developed, and even used formally for prediction, from expert opinion. However, if this route is taken, formal methods should be used wherever possible to identify what is data-derived versus derived from expert opinion in the conceptual models.

2) Identify potential causes of species declines and appropriate management responses to help determine which components of the system should be monitored, and to help link monitoring to management.

3) The development of conceptual models is likely to be iterative and the models can and should be refined as knowledge of the system improves.

Step 6: Identifying monitoring recommendations and critical uncertainties

We will work to identify monitoring recommendations and critical uncertainties in Task D of this Local Assistance Grant. Critical gaps in the data must be filled to create and implement a successful monitoring program. These gaps include locating and mapping all covered species populations, collecting comprehensive baseline data, and identifying and monitoring potential threats to habitats and covered species populations.

We will work with the Rare Plant LAG, County, City, and agency personnel on a database to help organize the monitoring activities undertaken to date. Critical uncertainties should become more evident as this effort proceeds. These data gaps and additional monitoring recommendations will be presented in a future report.

Step 7: Determining strategy for implementing monitoring

We will work to determine a strategy to implement monitoring in Task E of this project. Two initial recommendations include:

1) Pursue TransNet funding to accomplish the monitoring and management objectives wherever possible

2) Develop protocols that are feasible given the limited funding and staffing available. Dr. Kathryn McEachern will provide recommendations of feasible plant monitoring protocols in the Rare Plant Local Assistance Grant. Feasible animal monitoring protocols could be developed in a Rare Animal Local Assistance Grant.

3) *We will work to compile and synthesize the literature on monitoring.*

    a) Use baseline data and conceptual models to identify spatial and temporal scales relevant for monitoring.

    b) Explicitly incorporate relative costs and compare designs that differ in spatial coverage, revisits through time, and oversampling to estimate error rates.

    c) Acknowledge the role of uncertainty, model error, and natural variation in the selection of monitoring schemes that are robust.

    d) Develop separate but coordinated monitoring schemes designed to meet different objectives. This is a necessary compromise between a one-size-fits all plan and scattershot of independent, uncoordinated schemes.

Step 8: Developing data quality assurance, data management, analysis, and reporting strategies

Though this step is outside the Scope of Work for this project, we will identify strategies for improving these important aspects of the monitoring program. To begin, we strongly recommend the Three-Year synthesis report should be completed within the 3-year timeframe. These reports should summarize findings, adjust priorities as needed, and update conservation targets based on data collected in the previous 3 years. They should be completed with scientific rigor and in a timely manner, and be subjected to independent scientific review. The jurisdictions will need to continue (or begin) compiling and submitting annual monitoring summaries and reports to the wildlife agencies. The wildlife agencies will need to continue (or begin) compiling monitoring data from across the MSCP reserve. These compilations can then be accessed by the lead agency or responsible person for analysis and recommendations. This effort would be helped by a simple synthesis of data collected on an annual basis. If more resources become available over time, a more comprehensive synthesis report could be produced more often. The County is currently developing a database to keep track of all monitoring activities to date and the City will likely begin using the database as well. This effort should help decrease the burden on the agencies when compiling and synthesizing data for the Three-Year Report.

1) Compile and analyze sampling designs, protocols, data management strategies, and statistical analyses

    a) *We will provide recommendations on these issues, such as by identifying statistical analysis techniques upfront so monitoring data can be gathered in a way conducive to analysis, with results that are easily interpretable and can translate into management actions.*

2) Create and maintain a digital library of all MSCP monitoring documents, stored at one of the wildlife agencies. We will provide a bibliography of MSCP-related documents in and an attached CD of all relevant and available digital files upon the completion of this project. Dataset storage and maintenance should be addressed through BIOS and the Multi-Taxa Database, though additional copies of MSCP data and maps should be maintained with the MSCP digital library.

3) Data analysis could be improved through a better sampling design and protocols that allow for clear and simple analysis of data at the reserve-level and for synthesis at larger scales. The City has implemented the plan most closely to date, so they offer a good opportunity to analyze the gaps, problems, and positive parts of the current plan. The data they have collected could be analyzed as a case study to determine the baseline status of the City's Preserve lands, evaluate and modify the monitoring protocols, and link the results to management responses.

4) Improved implementation of the monitoring program, facilitated by improved protocols for data collection (i.e., implementing the protocols developed by Dr. McEachern for rare plants), and identification of appropriate analysis techniques upfront would facilitate the synthesis of monitoring data at the MSCP scale.

Step 9: Completing adaptive management loop by ensuring effective feedback to decision-making

Although this step is outside the Scope of Work for this project, work undertaken in previous steps will improve the link between monitoring and management. We will develop conceptual models to help identify threats and appropriate management responses. Setting conservation targets and triggers will also help strengthen the link between monitoring data that is collected and decision-making of when, where, and how to target management activities to address a problem that has been identified.

Conclusions

These initial recommendations were identified while compiling information relevant to monitoring program design, both for the MSCP and from the scientific literature. These issues will be considered in greater detail in future tasks, where specific recommendations, priorities, conceptual models, and strategies will be further developed. We are limited to what the jurisdictions and agencies have shared with us regarding their monitoring activities to date.

Some recommendations may already be completed or are currently being addressed by a participant in the monitoring program. If so, all such efforts should be identified and shared with the authors of this report so we can move forward with the best available data. Feedback on this report from all interested parties is encouraged.

Seven years into the Multiple Species Conservation Program, great strides have been made, including the conservation of over 127,000 acres of land for the reserve system, and the collection of baseline data for a variety of rare plant and animal species. The participating jurisdictions and agencies have worked hard to implement aspects of the monitoring program despite limited staffing and funding. With an updated monitoring program, the MSCP has great potential to be an example for regional conservation n efforts across the country.

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APPENDIX A: MSCP CONSERVATION TARGETS FOR COVERED SPECIES

The following table was compiled from the City and County of San Diego's Subarea Plans, and were based on estimates made at the time the plans were written.

		From City of San Diego Subarea Plan*	From San Diego County Subarea Plan[#]		
		Entire MSCP	County Subarea Only		
Scientific Name	Common Name	Conservation Targets	Number of Occurrences	Number Protected	% to be Protected
Plants					
Acanthomintha ilicifolia	San Diego thorn-mint	80-100% of 8 major populations, with 85% conserved overall	16	15.1	94
Agave shawii	Shaw's agave	100% of major populations	Not included in County Subarea Plan		
Ambrosia pumila	San Diego ambrosia	90% of only major population (plus USFWS population)	2	2	100
Aphanisma blitoides	Aphanisma	90% of potential habitat, 92% of southern foredunes, 88% of southern coastal bluff scrub	Not included in County Subarea Plan		
Arctostaphylos glanulosa var. *crassifolia*	Del Mar manzanita	91% of major populations and 67% of southern maritime chaparral habitat	6	6	100
Arctostaphylus otayensis	Otay manzanita	95% of major populations	25	24.7	99
Astragalus tener var. *titi*	Coastal dunes milk vetch	92% of southern foredunes	Not included in County Subarea Plan		
Baccharis vanessae	Encinitas baccharis	92% of major populations	25	24.4	98
Berberis nevinii	Nevin's barberry	100% of populations (occurrences are all persisting cultivars)	Not included in County Subarea Plan		
Brodiaea filifolia	Thread-leaved brodiaea	88% of vernal pool habitat, 38% of grassland	Not included in County Subarea Plan		
Brodiaea orcuttii	Orcutt's brodiaea	100% of major populations, 88% of vernal pool habitat, 38% of grassland	32	29.9	93
Calamagrostis densa	Dense reed grass	91% of major populations	5	4.7	94
Calochortus dunnii	Dunn' s Mariposa lily	100% of major populations	40	40	100
Caulanthus stenocarpus	Slender-pod jewelflower	75% of major populations (100% of 3 of 4 major populations)	21	20.7	99

		Entire MSCP	County Subarea Only		
Scientific Name	**Common Name**	**Conservation Targets**	**Number of Occurrences**	**Number Protected**	**% to be Protected**
Plants					
Ceanothus cyaneus	Lakeside ceanothus	75% of major populations (100% of 3 of 4 major populations)	7	5.2	74
Ceanothus verrucosus	Wart-stemmed ceanothus	67% of major populations, 64% of known localities	21	20.4	97
Cordylanthus maritimus ssp. *maritimus*	Salt marsh bird's beak	100% of major populations	Not included in County Subarea Plan		
Cordylanthus orcuttianus	Orcutt' s bird's beak	75% of major populations (100% of 3 of 4 major populations)	2	2	100
Cupressus forbesii	Tecate cypress	98% of major populations	23	22.1	96
Dudleya blochmaniae ssp. *brevifolia*	Short-leaved dudleya	100% of major populations	Not included in County Subarea Plan		
Dudleya variegata	Variegated dudleya	56% of major populations, 75% of known localities	125	123.8	99
Dudleya viscida	Sticky dudleya	100% of major populations	2	2	100
Ericameria palmeri ssp. *palmeri*	Palmer's ericameria	66% of major populations	17	14.9	88
Eryngium aristulatum var. *parishii*	San Diego button-celery	82% of major populations, 88% of vernal pool habitat	48	48	100
Erysimum ammophilum	Coast wallflower	92% of southern foredunes, 67% of southern maritime chaparral	Not included in County Subarea Plan		
Ferocactus viridescens	San Diego barrel cactus	81% of major populations	532	498.1	94
Deinandra (Hemizonia) conjugens	Otay tarplant	66% of major populations	78	77.5	99
Lepechinia cardiophylla	Heart-leaved pitcher sage	80-100% of 3 major populations, 100% of one population, with 85% conserved overall	Not included in County Subarea Plan		

		Entire MSCP	County Subarea Only		
Scientific Name	**Common Name**	**Conservation Targets**	**Number of Occurrences**	**Number Protected**	**% to be Protected**
Plants					
Lepechinia ganderi	Gander' s pitcher sage	100% of known locations	25	25	100
Lessingia (Corethrogyne) filaginifolia var. *linifolia*	Del Mar mesa sand aster	48% of major populations, 57% of known localities, 67% of southern maritime chaparral	Not included in County Subarea Plan		
Lotus nuttallianus	Nuttall's lotus	80-100% of major populations, 92% of southern foredune habitat	Not included in County Subarea Plan		
Monardella hypoleuca ssp. *lanata*	Felt-leaved monardella	89% of major populations	5	5	100
Monardella linoides ssp. *viminea*	Willowy monardella	100% of major populations	14	14	100
Muilla clevelandii	San Diego goldenstar	73% of major populations, 38% of grasslands	98	88.1	90
Navarretia fossalis	Prostrate navarretia	63% of only major population, 88% of vernal pool habitat	1	1	100
Nolina interrata	Dehesa bear-grass	90-100% of major populations	33	33	100
Opuntia parryi var. *serpentina*	Snake cholla	75% of major populations, 67% of southern maritime chaparral	9	9	100
Orcuttia californica	California Orcutt grass	86% of only major population, 88% of vernal pool habitat	Not included in County Subarea Plan		
Pinus torreyana	Torrey pine	100% of native population	Not included in County Subarea Plan		
Pogogyne abramsii	San Diego mesa mint	88% of vernal pool habitat	Not included in County Subarea Plan		
Pogogyne nudiuscula	Otay Mesa mint	91% of major population, 88% of vernal pool habitat	74	74	100

		Entire MSCP	County Subarea Only		
Scientific Name	**Common Name**	**Conservation Targets**	**Number of Occurrences**	**Number Protected**	**% to be Protected**
Plants					
Rosa minutifolia	Small-leaved rose	Only known population transplanted into preserve, propagation and restoration in appropriate habitat	Not included in County Subarea Plan		
Satureja chandleri	San Miguel savory	80-100% of future identified occurrences	2	1.7	85
Senecio ganderi	Gander' s butterweed	90-100% of major populations	4	4	100
Solanum tenuilobatum	Narrow-leaved nightshade	90% of major populations	100	99.7	99.7
Tetracoccus dioicus	Parry's tetracoccus	80-100% of major populations	30	30	100
Invertebrates					
Mitoura thornei	Thorne's hairstreak butterfly	98% of Tecate cypress forest (larval host plant)	Not included in County Subarea Plan		
Panoquina errans	Salt marsh skipper	93% of salt marsh habitat	Not included in County Subarea Plan		
Branchinecta sandiegoensis	San Diego fairy shrimp	88% of vernal pool habitat	Not included in County Subarea Plan		
Streptocephalus woottonii	Riverside fairy shrimp	88% of vernal pool habitat	Not included in County Subarea Plan		
Amphibians					
Bufo microscaphus californicus	Arroyo southwestern toad	100% of known locations, 78% riparian wetland areas in suitable habitat	1	1	100
Rana aurora draytoni	California red-legged frog	72% of riparian habitats and fresh water marsh	1	1	100
Reptiles					
Clemmys marmorata pallida	Southwestern pond turtle	72% of riparian habitats and fresh water marsh	3	2	67
Phrynosoma coronatum blainvillei	San Diego horned lizard	60% of potential habitat (64% of coastal sage scrub, 54% of chaparral, 44% of coastal sage/chaparral, 80% of riparian scrub), 63% of known point occurrences	134	114.2	85
Cnemidophorus hyperythrus beldingi	Orange-throated whiptail	59% of potential habitat (64% of coastal sage scrub, 60% of maritime succulent scrub, 54% of chaparral, 67% of southern maritime chaparral, 44% of coastal sage/chaparral), 62% of known point occurrences	195	165.6	85

		Entire MSCP	County Subarea Only		
Scientific Name	**Common Name**	**Conservation Targets**	**Number of Occurrences**	**Number Protected**	**% to be Protected**
Birds					
Accipiter cooperii	Cooper's hawk	59% of potential foraging habitat (47% of oak woodland, 58% of oak riparian, 64% of coastal sage scrub, 54% of chaparral, 44% of coastal sage scrub/chaparral), 57% of known localities, 52% of potential nesting habitat (58% of oak riparian, 47% of oak woodland), 92% of known occurrences	32	29.5	92
Agelaius tricolor	Tricolored blackbird	77% of breeding habitat (61% of freshwater marsh, 80% of riparian scrub), 59% of known localities	2	2	100
Aimophila ruficeps canescens	California rufous-crowned sparrow	61% of potential habitat (64% of coastal sage scrub, 60% of maritime succulent scrub, 44% of coastal sage/chaparral), 71% of mapped localities	185	175.6	95
Aquila chrysaetos	Golden eagle	53% of potential foraging/nesting habitat (coastal sage scrub, chaparral, grassland, oak woodland), large blocks of habitat conserved where active nesting territories exist, 7 of 11 active nesting territories within MSCP should remain viable	27	21	78
Branta canadensis	Canada goose	~8,200 acres of potential habitat	Not included in County Subarea Plan		
Buteo regalis	Ferruginous hawk	22% of foraging habitat (38% of grassland, 6% of agricultural fields)	1	0.7	70
Buteo swainsoni	Swainson' s hawk	22% of foraging habitat (38% of grassland, 6% of agricultural fields)	1	1	100
Campylorhynchus brunneicapillus cousei	Coastal cactus wren	60% of maritime succulent scrub habitat in large contiguous blocks, 4 of 5 major populations conserved	143	139.1	97

		Entire MSCP	County Subarea Only		
Scientific Name	**Common Name**	**Conservation Targets**	**Number of Occurrences**	**Number Protected**	**% to be Protected**
Birds					
Charadrius alexandrinus nivosus	Western snowy plover	93% of potential habitat (99% of saltpan, 90 - 95% of beach outside intensively used recreational beaches)	Not included in County Subarea Plan		
Charadrius montanus	Mountain plover	22% of potential foraging habitat (38% of grassland, 6% of agricultural fields)	Not included in County Subarea Plan		
Circus cyaneus	Northern harrier	42% of potential nesting habitat (93% of saltmarsh 68% of freshwater marsh, 38% of grasslands) plus ~85,000 acres of potential foraging habitat	14	12.8	91
Egretta rufescens	Reddish egret	92% of potential habitat (93% of southern coastal saltmarsh, 99% of salt pan, 88% of natural flood channel)	Not included in County Subarea Plan		
Empidonax traillii extimus	Southwestern willow flycatcher	76% of potential habitat (90% of riparian woodland, 80% of riparian scrub), 88% of known localities	Not included in County Subarea Plan		
Falcon peregrinus anatum	American peregrine falcon	61% of historic nesting sites, 58% of foraging habitat (93% southern coastal saltmarsh, 99% of saltpan, 68% of freshwater marsh, 91% of open water, 88% of natural flood channel, 64% of coastal sage scrub, 38% of grassland)	2	2	100
Haliaeetus leucocephalus	Bald eagle	89% of potential foraging habitat (wetlands - 68% of freshwater marsh, 92% of open water) plus foraging opportunities on 100,000+ acres will be conserved	3	2.1	70
Numenius americanus	Long-billed curlew	24% of potential foraging habitat (93% of southern coastal saltmarsh, 99% of saltpan, 38% of grassland, 6% of agricultural fields)	Not included in County Subarea Plan		

		Entire MSCP	County Subarea Only		
Scientific Name	**Common Name**	**Conservation Targets**	**Number of Occurrences**	**Number Protected**	**% to be Protected**
Birds					
Passerculus sandwichensis beldingi	Belding' s savannah sparrow	93% of potential habitat (~1,700 acres of southern coastal saltmarsh), 71% of mapped localities	1	1	100
Passerculus sandwichensis rostratus	Large-billed savannah sparrow	93% of potential habitat (~1,700 acres of southern coastal saltmarsh), 50% of mapped localities	Not included in County Subarea Plan		
Pelecanus occidentalis californicus	California brown pelican	91% of roosting and foraging habitat (93% of southern coastal saltmarsh, 88% of natural flood channel, 90-95% of beach outside of intensively used recreational beaches)	Not included in County Subarea Plan		
Plegadis chihi	White-faced ibis	78% of potential habitat (68% of freshwater marsh, 88% natural flood channel, plus ~1,800 acres of potential habitat agricultural land will be conserved)	Not included in County Subarea Plan		
Polioptila californica californica	California gnatcatcher	~73,300 acres of coastal sage scrub and interdigitated habitats in interconnected network of preserves, 81% of core areas where species occurs will be conserved, 65% of known locations will be conserved	937	894.2	95
Rallus longirostris levipes	Light-footed clapper rail	93% of potential habitat (southern coastal saltmarsh)	Not included in County Subarea Plan		
Sialia mexicana	Western bluebird	59% of potential habitat (57% of oak riparian forest, 47% of oak woodland, 34% of grassland)	2	1.7	85
Speotyto cunicularia hypugaea	Burrowing owl	4 known locations, 8 known locations within major amendment area (south County segment), ~4,000 acres of known habitat	10	7	70
Sterna elegans	Elegant tern	93% of potential habitat (99% of saltpan, 90 - 95% of beach outside intensively used recreational beaches)	Not included in County Subarea Plan		

		Entire MSCP	County Subarea Only		
Scientific Name	**Common Name**	**Conservation Targets**	**Number of Occurrences**	**Number Protected**	**% to be Protected**
Birds					
Sterna antillarum browni	California least tern	93% of potential habitat (99% of saltpan, 90-95% of beach outside intensively used recreational beaches)	Not included in County Subarea Plan		
Vireo bellii pusillus	Least Bell's vireo	81% of potential habitat (93% of riparian woodland, 58% of oak riparian forest), 82-100% of major populations	74	73.7	99.6
Mammals					
Felis concolor	Mountain lion	81% of seven core areas, connected by three linkages	17	9.1	54
Odocoileus hemionus fuliginata	Southern mule deer	81% of seven core areas, connected by three linkages	63	54	86
Taxidea taxus	American badger	58% of potential habitat (38% of grassland, 64% of coastal sage scrub, 44% of coastal sage/chaparral)	Not included in County Subarea Plan		

* Source: City of San Diego MSCP Subarea Plan, Appendix A: Species evaluated for coverage under the MSCP

[#] Source: County of San Diego MSCP Subarea Plan, Table 1-3: Anticipated Conservation Levels for Species in the County Subarea

APPENDIX B: SUMMARY OF SURVEYS, MONITORING, AND STUDIES OF COVERED SPECIES

Covered Plant Species

Species	Common Name	City Monitoring?	USFWS Monitoring?	Found in County Surveys?	MSCP Report Citations
Acanthomintha ilicifolia	San Diego thorn-mint	**Yes**	**Yes**	**Yes**	**McMillan et al. (2002), County of San Diego (2002), City of San Diego (2000a, 2001a, 2003a, 2004a)**
Agave shawii	Shaw's agave				
Ambrosia pumila	San Diego ambrosia	**Yes**	**Yes**	**Yes**	**Dudek & Associates (2000), McMillan et al. (2002), County of San Diego (2002), City of San Diego (2000b, 2001b, 2003b)**
Aphanisma blitoides	Aphanisma				
Arctostaphylos glandulosa var. crassifolia	Del Mar manzanita	**Yes**		**Yes**	**County of San Diego (2002), City of San Diego (2002a)**
Arctostaphylos otayensis	Otay manzanita		**Yes**		**Griffin (2003)**
Astragalus tener var. titi	Coastal dunes milk-vetch				
Baccharis vanessae	Encinitas baccharis				
Berberis nevinii	Nevin's barberry				

Species	Common Name	City Monitoring?	USFWS Monitoring?	Found in County Surveys?	MSCP Report Citations
Brodiaea filifolia	Thread-leaved brodiaea				
Brodiaea orcuttii	Orcutt's brodiaea	**Yes**		**Yes**	**McMillan et al. (2002), County of San Diego (2002), City of San Diego (2003c)**
Calamagrostis densa	Dense reed grass				
Calochortus dunnii	Dunn's mariposa lily				
Caulanthus stenocarpus	Slender-pod jewelflower				
Ceanothus cyaneus	Lakeside ceanothus			**Yes**	**County of San Diego (2002)**
Ceanothus verrucosus	Wart-stemmed ceanothus	**Yes**	**Yes**	**Yes**	**Imagis et al. (2001), McMilan et al. (2002), County of San Diego (2002)**
Cordylanthus maritimus ssp. maritimus	Salt marsh bird's beak				**McMillan et al. (2002), County of San Diego (2002)**
Cordylanthus orcuttianus	Orcutt's bird's-beak	**Yes**			**City of San Diego (2003d, 2004b)**
Cupressus forbesii	Tecate cypress			**Yes**	**County of San Diego (2002)**
Cylindropuntia parryi var. serpentina	Snake cholla	**Yes**	**Yes**		**Griffin (2003), City of San Diego (2002b)**

Species	Common Name	City Monitoring?	USFWS Monitoring?	Found in County Surveys?	MSCP Report Citations
Deinandra (=Hemizonia) conjugens	Otay tarplant	**Yes**	**Yes**		**McMillan et al. (2002), Griffin (2003), City of San Diego (2003e, 2004c), Coulter et al. (2004)**
Dudleya blochmaniae ssp. brevifolia	Short-leaved dudleya	**Yes**			**McMillan et al. (2002), City of San Diego (1999, 2000c, 2001c, 2002c, 2003f, 2004d)**
Dudleya variegata	Variegated dudleya	**Yes**	**Yes**	**Yes**	**CBI (2000), McMillan et al. (2002), County of San Diego (2002), Griffin (2003), City of San Diego (2003g, 2004e)**
Dudleya viscida	Sticky dudleya				
Ericameria palmeri ssp. palmeri	Palmer's ericameria		**Yes**		**Griffin (2002)**
Eryngium aristulatum var. parishii	San Diego button-celery				**USFWS (1998), Greer et al. (2002), McMillan et al. (2002), Coulter et al. (2004), City of San Diego (2004i)**
Erysimum ammophilum	Coast wallflower				
Ferocactus viridescens	San Diego barrel cactus		**Yes**	**Yes**	**County of San Diego (2002), Griffin (2003)**
Lepechinia cardiophylla	Heart-leaved pitcher sage				
Lepechinia ganderi	Gander's pitcher sage				
Lessingia (Corethrogyne) filaginifolia var. linifolia	Del Mar Mesa sand aster	**Yes**			**McMillan et al. (2002), City of San Diego (2003h)**

Species	Common Name	City Monitoring?	USFWS Monitoring?	Found in County Surveys?	MSCP Report Citations
Lotus nuttallianus	Nuttall's lotus	**Yes**	**Yes**		**McMillan et al. (2002), City of San Diego (2001d, 2002d, 2003i, 2004f)**
Monardella hypoleuca ssp. lanata	Felt-leaved monardella			**Yes**	**County of San Diego (2002)**
Monardella linoides ssp. viminea	Willowy monardella	**Yes**	**Yes**	**Yes**	**McMillan et al. (2002), County of San Diego (2002), City of San Diego (2000d, 2001e, 2002e, 2003j, 2004g)**
Muilla clevelandii	San Diego goldenstar	**Yes**	**Yes**	**Yes**	**McMillan et al. (2002), County of San Diego (2002), Griffin (2003), City of San Diego (2003k, 2004h)**
Navarretia fossalis	Prostrate navarretia				**USFWS (1998), McMillan et al. (2002)**
Nolina interrata	Dehesa beargrass		**Yes**	**Yes**	**County of San Diego (2002), Griffin (2003)**
Orcuttia californica	California Orcutt grass				**USFWS (1998)**
Pinus torreyana ssp. torreyana	Torrey pine				**McMillan et al. (2002)**
Pogogyne abramsii	San Diego Mesa mint				**USFWS (1998), McMillan et al. (2002)**
Pogogyne nudiuscula	Otay Mesa mint				**USFWS (1998), Greer et al. (2002), Coulter et al. (2004)**
Rosa minutifolia	Small-leaved rose				**Dodero and Hodge (1999)**

Species	Common Name	City Monitoring?	USFWS Monitoring?	Found in County Surveys?	MSCP Report Citations
Satureja chandleri	San Miguel savory				
Senecio ganderi	Gander's butterweed			**Yes**	**County of San Diego (2002)**
Solanum tenuilobatum	Narrow-leaved nightshade				
Tetracoccus dioicus	Parry's tetracoccus			**Yes**	**County of San Diego (2002)**

Covered Animal Species

Invertebrate Species	Common Name	City Surveys or Studies?	County Surveys or Studies?	USFWS Surveys or Studies?	USGS Surveys or Studies?	MSCP Report Citations
Panoquina errans	Salt marsh skipper butterfly					
Mitoura thornei	Thorne's hairstreak butterfly					
Streptocephalus woottoni	Riverside fairy shrimp	**Yes**				USFWS (1998), City of San Diego (2004i)
Branchinecta sandiegonensis	San Diego fairy shrimp	**Yes**				USFWS (1998), City of San Diego (2004i)

Amphibian Species	Common Name	City Surveys or Studies?	County Surveys or Studies?	USFWS Surveys or Studies?	USGS Surveys or Studies?	MSCP Report Citations
Bufo microscaphus californicus	Arroyo southwestern toad	**Yes**	**Yes**	**Yes**	**Yes**	CBI (2000), Meyer et al. (2003), Madden-Smith et al. (2003)
Rana aurora draytonii	California red-legged frog			**Yes**		USFWS (2002)

Reptile Species	Common Name	City Surveys or Studies?	County Surveys or Studies?	USFWS Surveys or Studies?	USGS Surveys or Studies?	MSCP Report Citations
Clemmys marmorata pallida	Southwestern pond turtle		**Yes**		**Yes**	Meyer et al. (2003)
Phrynosoma coronatum blainvillei	San Diego horned lizard		**Yes**			Rochester et al. (2001), Brown and Fisher (2002), Atkinson et al. (2003)
Cnemidophorus hyperythrus beldingi	Orange-throated whiptail		**Yes**		**Yes**	Rochester et al. (2001), Brown and Fisher (2002), Atkinson et al. (2003)

Bird Species	Common Name	City Surveys or Studies?	County Surveys or Studies?	USFWS Surveys or Studies?	USGS Surveys or Studies?	MSCP Report Citations
Accipiter cooperii	Cooper's hawk		**Yes**			WRI (2002)
Agelaius tricolor	Tricolored blackbird					
Aimophila ruficeps canescens	California rufous-crowned sparrow		**Yes**			

Bird Species	Common Name	City Surveys or Studies?	County Surveys or Studies?	USFWS Surveys or Studies?	USGS Surveys or Studies?	MSCP Report Citations
Aquila chrysaetos	Golden eagle		**Yes**			WRI (2002)
Branta canadensis	Canada goose					
Buteo regalis	Ferruginous hawk					WRI (2002)
Buteo swainsoni	Swainson's hawk					WRI (2002)
Campylorhynchus brunneicapillus couesi	Coastal cactus wren			**Yes**		
Charadrius alexandrinus nivosus	Western snowy plover					
Charadrius montanus	Mountain plover					
Circus cyaneus	Northern harrier					WRI (2002)
Egretta rufescens	Reddish egret					
Empidonax traillii extimus	Southwestern willow flycatcher			**Yes**	**Yes**	Kus and Beck (1998), Kus et al. (2003), Rourke et al. (2004), Griffin (2003)
Falco peregrinus	American peregrine falcon					WRI (2002)
Haliaeetus leucocephalus	Bald eagle					WRI (2002)
Numenius americanus	Long-billed curlew					

Bird Species	Common Name	City Surveys or Studies?	County Surveys or Studies?	USFWS Surveys or Studies?	USGS Surveys or Studies?	MSCP Report Citations
Passerculus sandwichensis beldingi	Belding's Savannah sparrow					
Passerculus sandwichensis rostratus	Large-billed Savannah sparrow					
Pelecanus occidentalis	California brown pelican					
Plegadis chihi	White-faced ibis					
Polioptila californica californica	California gnatcatcher	**Yes**	**Yes**	**Yes**		URS (2001), Campbell and Webb (2002, 2003), WRI (2004)
Rallus longirostris levipes	Light-footed clapper rail			**Yes**		
Sialia mexicana	Western bluebird					
Speotyto cunicularia	Burrowing owl	**Yes**				Lincer (2001), WRI (2002, 2003)
Sterna antillarum browni	California least tern			**Yes**		
Sterna elegans	Elegant tern					
Vireo bellii pusillus	Least Bell's vireo	**Yes**		**Yes**	**Yes**	Kus and Beck (1998), CBI (2000), Griffin (2003)

Mammal Species	Common Name	City Surveys or Studies?	County Surveys or Studies?	USFWS Surveys or Studies?	USGS Surveys or Studies?	MSCP Report Citations
Taxidea taxus	American badger	**Yes**	**Yes**			Wildlife Corridor Studies:
Felis concolor	Mountain lion	**Yes**	**Yes**			Hayden (2001), CBI (2002, 2003a, 2003b)
Odocoileus hemionus fuliginata	Southern mule deer	**Yes**	**Yes**			