Developing Conceptual Models to Improve the Biological Monitoring Plan for San Diego's Multiple Species Conservation Program

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Executive Summary

This report presents the results of Task C from Local Assistance Grant P0450009, *Develop simple management-oriented conceptual models.* We establish a framework for building conceptual models for species, communities, and landscapes in San Diego's Multiple Species Conservation Program (MSCP) and present four case studies which illustrate the construction of conceptual models and their utility in identifying components for monitoring.

Developing conceptual models is often identified as a critical step in the design of biological monitoring plans (Atkinson et al. 2004, Davis 1993, Manley et al. 2000, Margoluis & Salafsky 1998). The model development process can help identify the factors that impact the species/community/landscape, and the components that should be monitored directly to assess its status. Conceptual models also highlight data gaps, and assist in the formulation of hypotheses that can be tested through monitoring. Ultimately, the conceptual model helps managers document their understanding of the system in a comprehensive way that can be examined and agreed upon by the involved stakeholders. The model can help these managers identify *what* to monitor, and lead directly to the development of a monitoring program for that species or community of concern.

We present case studies of conceptual models for a covered plant (*Ambrosia pumila*) and animal species (California gnatcatcher), a community (coastal sage scrub), and a landscape (coastal sage scrub-chaparral-grassland). As this is an iterative process, we present a first version of each model, followed by comments made at a workshop with the MSCP partners, our responses, and a revised version of the model. We also identify key uncertainties for each case study.

We recommend four major steps in conceptual model development to help identify the parameters and elements to be monitored:

1. Identify the monitoring goals for the relevant species, community, or landscape.
2. Identify the major current and historical anthropogenic threats, natural drivers, and population or community parameters that dictate current or future status and trends.
3. Identify potential management responses for the relevant species or system.
4. Identify what to monitor based on the main parameters that link to the dynamics of the relevant species or community in the context of the monitoring goals.

Using the case studies presented here as a guide, the MSCP partners can develop conceptual models for other species, communities, and landscapes as the monitoring program proceeds. These models can and should be updated as the knowledge base for these systems improves as a result of monitoring and management implementation.

1. Introduction

This report presents the results of Task C from Local Assistance Grant P0450009, *Develop simple management-oriented conceptual models.* We establish a framework for building conceptual models for species, communities, and landscapes in San Diego's Multiple Species Conservation Program (MSCP) and present four case studies which illustrate the construction of conceptual models and their utility in identifying components for monitoring.

Developing conceptual models is often identified as a critical step in the design of biological monitoring plans (Atkinson et al. 2004, Davis 1993, Manley et al. 2000, Margoluis & Salafsky 1998). The literature is rife with recommendations on how to build conceptual models and examples vary in structure from verbal accounts to mathematical formulae to graphical diagrams (Andelman et al. 2001). The content can also vary depending on the purpose of the model. For the MSCP monitoring program, the most relevant components include direct and indirect relationships between stressors (drivers) and their effects on target populations, species, communities, and landscapes (Margoluis & Salafsky 1998, Noon 2003).

Monitoring large-scale conservation areas requires identifying clear goals, and then selecting attributes to monitor based on the best available knowledge of the system (Manley et al. 2000). Monitoring programs often put inadequate effort into compiling and examining the current state of knowledge of a system or species as it relates to the monitoring goals. As a result, the selection of monitoring targets has often had little relevance for management and does not make full use of the existing state of knowledge (Manley et al. 2000). Conceptual models that are based on clear monitoring goals and are closely linked to management will have the best chance of elucidating and prioritizing the main population parameters and stressors for monitoring. This can then prompt managers to implement appropriate management responses when necessary (Manley et al. 2000, Rahn 2005).

Another important aspect of conceptual model development in a multi-stakeholder monitoring program such as the MSCP is that it provides a forum for stakeholders to come to a common agreement on the important dynamics and the state of understanding of the system. Margoluis & Salafsky (1998) argue that model development is similar to generating hypotheses, where the relationships believed to affect the target condition are stated. The monitoring efforts should be designed to test those hypotheses.

Newton et al. (1998) identify the following advantages of conceptual models for a monitoring program, which are relevant for the context of the MSCP:

1. They provide general scientific agreement for the ecological framework of the system;
2. They provide a basis to identify gaps in knowledge and understanding;
3. They provide a basis for managers to ask questions, to see the complexity of the information required for answers, and to see relationships between management activities and ecosystem response;
4. They provide a basis for scientists to design monitoring and research programs to answer questions;
5. They provide context for presenting results. (Newton 1998)

This report presents an effort to develop conceptual models for the MSCP, aimed at moving monitoring program design forward with a stronger scientific basis. Section 2 describes how conceptual models are useful in monitoring program design; Section 3 describes a rationale for designing parsimonious models; and Section 4 presents case studies of conceptual models for a covered plant (*Ambrosia pumila*) and animal species (California gnatcatcher), a community (coastal sage scrub), and a landscape (coastal sage scrub-chaparral-grassland).

2. How conceptual models improve a monitoring program

As described in Section 1, conceptual model development is a useful step in designing a monitoring program. Figure 1 presents a flow chart of the process of conservation planning and adaptive management that highlights where conceptual models and monitoring fit in. For the MSCP, biological goals were identified early in the planning process. These include conserving covered species and conserving community function and diversity. While monitoring is mandated for the MSCP, that is not the only impetus for monitoring. Monitoring should reveal whether the MSCP is meeting these overarching goals and ultimately provide ongoing information to assist in management decisions. As resources are too limited to monitor all covered species and communities, species and communities must be prioritized for monitoring. This was the subject of two previous reports (Regan et al. 2006 and Franklin et al. 2006). A prioritization scheme based on risk was applied to species, whereas communities and vegetation types were prioritized based on representation and risk.

Once species and communities are prioritized, species- or community-specific management goals and objectives for these elements should be defined. For instance, if a species-specific goal of the MSCP is to preserve all the main populations of *Ambrosia pumila* then this should be stated. This step is crucial in ensuring that the correct monitoring elements are identified to measure whether this goal is being met. For some species these goals have been articulated in Table 3-5 of the MSCP Plan (Ogden Environmental 1998). However, they should be revisited and modified where necessary to provide a clear relationship with monitoring and management outcomes. Ideally, the species- and community-specific goals will reflect these elements' contributions to achieving the overarching MSCP goals through management and monitoring.

Along with these goals and objectives, the planning partners should identify management decision criteria. These would include such things as implementing management actions when invasive species cover reaches a specified level or when a population declines below a specified level. Management decision criteria do not have to be strict thresholds or triggers. They are intended to provide guidance on when to implement management and they should reflect the species- and community-specific goals and objectives. Note that management decision criteria and, in turn, goals and objectives for monitoring, can and should be updated as the knowledge base is updated with new information derived through monitoring and subsequent data analysis.

Once species- or community-level goals and objectives have been defined, conceptual models can be developed. Conceptual models document the current state of knowledge of the system as it pertains to species- and community-specific goals, and they highlight the main drivers

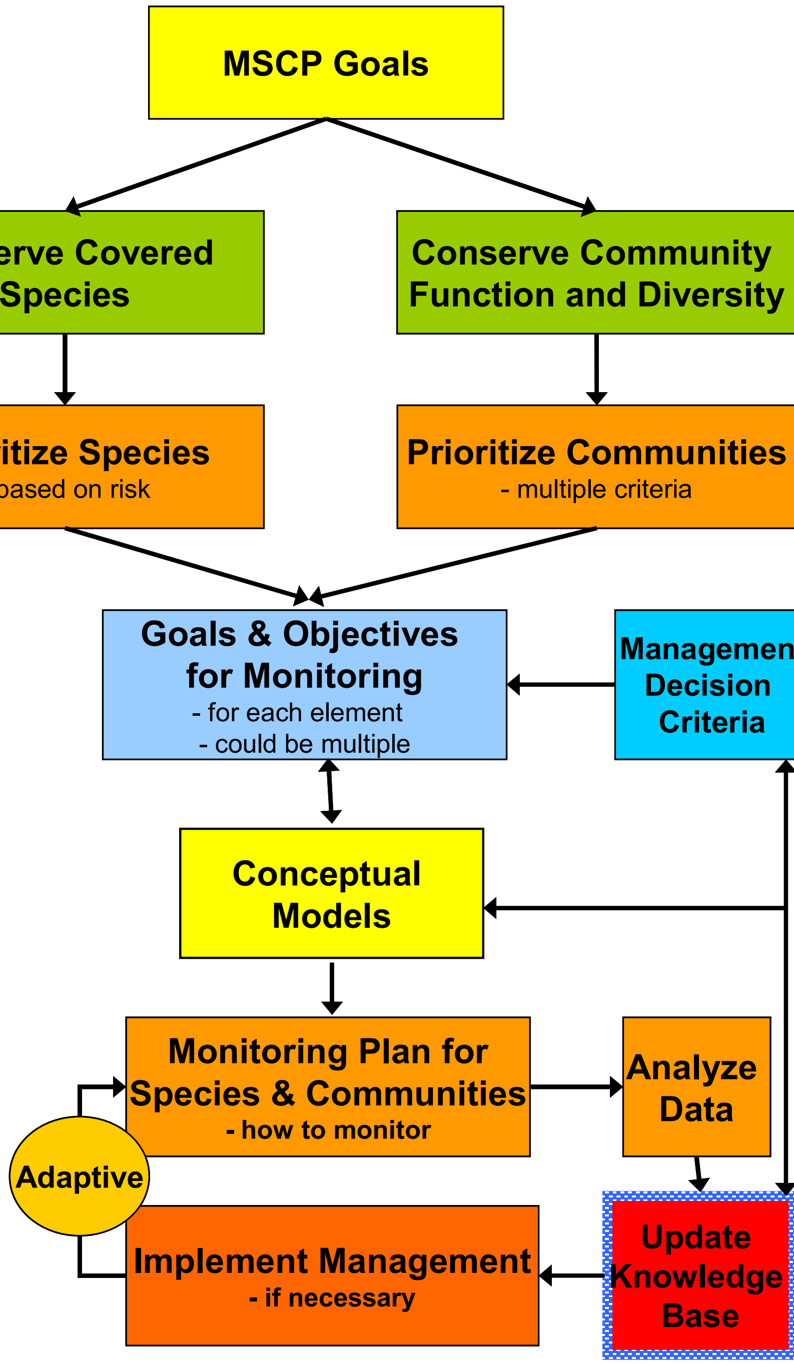

Figure 1. Flow diagram of where conceptual model development fits into a conservation program's monitoring plan design process.

affecting the status and trends of the species or community. The model development process can help identify the factors that impact the species/community, and the components that should be monitored directly to assess its status. For example, by identifying invasive species and trampling as the major threats to *Ambrosia pumila* (see Section 4.1), monitoring recommendations can target demographic parameters of the species, invasive cover and trampling intensity. Conceptual models should also highlight the data gaps that are necessary to fill in order to gauge whether species- and community-specific goals and objectives are being met. They also assist in the formulation of hypotheses that can be tested through monitoring. Experimental design and statistical theory can then be applied to provide a strategy for monitoring the components highlighted through the conceptual model. Ideally, an adaptive management framework will include aspects of monitoring that can gauge the effectiveness of management actions.

Ultimately, the conceptual model helps managers document their understanding of the system in a comprehensive way that can be examined and agreed upon by the involved stakeholders. The model can help these managers identify *what* to monitor, and lead directly to the development of a monitoring program for that species or community of concern. We also emphasize that the development of the monitoring program must include a serious commitment to data analysis. This serves a number of important purposes: it increases the quality of the knowledge base used to determine if conservation goals are being met, it provides information on which to base management decisions, it can provide input leading to revisions of management decision criteria, it can be used to update aspects of the monitoring design, and it can provide information that can improve the structure of the conceptual model which can lead to revisions in recommendations for monitoring components. It should also be noted that new information derived through monitoring can be used to update the species and community prioritizations (although this is not highlighted with arrows in Figure 1). In this way, monitoring serves as the link between management and learning—it is the essential ingredient of any adaptive management plan.

3. Designing models

Conceptual models need to be constrained by the types of questions they intend to answer. They should be sufficiently detailed to provide answers to relevant questions, and no more detailed (Burgman 2005). For some purposes, complex conceptual models with many components may be desirable. For instance, a fault tree for the Space Shuttle is detailed because the overriding question is “what can cause failure?” (Seife 2003). Since failure can occur from many sources including a faulty O-ring, a bolt snapping, or foam insulation flying off, the conceptual failure model needs to incorporate the level of detail that represents those components. In this well-studied system the causal mechanisms are well understood and the level of detail required to represent potential sources of failure is high, so a complex model is justified and useful.

Since conceptual models for ecological systems are representations of our collective knowledge of how the natural world works, and the natural world is complex, variable, and contingent on a multitude of inter-connecting factors, there can be a tendency to create highly complex models (Abrams et al. 1996). This is particularly the case when there is a desire to include the opinions and expertise of multiple stakeholders and experts who come to the table with different experiences and perspectives. However, in designing conceptual models for monitoring ecological systems, less is more. In this case, complex models are unjustified and unwarranted for two main reasons. The first is uncertainty. As more components and detail are added to the model, more data is required to faithfully represent those components and their role in the ecological system. Often this data is lacking. For instance, it may be suspected that density dependence plays some role in the population dynamics (which in turn dictates the status and trend) of a covered plant species, but the form of the density dependence is completely unknown and its importance is doubted. Including this component in the conceptual model does not help in representing what we know about the system for the purposes of management. And once such a component is included in a model the danger exists that it will be treated as an addition for which we are certain. If, on the other hand, it is believed that data collection on density dependence would be crucial for guiding successful management of the species then including such a component in the conceptual model would be useful and warranted, provided the uncertainty is reported. Note that this second case is based on some established knowledge of the importance of density dependence in managing the species, whereas the first case is devoid of this knowledge.

In constructing any model there is always a trade-off between complexity (or realism) and uncertainty (Bartell et al. 2003, Regan et al. 2002). In data poor situations, where we are trying to represent the current state of knowledge of the system, parsimonious models supported by data are always preferable to complex models based on conjecture and supposition. Furthermore, there is a significant risk that additional errors can be introduced when adding complexity to a model for which there is insufficient data or knowledge.

The second argument for opting for parsimonious models is that, given constraints on resources, it will be impossible to monitor everything. Constructing highly complex conceptual models makes the task of selecting monitoring components overly onerous—it obscures the forest for the trees. It is easier to prioritize among a few key features than it is to wade through hundreds of potential monitoring components, all of which may contribute to the functioning of the system in different ways and to different degrees. Groups should decide on the overarching features that dictate management of the system, keeping in mind that it will only be feasible to monitor a small subset of these. It is more important to faithfully and carefully represent a few important overarching mechanisms that we are sure of than it is to include all the possible interacting factors for which we are uncertain and can't possibly monitor due to resource constraints. In the case studies below we present a general strategy for constructing conceptual models that balances parsimony and the level of detail necessary to address the monitoring and management goals of the MSCP in the face of uncertainty.

4. Case studies

4.1 *Ambrosia pumila*

To illustrate the recommended approach to developing conceptual models for covered species in the MSCP, we first chose *Ambrosia pumila*. This rare plant species was the focus of a draft conservation plan in the recent report on review and revision of the MSCP's rare plant monitoring program (McEachern et al. 2006). It was used as an illustrative case study of an adaptive management conservation plan. As such, a conceptual model was embedded in this draft plan in text form. We have interpreted and made it explicit and graphical, and use it to illustrate the structure we recommend for conceptual models in this context, and the elements they should contain. It was straightforward to develop a conceptual model for this species given that the draft plan explicitly defined a management goal and linked monitoring to management (what they called "effectiveness monitoring").

Our first draft of a conceptual model is shown in Figure 2. It is organized with the conservation management goal at the top. Anthropogenic threats are aligned on the left side of the figure, and natural drivers of population change along the top. The green ellipse represents the target species and the boxes within it are the variables associated with that species that should be monitored in order to evaluate if the goal is met and also response to management (effectiveness monitoring). All boxes outlined in blue indicate variables that need to be measured during monitoring, and include both species and environmental attributes (natural and/or anthropogenic). The gray box in the lower right describes potential management activities or tools, and the letters indicate which process in the diagram each activity would affect. For this particular species we distinguished between current anthropogenic threats, which may potentially be mitigated by management tools, versus historical threats, things that already happened that contributed to the rarity or endangered status of the species.

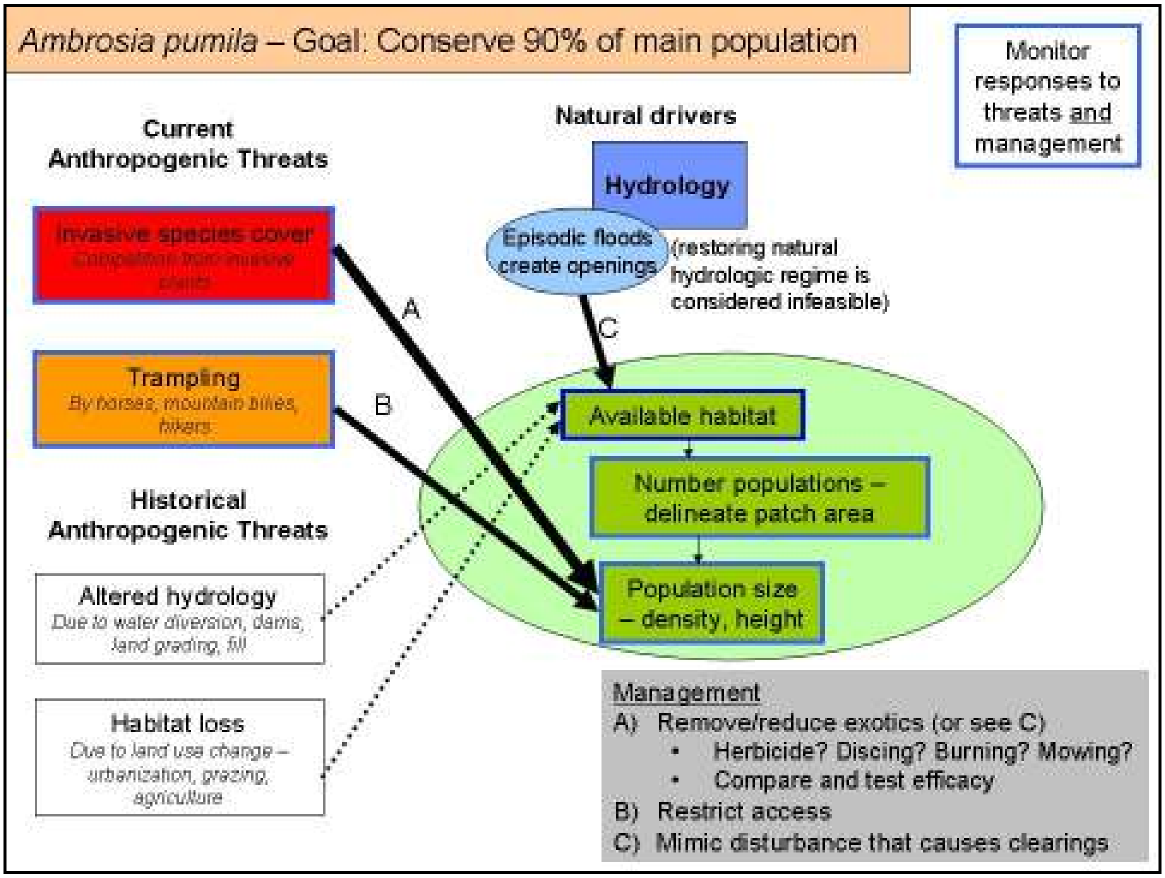

Figure 2. Conceptual model for *Ambrosia pumila*; first draft.

When this model was reviewed in a workshop comprising MSCP monitoring partners (attendees listed in Appendix A), the following comments were made. In practice conceptual models will be developed in an iterative fashion, so we have interspersed our responses to these comments where appropriate.

- General agreement that this model captured most of the important drivers and threats to this species
- <u>Trampling</u> is not always bad for this species
    - "…trampling and soil compaction by humans, vehicles and horses" was cited in the draft management plan (McEachern et al. 2006, p. 90) as a threat, so we did not change this part of the conceptual model.
- The plant sometimes occurs on slopes and sediment-affected upslope areas in addition to floodplains
    - While we agree that the conceptual model emphasizes open habitat created by flooding, we think that the species-associated variable "Available Habitat" is general enough to encompass upland sites where the species occurs.
- Add a <u>Demographics</u> box
    - We have added this issue to our key uncertainties below, but have not added a Demographics box to the model because the draft management plan did not include this as a key management question for the MSCP.

- Should seed viability be included/studied further
    - Perhaps, so we have added this to the key uncertainties listed below, but since the draft management plan concluded that this is not a key management question for the MSCP goals, we did not include it in this model.
- Mowing as a management option appeared to be successful in one area it has been used
    - This is a helpful comment because it provides support for the conceptual model.
- Goal needs improving – suggestion was made to keep 'Conserve 90% of main population' as "Legal Requirement" but add a better-defined "Goal", which should be expanded to cover all populations. Another comment noted that altering the goals should be done cautiously as this can have large implications for the monitoring partners.
    - Interestingly, our original interpretation of the goal for this species, based on the overall goal of the MSCP, was simply "maintain existing populations." We then changed that to the goal stated in Table 3-5 of the MSCP Plan (Ogden Environmental 1998), "conserve 90% of the main (Mission Trails) population" because of the legal (regulatory) status of that document. However, upon revisiting this issue, we note that McEachern et al. (2006) stated the MSCP-wide goal for this covered species as "enhance all eight existing management units (MU): increase numbers of ramets within each MU and increase spatial extent; population resilience in the face of stochasticity, persistence over many years." Assuming the recommendations of that report are adopted, then the conceptual model should be modified to reflect this revised goal. Further, the revised goal states specifically that the number of ramets (density of individuals) and spatial extent of the patch should increase, with an objective of >1000 ramets per MU. This leads us to refine the population variables to be monitored to population density (within patches) and size of patches. The draft plan goes on to define specific objectives for each management unit, but this step comes after conceptual model development. We have simply chosen a covered species to illustrate our approach to conceptual modeling that has already received considerable attention regarding specific details of its conservation plan.

Not mentioned in the workshop, but something else that we noted, is that the draft conservation plan suggests transplanting as a management tool, and so it has been added to the revised conceptual model. Figure 3 shows a second iteration of the conceptual model. We use these case studies to illustrate that the development of conceptual models is embedded in the process of designing habitat reserves and their monitoring programs and should be iterative (Section 2).

Key Uncertainties:

- Is trampling good or bad for the species?
- What role do major disturbance events play in the species' persistence?
- Does this plant reproduce via seed? Are there other demographic issues of concern?
- Will genetic mixing be an issue if the species is transplanted?

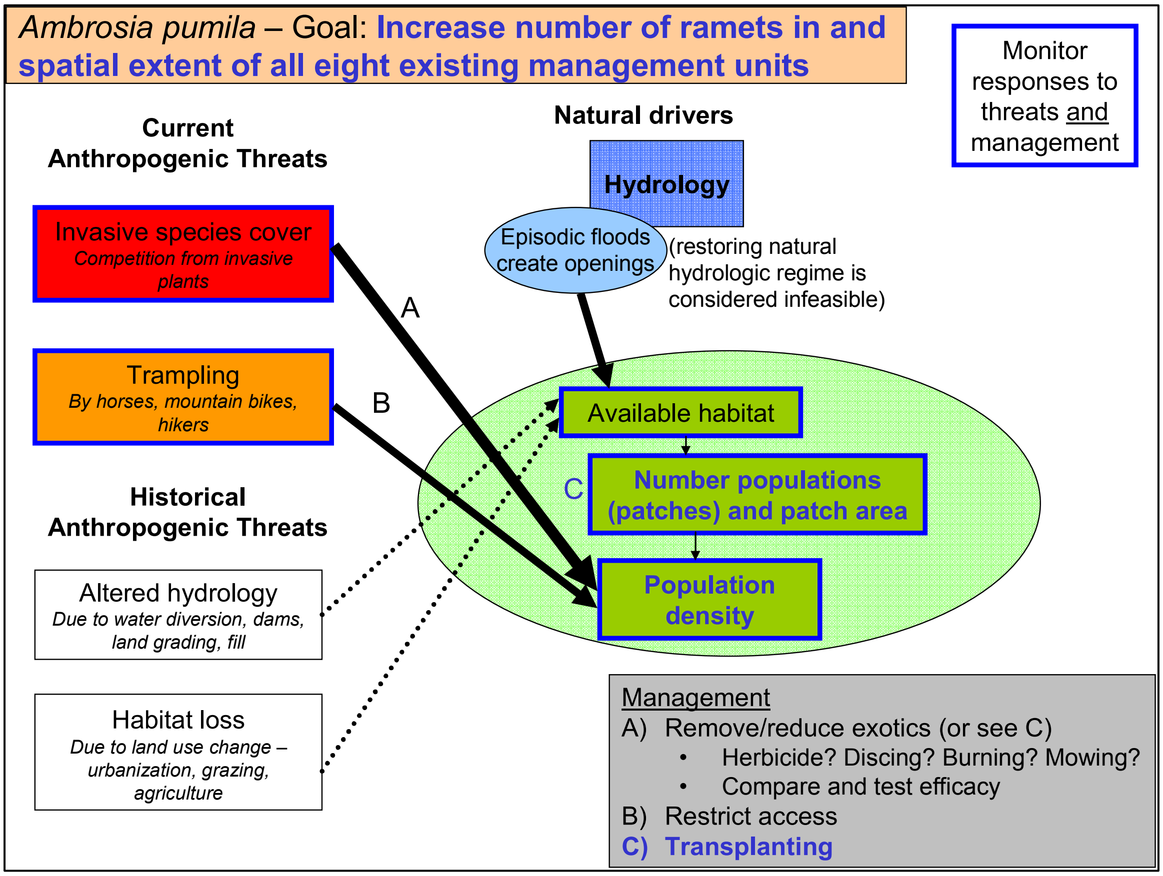

Figure 3. Conceptual model for *Ambrosia pumila*; revised. Revisions to text are shown in blue.

Finally, while conceptual models should identify what variables need to be monitored, they should guide but do not fully define how they should be monitored (sampling design and measurement protocols). We illustrate this using the following example. As shown in Figure 4, even within the main population *A. pumila* is interspersed with exotic grasses. With the specific management objective that "the number of ramets (density of individuals) and spatial extent of the patch, should increase," monitoring methods must be capable of not only measuring plant density (as in the lower right) but also patch extent (upper right).

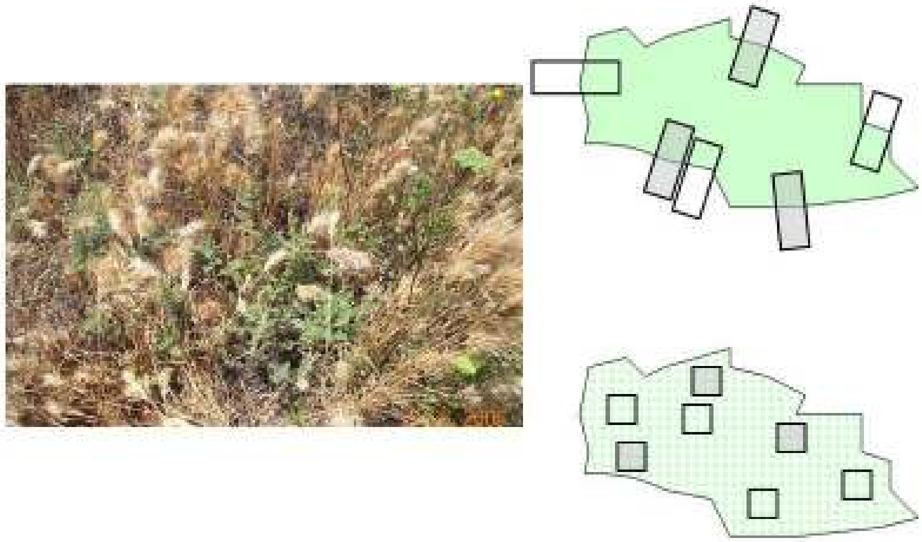

Figure 4. Left: photo (by J. Franklin) of *A. pumila* at Mission Trails Regional Park (May 2006) showing interspersed nature of target species and exotic grasses. Lower right: typical sample design for measuring plant density in treatment (gray) versus control (open) plots (boxes). Upper right: sample plots placed randomly along patch boundary, again treatment (gray) versus control (open) plots, allowing changes in patch extent (boundary) to be monitored.

See Section 6: Literature Cited for list of sources used in development of *Ambrosia pumila* model.

4.2 California gnatcatcher (*Polioptila californica californica*)

To further illustrate our recommended approach for developing conceptual models for covered species in the MSCP, we chose the California gnatcatcher (*Polioptila californica californica*), a small songbird. This is a flagship vertebrate species around which much of the MSCP conservation was based, and has benefited from several years of regional monitoring. This model was developed through several iterations with the collaboration of a species expert, Clark Winchell from the U. S. Fish and Wildlife Service, who has been studying and monitoring this species for years.

Our first draft of a conceptual model for the gnatcatcher is shown in Figure 5. As with the *Ambrosia pumila* model, it contains a conservation management goal at the top. Anthropogenic threats are listed on the left side of the figure, and natural drivers of population change are presented in the middle. The green ellipse represents the target species and its habitat needs, and the boxes within it are the variables associated with that species that should be monitored in order to evaluate if the goal being met and to assess responses to management (effectiveness monitoring). All boxes outlined in blue are variables that should be monitored directly, and include both species and environmental attributes (natural and/or anthropogenic). The gray box in the lower right describes potential management activities, and the letters indicate which process, represented in the diagram, each activity would affect. We distinguish between current anthropogenic threats, which may potentially be mitigated by management tools, versus historical threats, which contributed to the rarity or endangered status of the species.

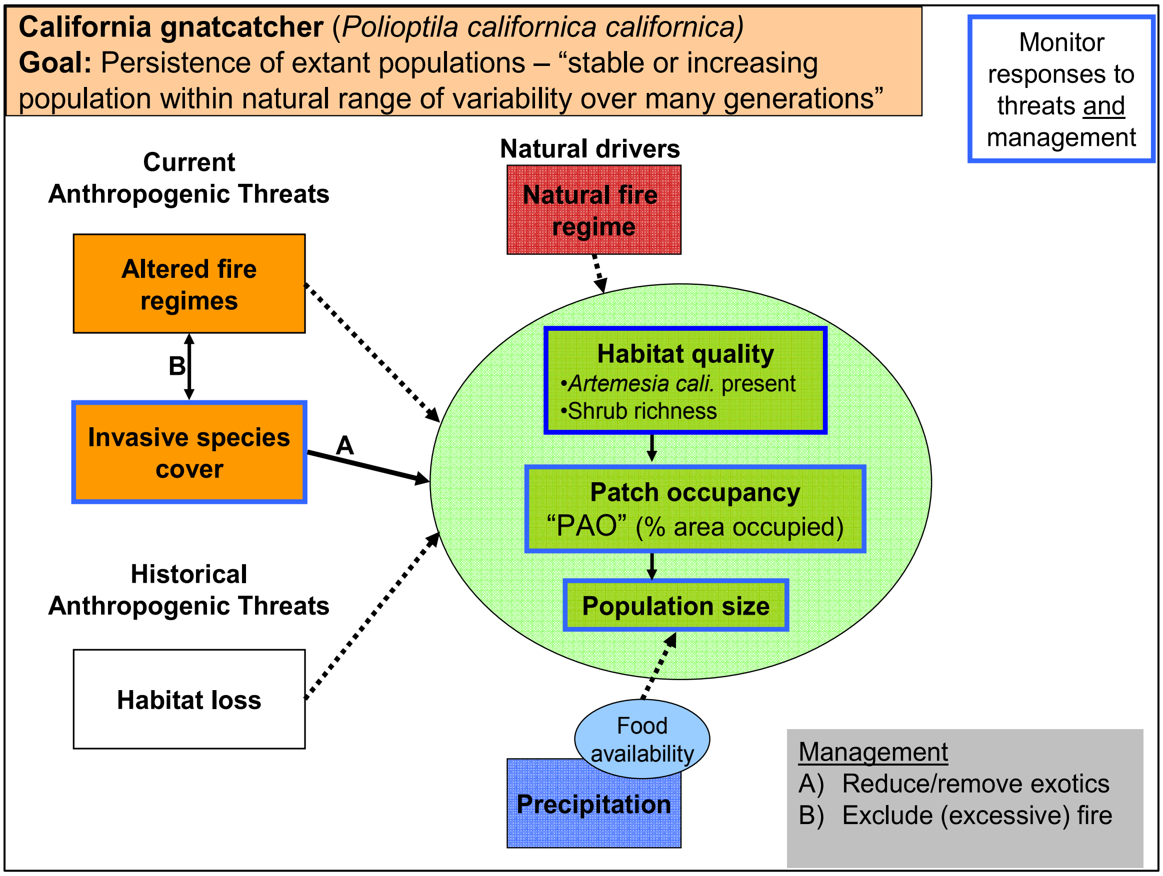

Figure 5. Conceptual model for the California gnatcatcher, *Polioptila californica californica*; first draft.

When this model was reviewed in a workshop comprising MSCP monitoring partners, the following comments were made. We have interspersed our responses to these comments.

- Many refinements were suggested for the Habitat Quality box, including: shrub height, shrub density, low to moderate slopes, coastal influence, low presence of non-native grasses; factors positively associated with habitat quality included – presence of *Artemesia*, buckwheat, *Viguiera*, broom baccharis, cholla cactus, negative factors included – increased presence of Malosma, Rhus, toyon, steep slopes, cowbirds, boulders
    - We acknowledge that presence of *Artemesia californica* and shrub richness are two of many potential variables that could be measured to assess "Habitat Quality" for gnatcatchers. However, these two variables were found to be the most significantly associated with gnatcatcher presence in a study by Winchell et al. (2006).
- Add Patch Size (and/or Fragmentation and/or Connectivity) box(es) with arrows to Habitat Quality box

  - Winchell et al. (2006) study did not find that Patch Size improved their model predicting gnatcatcher presence, so we have not added a box for this. However, we have added this issue to our list of key uncertainties below.
- Excluding fire as a management option isn't realistic, though perhaps frequency could be decreased through some management activities
  - We altered the wording to be more explicit that fire would be excluded to the extent possible.
- Add a box for Predation (some anthropogenically-driven (cats) and some natural (snakes))
  - We have added a box for Predation under current anthropogenic threats.
- Do we know the natural range of variability of the population, or would this need to be established with monitoring; is the population variability so extreme it would mask any trends?
  - We have added this to the uncertainties below, but recognize that continued monitoring of the species' population will help answer this question.
- Is the Patch Occupancy box a population parameter or a monitoring protocol
  - We maintained the Patch Occupancy box but removed the specific mention of the measurement "% Area Occupied".
- Temperature and moisture were noted to affect reproduction
  - We believe this dynamic is captured in the Precipitation box, which affects food supply and population size. However, we added this issue to the critical uncertainties.
- Questions raised of what the "natural" versus "altered" fire regime might be
  - We removed references to a natural versus altered fire regime and added boxes for fire management and human ignitions, which affect the fire regime, which in turn affects the CSS habitat used by gnatcatchers.

Key uncertainties:

- Is fragmentation, patch size, or connectivity an issue for this species' persistence?

- What is the mortality rate of gnatcatchers? Is this important to measure?

- What is the natural range of variability of the species? Is long-term monitoring going to be able to detect a trend or will large variability mask any trends?

- How do temperature and moisture affect reproduction?

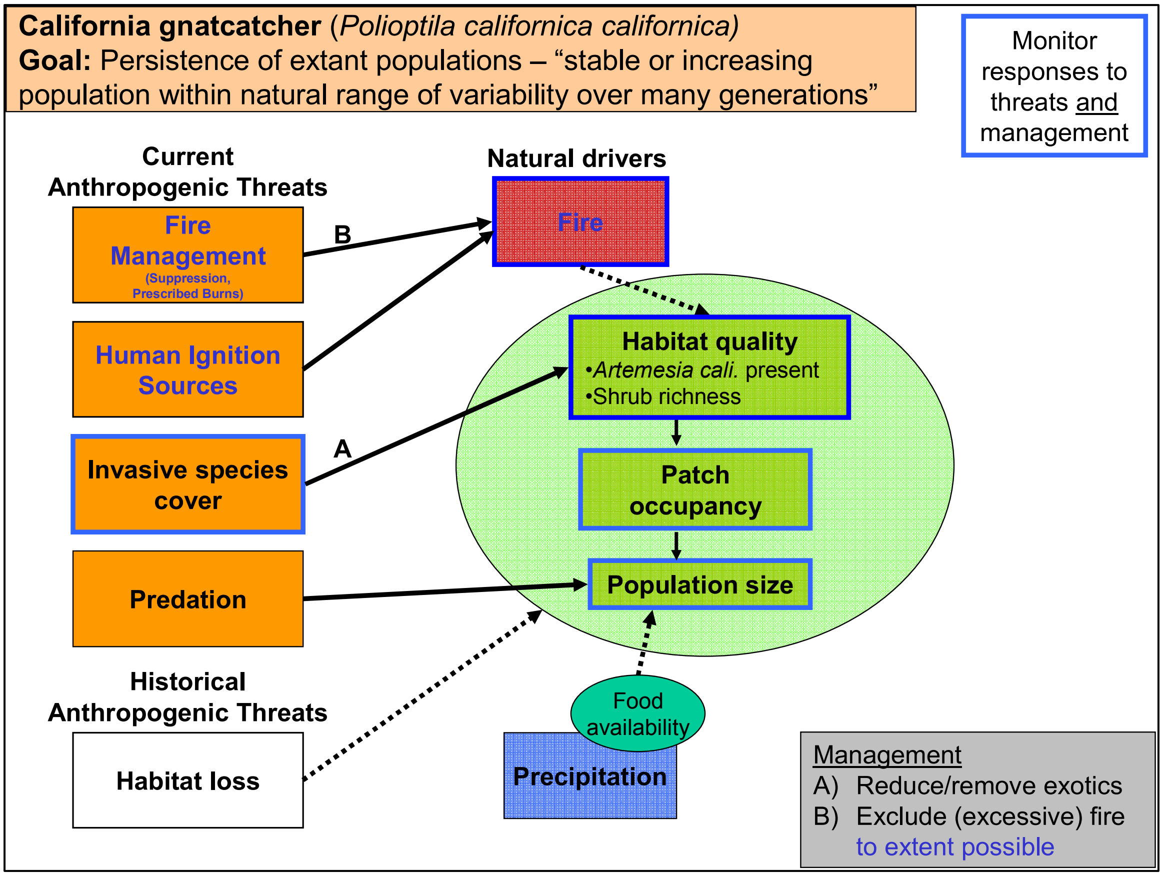

Figure 6. Conceptual model for the California gnatcatcher, *Polioptila californica californica*; revised. Revisions to text are shown in blue.

As stated in the previous section, this model helps identify which variables need to be monitored, but does not define specifically how they should be monitored (i.e., sampling design and measurement protocols). This next step needs to be made by the monitoring partners, and is underway with a Local Assistance Grant project to develop fauna monitoring protocols that was initiated in October 2006.

4.3 Coastal sage scrub plant community

We next applied our framework for building conceptual models to the coastal sage scrub vegetation community. This community has been a focus of MSCP conservation activities and provides habitat for many covered species.

Our first draft of a conceptual model for the coastal sage scrub community is shown in Figure 7. As with the species models, it contains a conservation management goal at the top and anthropogenic threats listed on the left side of the figure. Natural drivers of change in the community are presented down the middle. The green ellipse represents the dynamic between native CSS plants and exotics, and soils that mediate that dynamic. In the first draft we had not selected which features should be monitored (indicated by boxes outlined in blue), but the revised version has monitoring targets identified. The gray box in the lower right describes potential management activities.

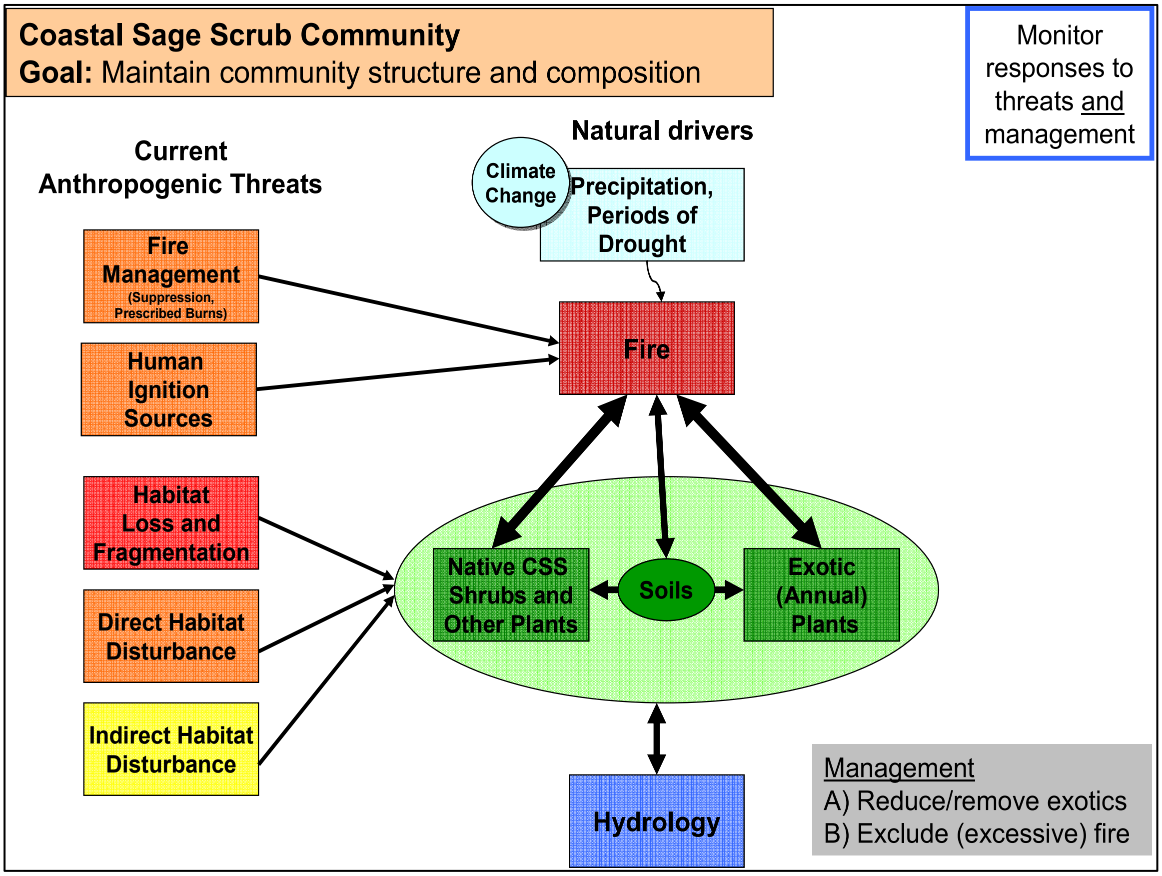

Figure 7. Conceptual model for the coastal sage scrub plant community; first draft.

When this model was reviewed in a workshop comprising MSCP monitoring partners, the following comments were made. We have interspersed our responses to these comments.

- Questions were raised regarding the Goal – does "maintain community structure" mean current structure, heterogeneous structures, or some "ideal" structure? For what species (open vs dense structure affects different animal species differently)? Is it limited to flora? Suggestion to include plants, animals, and insects.
  - We have added the word 'dynamic', but are otherwise keeping the goal as is. We believe that in order to meet the overall MSCP goal of "maintaining ecosystem function and diversity" (Ogden Environmental 1998) we need to make the community monitoring goals feasible to measure in the field. Community structure and composition, which should reflect the functioning and diversity of the community, meet this criteria.
- Should management be undertaken to favor covered species rather than relying on fire?
  - The goal of the community monitoring is separate from that of covered species monitoring, which could include monitoring and managing CSS as habitat for a particular species. In that case, a monitoring and management plan would be

    developed specifically for the individual species. For community-level monitoring and management it would be difficult to select which species to manage the community for, particularly since covered species may have conflicting habitat requirements.

- Add box for Roads
    - We did not identify this as a primary driver in the CSS community based on the literature so did not add it to the revised model. This threat could also be considered part of the "habitat fragmentation" box already included in the revised model.
- First season reproduction following disturbance (fire) is most affected by precipitation levels and timing (month it occurs) – monitoring first year post-fire is likely to be important
    - We added a box to the revised model to highlight the potential importance of monitoring the first year post-fire.
- Include both exotic annual and exotic perennial plants
    - We changed the 'exotic annual plants' box to 'exotic plants' to include all types.
- Include altered soil nutrients (nitrogen, carbon) from roads, power plants, and fire
    - As we have not found studies that identify this as an important issue in San Diego's CSS, we did not add a box to the revised model, but added this issue to our list of key uncertainties below.
- Excluding fire is unrealistic, and what fire regime are we trying to maintain, though others noted that some management might be done to prevent very frequent fires
    - We altered the wording to be more explicit that fire would be excluded to the extent possible.

Key Uncertainties:

- Can we uniquely define a few CSS associations in the MSCP or are the communities more heterogeneous and grade into each other?

- Are altered soil nutrients affecting the CSS vegetation community?

- Are herbivory and granivory also significant drivers in this community?

- How much impact do burrowing animals have on the system, e.g., by shaping the soil structure?

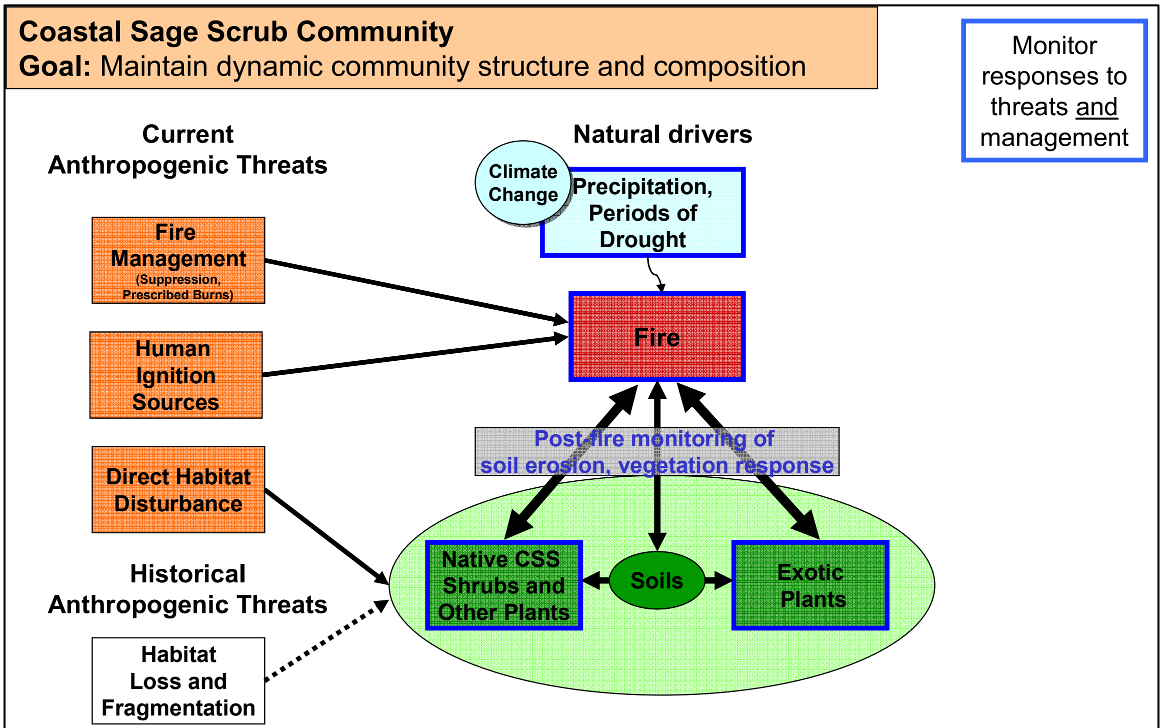

Figure 8. Conceptual model for the Coastal Sage Scrub plant
Revisions to text are shown in blue.

Sources used to develop coastal sage scrub community model

A technical report entitled "Coastal Sage Scrub response to disturbance. A literature review and annotated bibliography," prepared by Dr. Jay Diffendorfer et al. (1992) for California Department of Fish and Game, was instrumental in developing this model. It is comprehensive and organized according to types of threats as they affect major animal groups, as well as plants, in the CSS ecological community. In addition, the following references pertain directly to the effects of threats and disturbances to plant community composition and structure.

- **Fire Management** – Axelrod 1978; Dodge 1975; Keeley 2002; Wells et al. 2004; Zedler 1995; Zedler et al. 1983

- **Fire Regime** – Callaway and Davis 1993; Cuddington & Hastings 2004; D'Antonio & Vitousek 1992; Diaz-Delgado et al. 2002; Eliason & Allen 1997; Giessow 1997; Haidinger & Keeley 1993; Keeley 1990, 1993, 2001; Keeley et al. 2005; Keeley & Keeley 1984; Mack & D'Antonio 1998; Malanson & Westman 1985; O'Leary 1988, 1990, 1995; O'Leary & Westman 1988; Rundel & King 2001; Westman 1981a,b; White 1995; Zedler 1995; Zedler et al. 1983

- **Habitat Loss and Fragmentation** – Alberts et al. 1993; Escofet & Espejel 1999; Holway 2005; Leyva et al. 2006; O'Leary 1990, 1995; Zedler 1988

- **Direct Habitat Disturbance -** Axelrod 1978; Callaway and Davis 1993; Davis 1994; Dodge 1975; McBride 1974; Mensing 1998; Minnich 1982; O'Leary 1995; Van Vuren & Coblentz 1987; Westman 1981; Witztum & Stow 2004; Zedler 1981; Zink et al. 1995

- **Exotics** – Beyers 2004; Eliason & Allen 1997; Lambrinos 2000; Randall et al. 1998; Rundel 2000; Sax 2002

- **Management** – Allen et al. 2005; Beyers 2004; Cione et al. 2002; Keeley 2002, 2006; Moyes et al. 2005

See Section 6: Literature Cited for full citations.

4.4 Landscape Model – Upland Shrub Communities

While in a previous report (Franklin et al. 2006) we rejected the notion of the community assemblage as a level of ecological organization (between the community and the landscape), we acknowledge that a natural division exists between upland and riparian/aquatic/wetland habitats in their spatial location and extent in the reserve and in the processes that govern their dynamics. We focus this landscape model on the most extensive upland habitats that are linked by pattern and process. Coastal Sage Scrub, Chaparral and Grassland make up 80% of the MSCP (Figure 9). Other upland communities are defined on the basis of indicator species that are also covered species (Torrey pine, Tecate cypress) and occur in a matrix of shrublands (Franklin et al. 2006). CSS is the "flagship" community defining the southern California Natural Community Conservation Planning process (State of California 1993). While direct habitat loss has affected all native vegetation types in southern California, coastal sage scrub species have been disproportionately impacted due to their spatial coexistence with urban development patterns (O'Leary 1995).

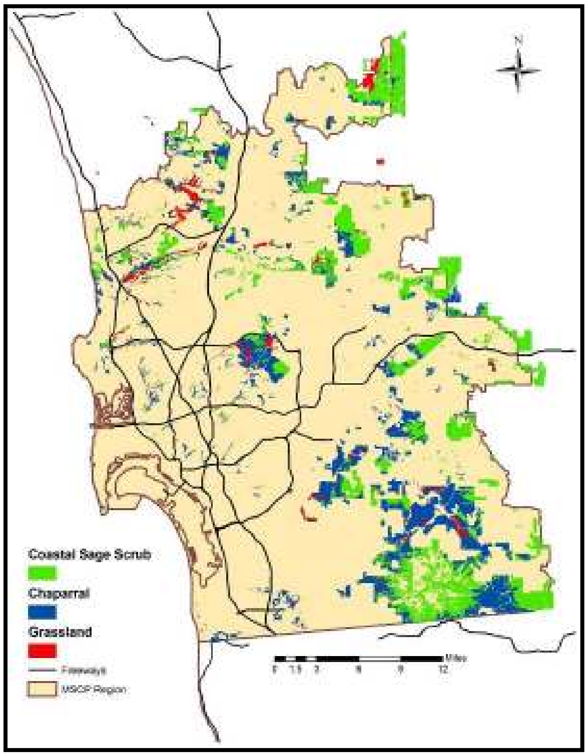

Figure 9. Distribution of Coastal Sage Scrub, Chaparral and Grassland within the MSCP.

We focus the landscape model on these extensive communities because of how they are linked by landscape-scale processes, especially fire and exotic species spread.

Background

The following literature review describes the state of scientific knowledge about the current threats to community composition and structure in the shrublands that dominate the upland MSCP. The following is paraphrased from Syphard et al. (2006):

- While land use change historically reduced the extent of Southern California's native habitats, currently indirect effects of human population expansion, including altered fire regimes and biological invasions, are becoming serious threats (Rundel and King 2001).
- Although chaparral is resilient to a range of fire return intervals (ranging from 20 to 150 years), unnaturally short time periods between fires (less than 15 years) are starting to threaten the persistence of some shrubs (Keeley 1981, Haidinger and Keeley 1993).
- The introduction and spread of non-native species, particularly annual grasses, threatens native vegetation in southern California. Exotic grasses are successful invaders of disturbed areas and typically spread from residential areas, roads, or areas cleared for fuel breaks (Rundel 2000, Beyers 2004).
- Grasses sustain high fire frequencies and can even promote fire, which in turn can lead to positive feedbacks in which fire opens up the vegetative canopy and allows the introduction of the grasses that continue to facilitate more fire and canopy opening (Mack and D'Antonio 1998).

- Eventually fire frequency exceeds that to which native species are adapted, resulting in a type conversion from native shrubland to exotic grassland (Zedler et al.1983, Haidinger and Keeley 1993, Minnich and Dezzani 1998).
- Although they were initially introduced during European colonization, these grasses have proliferated exponentially in the last century, paralleling human population growth and increased fire frequency (Randall et al. 1998).

A recent article published by Jon Keeley (2006) further elaborates on the relationship between fire, exotics and plant community resilience:

- Type conversion to alien grasslands is happening at an alarming rate in all of the lower-elevation foothills in southern California (p. 379), including in chaparral and coastal sage shrublands. Alien invasion has historically been exacerbated by fire management practices that included prescription burning for range improvement. *Bromus madritensis* L.*, B. hordeaceous* L.*,* and *B. diandrus* Roth., and forbs such as *Erodium cicutarium* (L.) L'Her., rapidly expanded to fill the void created by removing native shrubs (Keeley 1990, 2001, 2004).

- Typically a repeat fire within the first postfire decade is sufficient to provide an initial foothold for aliens. With the first entry of alien annuals into these shrubland ecosystems, there is a potential shift from a crown-fire regime to a mixture of surface and crown fires.

- As fire frequency increases there is a threshold beyond which the native shrub cover cannot recover (Zedler et al. 1983; Haidinger & Keeley 1993; Jacobson et al. 2004).

- In these shrublands and in other ecosystems, alien grasses alter fire regimes in ways that enhance their own success, in what has been described as a "grass/fire cycle" (D'Antonio & Vitousek 1992), "niche construction" (Keeley 2001), or "invasive engineering" (Cuddington & Hastings 2004).

- Current infestations of annual grasses in both regions require enhanced efforts at fire prevention, fire suppression, and avoidance of prescribed burning under many situations. (p. 382)

Based on this review of the literature we proposed the conceptual model shown in Figure 10. It was different in graphical form from the previous examples because, based on a published model of arid lands degradation (Schlesinger et al. 1990) we wanted to show that anthropogenic threats (the weights on the right side of the triangle) could reach some threshold level and tip the triangle towards the right corner – a type conversion (state change) to exotic grassland. We also wanted to show that, while the three plant communities are usually found, and always mapped, as discrete entities on the landscape, they in fact can grade into one another at their ecotones (intermediate positions on the environmental gradient) in terms of species composition (what species are present, and their abundance), and that shifts from chaparral to CSS, from chaparral to grassland, and from CSS to grassland, in response to extremely high fire frequency, have all been documented.

Further, while the MSCP defines some landscape-level goals including preserving landscape linkages, it only provided the general goal of "conserving the diversity and function of the ecosystem" (Ogden Environmental 1998). Therefore we developed the landscape goal based on our interpretation of the literature regarding threats to community composition and structure.

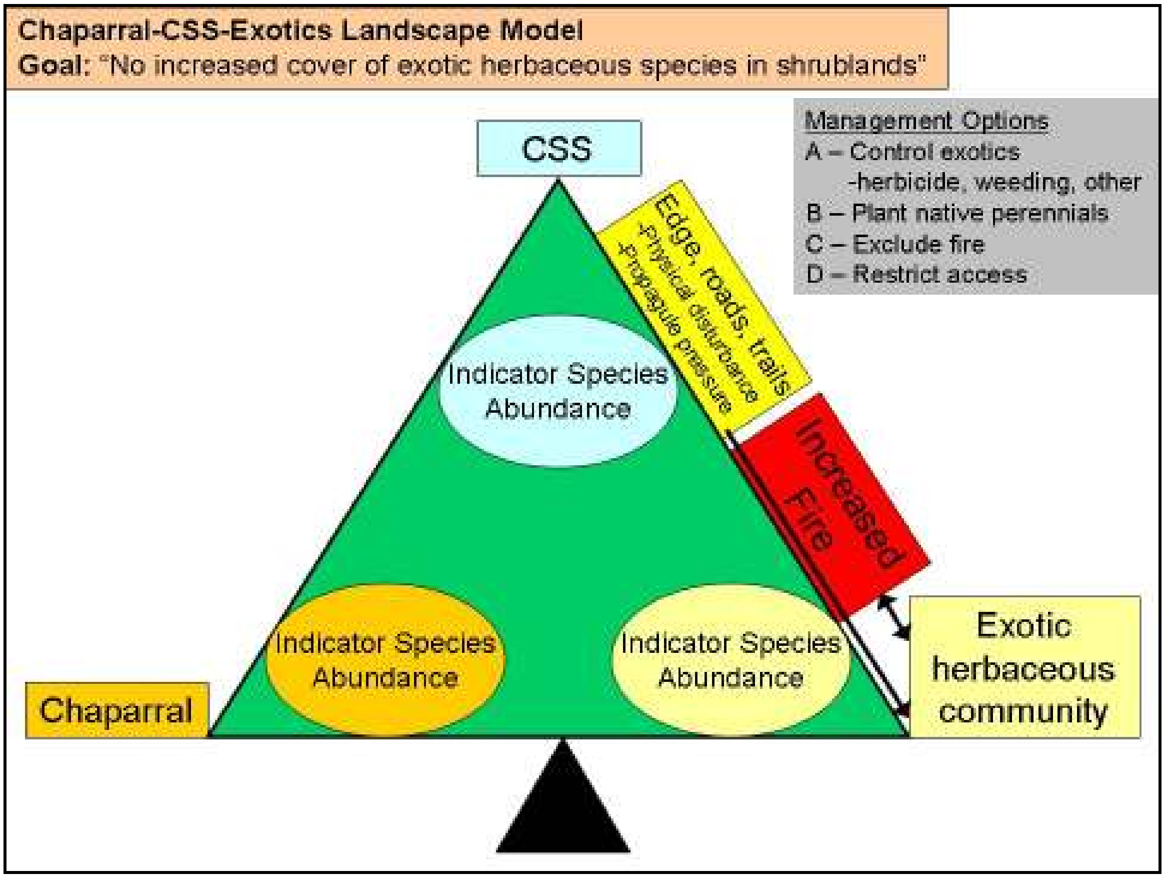

Figure 10. Landscape conceptual model, first draft.

Comments made in the workshop on this landscape conceptual model and responses:

- Redefine the Goal – question of whether the goal suggests that exotic communities are an end state you are trying to avoid? Suggestion to include all exotic species in goal. One suggested wording: "reduce exotic cover and enhance native species", and an alternate suggestion of: "maintain succession and processes on the landscape" – i.e., want to have all three native communities at the end of the day
  - We have restructured the model entirely so that its graphical structure is similar to the other models we have presented. The monitoring targets are now defined as three native plant communities, two dominated by shrubs (CSS and chaparral) and one dominated by herbaceous plants (e.g., "native grassland"). The goal has been restated as: "No increased cover of exotic herbaceous species in native-dominated plant communities." This could be further refined to acknowledge that these three native communities have some natural range of variability in species composition and structure, and are temporally dynamic.

- Question of where native grasslands fit into this model?
  - They are now incorporated into the model.
- Recommendation to redesign the model – perhaps as a teeter-totter between native CSS, chaparral, grassland vs. non-native – current design leaves out native grassland and seems to be trying to do too much
  - As noted, we have completely redesigned it, using the same structure as was used for the other case studies, and abandoning the fulcrum metaphor, although we were fond of it.
- Regarding fire management, noted that some sites may need to burn
  - The revised model tries to acknowledge the explicit effect of the fire regime on the natural dynamics of the communities, and specify that in recent decades humans mainly affect the fire regime through increased ignitions in the coastal region where the MSCP is located. Implicit (but not explicit) is the negative effect of reduced fire frequency (for example in isolated urban canyons) on community dynamics. This is an area where the model could be improved.
- Questioned what indicators to measure and at what scale?
  - The model suggests that the indicators are those species that define the community. 'Indicator species' has a formal definition and indicators can be analytically defined as those species that are always found in a community and hardly ever in other communities.
- Management suggestion to educate public on weed-free seed
  - Need more information on these management responses in order to include them. Educate public about what? Weed-free seed for what? For reestablishing native perennials?
- Management option of planting native perennials was noted to be contingent on site-specific history and reference sites
  - Should we make this more general? "Site restoration"?
- Questioned whether transitions between CSS and chaparral are important to monitor
  - See response to first comment. This could be further refined to acknowledge that these three native communities are temporally dynamic encompassing some natural range of variability in species composition and structure within and between communities. We think these transitions are important to monitor because the distribution of habitats within the MSCP may not be static and in the long run this is important to know.

Key Uncertainties:

- How important are edge effects?
- How can disturbance be measured?

The following revised model emphasizes that historical threats to these upland communities include habitat loss (land conversion for urban and crop agricultural use) and grazing (a more extensive form of agricultural land use). Current threats are increased anthropogenic fire in some parts of the landscape and "edge effects" of habitat fragmentation including both physical disturbance and propagule pressure from exotic species. Both of these current threats mainly affect the plant communities via increased abundance of invasive exotic plant species. Elements to be monitored include the species composition of the communities and the threats – exotic species cover and some measure of edge effects (distance to edges of various kinds, some measure of disturbance intensity).

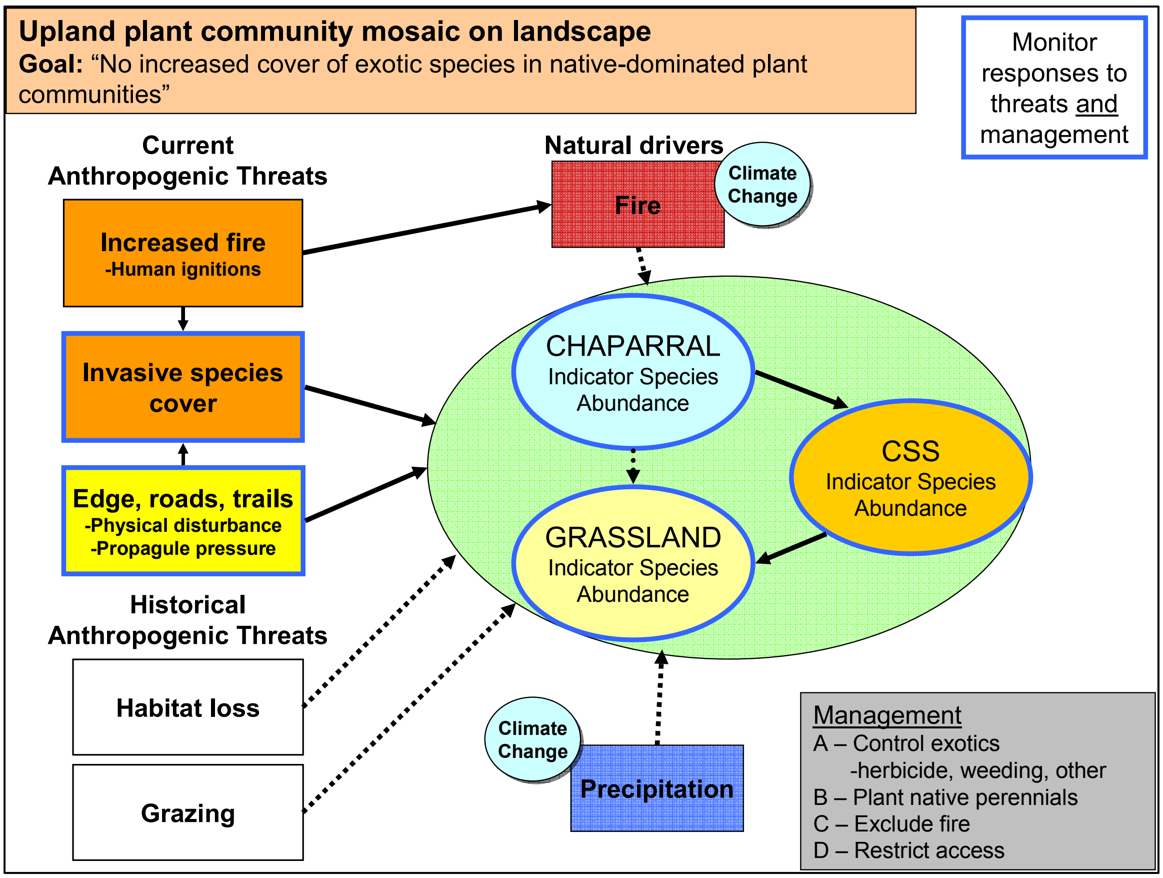

Figure 11. Landscape conceptual model, revised.

Sources used developing CSS-Chaparral-Exotics landscape model

The following references document transitions in species composition between the plant communities, as indicated, on sites in southern California, as a result of fire frequency (natural variability and human effects) and other anthropogenic impacts, especially land use change and landscape disturbance, as shown in Figure 11 (land clearing, grazing , edge effects, propagule pressure, etc.). See Section 6: Literature Cited for full citations.

- **Grassland → CSS:** Axelrod 1978; Callaway and Davis 1993; DeSimone & Zedler 2001; Dodge 1975

- **CSS → Grassland:** Allen et al. 2005; Callaway & Davis 1993; Chalekian 2002; Cione et al. 2002; Cuddington & Hastings 2004; Davis 1993; D'Antonio & Vitousek 1992;

Eliason & Allen 1997; Freudenberger et al. 1987; Haidinger & Keeley 1993; Keeley 1981, 2002, 2006; Keeley et al. 2005; Mack and D'Antonio 1998; Minnich 1982; Minnich & Dezzani 1998; Moyes et al. 2005; O'Leary 1995; O'Leary and Westman 1988; Randall et al. 1998; Rundel 2000; Rundel and King 2001; Wood et al. 2006; Zedler et al. 1983; Zink et al. 1995

- **Chaparral → Grassland:** Haidinger & Keeley 1993; Keeley 1981, 2006
- **CSS → Chaparral:** Epling & Lewis 1942; Gray 1981, 1982, 1983; Keeley 2006; Kolb & Davis 1994; Malanson & O'Leary 1985, 1995; Westman 1979, 1991; Zedler et al. 1983

5. Conclusions and Recommendations

Conceptual models help identify monitoring components, including population/community parameters and associated threats. Once these models are developed, the next step is to determine the specific protocols for measuring the variables identified in the model as being important in meeting the monitoring goals. This is the subject of ongoing work.

This report presents a framework for developing conceptual models for the MSCP Monitoring Program. We recommend four major steps in identifying the parameters and elements to be monitored:

1. Identify the monitoring goals for the relevant species or community.
2. Identify the major current and historical anthropogenic threats, natural drivers, and population or community parameters that dictate current or future status and trends.
3. Identify potential management responses for the relevant species or system.
4. Identify the main parameters that link to the dynamics of the relevant species or community in the context of the monitoring goals.

Using the case studies presented here as a guide, the MSCP partners can develop conceptual models for other species, communities, and landscapes as the monitoring program proceeds. These models can and should be updated as the knowledge base for these systems improves as a result of monitoring and management implementation.

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Appendix A: MSCP Conceptual Model Workshop Participants

A workshop was held on August 3, 2006 to discuss the conceptual models presented in this report. Participants provided the valuable input summarized for each case study in Section 4.

Participants:

Kathleen Brubaker (U.S. Fish and Wildlife Service)

Doug Deutschman (San Diego State University)

Pete Famolaro (Sweetwater Authority)

Janet Franklin (San Diego State University)

Keith Greer (City of San Diego)

Jeremy Groom (U.S. Fish and Wildlife Service)

Maeve Hanley (County of San Diego)

Stacie Hathaway (USGS)

Lauren Hierl (San Diego State University)

Brenda Johnson (California Department of Fish and Game)

Melanie Johnson Rocks (City of San Diego)

Casey Lydon (County of San Diego)

Dave Mayer (California Department of Fish and Game)

Steve Newton-Reed (California Department of Fish and Game)

Tom Oberbauer (County of San Diego)

Meredith Osborne (California Department of Fish and Game)

Helen Regan (San Diego State University)

Adam Wagschal (County of San Diego)

Clark Winchell (U.S. Fish and Wildlife Service)

Susan Wynn (U.S. Fish and Wildlife Service)