Title
Systematic Conservation Planning in California: The Role of Conceptual and Spatial Models in Decision Making, Planning, and Management

Author
Parisi, Monica D

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Systematic Conservation Planning in California:
The Role of Conceptual and Spatial Models
in Decision Making, Planning, and Management

By

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DISSERTATION

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Approved:

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Steven E. Greco, Chair

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William B. Lacy

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Douglas H. Deutschman

Committee in Charge

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List of Acronyms

ACE II – Areas of Conservation Emphasis II
BLM – boundary length modifier (FRAGSTATS software)
CDFW – California Department of Fish and Wildlife
CDOF – California Department of Finance
CESA – California Endangered Species Act
CNDDB – California Natural Diversity Database
CWHR – California Wildlife Habitat Relationships
GIS – geographic information system
HCP – Habitat Conservation Plan
LAC/RIV – lacustrine/riverine
MHCP – multiple habitat conservation program
MSCP – multiple species conservation program
MSHCP – multi-species habitat conservation plan
NCCP – Natural Community Conservation Plan
NCCPA – Natural Community Conservation Planning Act
OS – Open Standards for the Practice of Conservation
PVA – population viability analysis
SAM – species account model
SANDAG – San Diego Association of Governments
SCM – species conceptual model
SCP – systematic conservation planning
SDM – species distribution model
SDMMP – San Diego Management and Monitoring Program
SDSU IEMMP – San Diego State University Institute for Ecological Monitoring and Management
SPVA – spatial population viability analysis
USFWS – United States Fish and Wildlife Service
USGS – United States Geological Survey

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This pursuit has been in two phases, with a hiatus of ten years in between them to complete my career with the California Department of Fish and Wildlife (CDFW). My earliest research direction was tied closely to species-habitat modeling itself, and I wish to acknowledge the thoughtful advice given to me in those early days by Dr. Deborah Elliot-Fisk, my original Major Advisor at UC Davis, and Dr. William F. Laudenslayer, Jr. of the US Forest Service Pacific Southwest Research Station. For their moral support, I also thank my closest colleagues at CDFW: Ronald Rogers, Joseph Carboni, Dr. Brenda Johnson, and all of my staff in the Landscape Conservation Planning Program.

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Abstract

This dissertation is a three-part study of the practice of systematic conservation planning (SCP) on a regional scale in California, necessary for protecting the more than 2,000 plant species and more than 900 animal species considered to be at risk. Natural Community Conservation Plans (NCCPs) pursuant to California Endangered Species Act represent the most powerful tool in statute for such planning, with the highest standards for conserving species. Study results are intended to improve practice in the explicit use of species conceptual models (SCMs) and management-oriented species distribution models (SDMs).

Chapter 1 analyzes 18 NCCPs to determine if or how explicit connections were made between both types of models for a covered species and key components of its conservation strategy. Results indicate plans were strong in the use of SDMs, however, each deferred preparing or using SCMs to later management and monitoring phases. A more effective best practice for developing a conservation strategy is to explicitly integrate SCMs and SDMs during plan preparation.

Chapter 2 acknowledges the central role scientists play in systematic conservation planning and the decisions they must make regarding management and monitoring in the face of many biological and ecological uncertainties. SCMs are a way for species experts and other stakeholders to share knowledge and document these uncertainties as they determine the most effective conservation strategy for a species. Using San Diego County, California, as a case study, this chapter examines when, how, and by whom SCMs are created and later refined. Keyword searches of planning documents and interviews with scientists revealed that many SCMs have been created but have not yet been formally refined based on monitoring data and

stakeholder input. A grounded theory analysis of SCM workshop proceedings and interviews with scientists to determine how and by whom yielded the emergent theory “A Collaborative Ideal: Personalities and Attitudes of Individuals Affect Outcomes and Consensus is Reported.” The chapter concludes with a discussion of best practices for ensuring useful SCMs that reflect species expertise and the input of other stakeholders.

Chapter 3 is built on the premise that habitat connectivity is key when designing reserve networks for species conservation. However, acquiring land over time to achieve connectivity for multiple species in a conservation plan can pose a data challenge because of limited species occurrence data and complexity in using multiple species models together. Using an NCCP for Yolo County, California, as a case study, four land acquisition strategies were evaluated in their ability to meet each of three objectives: 1) meet conservation targets, 2) maximize structural habitat connectivity, and 3) maximize connectivity for multiple focal species. The efficiency of each strategy to meet conservation targets was assessed using MARXAN. Structural habitat connectivity of MARXAN solutions for each strategy was analyzed using ‘Contiguity Index’ and ‘Perimeter-Area Ratio’ in FRAGSTATS, and ‘Nearest Neighbor’ in ArcGIS. Focal species connectivity was evaluated by using ‘Cost Connectivity’ in ArcGIS to define species-specific least cost networks and then assessing each network’s conformity with MARXAN solutions. The strategy of acquiring Priority 1 parcels and corridor parcels together provides the best combination for attaining all three objectives. The chapter demonstrates how to use several measures of connectivity in decision-making and recommends using spatial prioritization software often, especially because land acquisition patterns are time sensitive and data may be limited.

Introduction

This dissertation examines the explicit use of species models in the science and practice of systematic conservation planning in California. Systematic species conservation planning on a regional scale in California is a critical ongoing need for the state. California has more than 2,000 plant species and more than 900 animal species that are considered to be at risk – meaning they are already state or federally listed as threatened or endangered or are at risk for becoming so (CDFW 2022a). The state's population is 40 million and is expected to reach 43 million by the year 2040 (CDOF 2022).

Regional conservation planning is a tool for resolving potential conflicts between economic development (e.g. urbanization, agriculture) and threatened and endangered (listed) species, especially in biologically rich areas of the state that face high levels of growth and development (Atkinson et al., 2004). State and federal wildlife agencies in California have two primary tools in statute to accomplish species conservation – state Natural Community Conservation Plans (NCCPs) under California Fish and Game Code Section 2800 et seq. and federal Habitat Conservation Plans (HCPs) under the Endangered Species Act Section 10(a)(1)(B). These plans are intended to establish large reserve networks of permanently protected lands and long-term programs designed to conserve and manage species legally "covered" by a plan while they allow compatible and appropriate development. All NCCPs in California are joint state and federal NCCP/HCPs, although they will be referred to here as NCCPs. Presently, 17 NCCPs have been approved in California and eight are in preparation. Collectively, they cover 8.4 million acres, with a reserve commitment of 1.6 million acres, and will provide conservation for more than 400 species at risk (CDFW 2021).

The dissertation focuses on NCCPs in California as systematic conservation plans, the term “systematic conservation planning” having come from the seminal and highly cited work of the same name published in *Nature* by Margules & Pressey (2000). Systematic conservation planning (SCP) has been identified as one of several decision support frameworks used in conservation (Schwartz et al. 2018). It was selected here because, among the frameworks compared by Schwartz et al. (2018), the key features of SCP most closely match those of NCCPs. First, theoretical foundations for NCCPs are in landscape ecology and land use planning, what Schwartz et al. term “geospatial planning.” Second, core tools for decision-making include spatial prioritization tools, such as will be examined here. Finally, core tools are applied to designing reserves, key features of each NCCP.

In fact, NCCPs may be among the best examples of systematic conservation planning in the United States. To approve an NCCP, the state government must find that “the development of reserve systems and conservation measures in the plan area provides, as needed for the conservation of species: …the establishment of …one or more reserves or other measures that provide equivalent conservation of Covered Species within the Plan Area and linkages between them and adjacent habitat areas outside the Plan Area” (Section 2820(a)(4)(B)). “Conservation” means “to use, and the use of, methods and procedures within the plan area that are necessary to bring any covered species to the point at which the measures provided pursuant to Chapter 1.5 (commencing with Section 2050) [The California Endangered Species Act] are not necessary’” (Section 2805(d)). Requiring that a species be brought to the point of no longer requiring protection under the California Endangered Species Act is effectively a standard of recovery (Hopkins 2004, Presley 2011). Thus, NCCPs are mandated to provide both recovery and habitat connectivity beyond plan boundaries for covered species, a powerful combination for the conservation of a species across its entire geographic range. California is the only state with this level of species protection encoded in statute.

Margules & Pressey (2000) outlined a systematic approach to locating and designing reserves and conservation goals, even as they highlighted the uncertainty inherent in every stage of the process and called for explicitness in analytical methods, geographical scales, goals, and the assumptions made by participants in a 6-stage iterative process. The framework has subsequently been expanded to include 11 stages (Pressey & Bottrill 2008): 1) scoping and costing the planning process, 2) identifying and involving stakeholders, 3) identifying the context for conservation areas, 4) identifying conservation goals, 5) collecting socio-economic data, 6) collecting data on biodiversity and other natural features, 7) setting conservation targets, 8) reviewing target achievement in existing conservation areas, 9) selecting additional conservation areas, 10) applying conservation actions to selected areas, and 11) maintaining and monitoring established conservation areas.

This work also represents a series of research questions sourced from my 30-year career in conservation, 10 years of which were spent managing the California Wildlife Habitat Relationships (CWHR), a modeling system for 700+ terrestrial vertebrate species, and eight years of which were spent as a conservation planner in the Natural Community Conservation Planning (NCCP) Program, both for the California Department of Fish and Wildlife. Many researchers have noted a research-implementation gap in conservation (Weins 2009, McAlpine et al. 2010, Guisan et al. 2013) and have called for sourcing research questions from practitioners (Knight et al. 2008, Schwartz et al. 2018). What was most clear to me as a practitioner, first in developing species models for CWHR and later in reviewing NCCPs that referenced a variety of species model types, is that there was not always an explicit connection between everything known regarding the biology, ecology, distribution, and status of a species and the strategy proposed for its conservation. The aim has been to use results to improve best practices for systematic conservation planning.

Chapter 1 is a meta-analysis of planning documents to examine how both management-oriented species conceptual models (SCMs) and species distribution models (SDMs) developed for an NCCP translate into the plan's biological goals and objectives, reserve design, and anticipated adaptive management and monitoring plan. Chapter 2 is a grounded theory study of scientists who create models for adaptive management and monitoring decisions. It examines San Diego County, California, as a case study. Chapter 3 is a geospatial analysis comparing reserve design strategies and their effectiveness in maximizing structural and functional habitat connectivity for multiple species. Using Yolo County, California, as a case study, it makes use of multiple SDMs together to determine the most effective strategy.

Chapter 1. The Explicit Integration of Species Conceptual Models and Species Distribution Models as a Best Practice for Systematic Conservation Planning in California

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ABSTRACT

Natural Community Conservation Plans (NCCPs) represent the most powerful tool in statute for regional and systematic conservation planning for species at risk in California. This study examines the use of species conceptual models (SCMs) and species distribution models (SDMs) in such planning. Eighteen Natural Community Conservation Plans (NCCPs) were analyzed to determine if or how explicit connections were made between both types of models for a covered species and key components of its conservation strategy. Results indicate plans were strong in the use of SDMs, however, each deferred preparing or using SCMs to later management and monitoring phases. A more effective best planning practice for developing a conservation strategy is to explicitly integrate SCMs and SDMs during plan preparation.

Keywords: endangered species, habitat conservation planning, Natural Community Conservation Planning (NCCP), species conceptual models, species distribution models

INTRODUCTION

This is a study of the explicit and effective integration of species models into the planning processes of Natural Community Conservation Plans (NCCPs). As discussed herein, NCCPs are California's most powerful tool in statute for species conservation on a regional scale, with a higher standard for conservation than federal Habitat Conservation Plans (HCPs). In statute, NCCPs (California Fish and Game Code Section 2800 et seq.) are an alternative to the project-by-project incidental take permitting process (California Fish and Game Code Section 2081) under the California Endangered Species Act (CESA). Such systematic and regional conservation planning is a critical ongoing need for the state and identifying "best practices" for all aspects of creating these plans is also an ongoing need. California has more than 2,000 plant species and more than 400 animal species that are considered to be at risk – meaning they are already state or federally listed as threatened or endangered or are at risk for becoming so (California Department of Fish and Wildlife 2020). The state's population is near 40 million and is expected to reach 45 million by the year 2035 (California Department of Finance 2019).

Species models serve to gather the collective scientific knowledge of a species (Franklin 2009). Species account models (SAMs) are verbal accounts, yet they provide conceptual information such life history, habitat use, geographic range, distribution, threats, and population trends and so may be considered a form of modeling (Andelman et al. 2001). Management-oriented species conceptual models (SCMs), in graph form, clarify assumptions regarding a species' relationship to ecosystem components, stressors, and its response to potential management actions (Atkinson et al. 2004; Hopkins 2004). They also identify remaining uncertainties, key to hypothesis testing in an adaptive management and monitoring context. SCMs provide a bridge between the goals and objectives of a conservation plan and the conservation measures or management actions assumed necessary for achieving them and thus preparing them at the time a conservation plan is being written would be a best practice.

Explicitness in the development and use of species distribution models (SDMs) in conservation planning, particularly reserve design, would also be a best practice. The design of a reserve network is inherently spatial. SDMs provide spatial data on both known occurrences of a species as well as environmental variables thought to predict its occurrence. They also provide the rule base linking species occurrences to environmental variables (Franklin 2009).

Explicitly disclosing rules and assumptions for mapping the predicted distribution of a species allows a user to both replicate a model and evaluate uncertainty in the prediction.

SAMs, SCMs and SDMs are communication tools, for stakeholders in the present and future. Over the lifetime of a plan, often 50 years or more, they can serve as a marker for future planners on the knowledge and assumptions guiding scientists and planners during the time at which a plan was approved.

Regional conservation planning is a tool for resolving potential conflicts between economic development (e.g., urbanization, agriculture) and threatened and endangered (listed) species, especially in biologically rich areas of the state that face high levels of growth and development (Atkinson et al., 2004). State and federal wildlife agencies in California have two primary statutes to accomplish species conservation – state Natural Community Conservation Plans (NCCPs) under California Fish and Game Code Section 2800 et seq. and federal Habitat Conservation Plans (HCPs) under the Endangered Species Act Section 10(a)(1)(B). These plans are intended to establish large reserve networks of permanently protected lands and long-term programs designed to conserve, mitigate for, and manage species legally "covered" by a plan while they allow compatible and appropriate development (Presley 2011). In California an HCP can be implemented without an NCCP. However, all NCCPs are joint state and federal NCCP/HCPs, although hereafter they will be referred to as NCCPs. NCCPs in California may also be thought of as systematic conservation plans, the term "systematic conservation planning" having come from the seminal and highly cited work of the same name published in *Nature* by Christopher Margules and Robert Pressey (2000).

NCCPs may, in fact, be among the best examples of government-sponsored systematic conservation planning. Both NCCPs and HCPs provide conservation benefits beyond that of traditional approaches to endangered species conservation, which allow limited “incidental take” of species in exchange for habitat mitigation actions or offsets, often on a project-by-project basis (McKenney & Kiesecker 2010:174). This practice results in uncoordinated or piecemeal mitigation, far less effective than a coordinated, regional approach (Underwood 2011). NCCPs and HCPs provide coordinated mitigation and conservation actions that can result in larger blocks of higher quality and more connected habitats (Noss et al. 1997). Underwood (2010) demonstrated the effectiveness of this approach by comparing two large areas of San Diego County and finding that the portion with a multispecies NCCP/HCP had implemented 5-10 times more area for conservation of rare species than the portion practicing project-by-project or piecemeal mitigation.

Beyond this, NCCPs are subject to an even higher standard for conservation than HCPs. To approve an HCP under the federal Endangered Species Act (16 USC §§ 1531-1544), the federal government must find that the taking of a species by a proposed project will not “appreciably reduce the likelihood of the survival and recovery of the species in the wild” (Section 10(a)(1)(B)(iv). By legislative intent, this finding is treated as equivalent to the language in Section 7(a)(2) – that a proposed project “… is not likely to jeopardize the continued existence of any endangered species or threatened species or result in the destruction or adverse modification of habitat” for the species. (See USFWS 2007 for example of equivalence language.) Effectively the standard is one of “no jeopardy” (Pollak 2001).

To approve an NCCP under California's Endangered Species Act (FGC §§ 2050-2089), the state government must find that "the development of reserve systems and conservation measures in the plan area provides, as needed for the conservation of species: …the establishment of …one or more reserves or other measures that provide equivalent conservation of Covered Species within the Plan Area and linkages between them and adjacent habitat areas outside the Plan Area" (Section 2820(a)(4)(B)). "Conservation" means "to use, and the use of, methods and procedures within the plan area that are necessary to bring any covered species to the point at which the measures provided pursuant to Chapter 1.5 (commencing with Section 2050) [The California Endangered Species Act] are not necessary'" (Section 2805(d)). Requiring that a species be brought to the point of no longer requiring protection under the California Endangered Species Act is effectively a standard of recovery (Hopkins 2004, Presley 2011).

Thus, NCCPs are mandated to provide both recovery and habitat connectivity beyond plan boundaries for covered species, a powerful combination for the conservation of a species across its entire geographic range. Greco (2020) examined the mix of conservation standards across the geographic range of the federally and state-listed threatened giant garter snake (*Thamnophis gigas*) in California, finding only 14% of the range to be subject to an NCCP recovery standard and concluding that the variation in standards could have significant implications for recovery.

In this study, we examined the integration of species conceptual models and spatial models in the NCCP planning process (see Table 1.1 for a typology of models used in NCCPs). Often such models are included as appendices in NCCPs, but it is not always clear if and how

Table 1.1: Typology of models used in NCCPs. According to Andelman et al. (2001), verbal accounts, mathematical formulae, and graphical diagrams are all structural variations of conceptual models. The conceptual model of interest here is a "management-oriented" species conceptual model (SCM). The spatial model of interest is a species distribution model (SDM).

Model Used in NCCP	**Model Type and Structure**	**Alternate Terminology for Model Structure**	**Model Inputs in NCCPs**
Species Account Model (SAM)	Conceptual model: verbal (text-based) account	Species account Ecological account Species profile	Legal status Species description Life history Habitat associations Geographic range Home range or territory size Distribution of occurrences in the plan area Threats Population trends Abundance estimates
Management-oriented Species Conceptual Model (SCM)	Conceptual model: graphical diagram	Influence diagram (Clemen 2001) Conceptual diagram (Goodwin & Wright 1991) Envirogram (Andrewartha & Birch 1984, James et al. 1997) Causal web (Andelman et al. 2001)	Measurable aspects of response (e.g. habitat quality, patch occupancy, population size) Anthropogenic threats Natural drivers Management actions Critical uncertainties

Model Used in NCCP	Model Type and Structure	Alternate Terminology for Model Structure	Model Inputs in NCCPs
Species Distribution Model (SDM), using discrete or continuous variables	Spatial model: distribution map	Species distribution model (Franklin 2009) Index of habitat suitability or potential occupancy (Barrows et al. 2005)	Mapped occurrences or population locations Classified (expert opinion) suitiable habitat – mapped as discrete polygons in vector format (if habitat features can be mapped) Or Environmental variables that correlate with species presence – mapped as a composite of continuous variables in raster format
Population Viability Analysis (PVA), depending on available data	Conceptual model: mathematical formula	Count-based population viability analysis (Santa Clara Valley Habitat Plan 2012) Count-based extinction analysis (Morris et al. 1999)	Known numbers of adults Population growth rates Reproductive rates
Spatial PVA (SPVA), depending on available data	Spatial model: spatially-explicit movement model with population size and demography	Individual model Occupancy map Population projection (size and demography) (Schumaker 1998, 2010)	SDM (with habitat suitability) PVA parameters Movement parameters

they are used in the planning process. Specifically, we looked at how management-oriented species conceptual models (SCMs) and species distribution models (SDMs) are currently used in NCCPs – to guide biological goals and objectives, adaptive management and monitoring, and reserve design (see Figure 1.1). Calls in the literature for explicitness in how models translate into conservation strategies and reserve designs come from Atkinson et al. (2004), Franklin et al. (2011), Guisan et al. (2013), and Tulloch et al. (2016). Specifically regarding SDMs, researchers have shown how the vast majority of research focuses on methods rather than implementation in the context of systematic conservation planning, implying that research on the explicit connections between SDMs and reserve design strategies is rare (Mair et al. 2019, Guisan et al. 2013). We assessed past and current practice regarding model integration (i.e., SAM, SCM, SDM) for systematic conservation planning throughout California.

We examined four central research questions, presented here with some key background information related to each question. First, what is the level of modelling done in the planning phase of an NCCP and do NCCPs prepare SCMs and SDMs during this phase? All NCCPs are in one of two phases: planning or implementation. In the planning phase, an Enrollment Agreement or Planning Agreement has been signed by the permittee organizations and the state and federal wildlife agencies who will approve and permit the plans. As the plan is being developed, one or more administrative drafts may be produced internally before a draft is prepared for public review (Presley 2011). A core component of each NCCP is the conservation strategy, consisting of both the biological goals, objectives and conservation measures for the plan and a strategy for reserve design (Hopkins 2004). In the implementation phase, a plan has

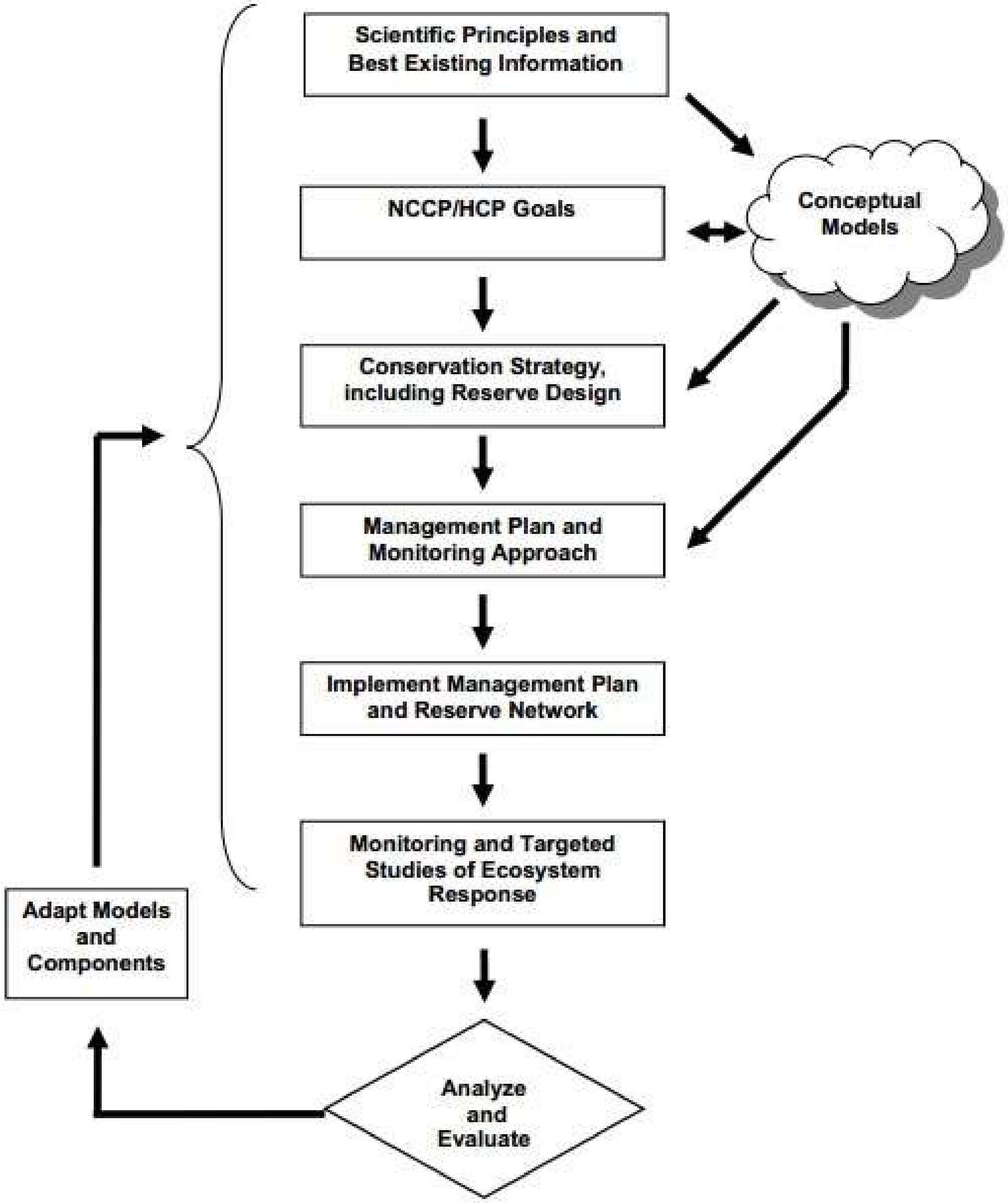

Figure 1.1. A flow diagram of where conceptual models fit into the adaptive management and monitoring process for an NCCP. (Reprinted from: Atkinson et al. 2004).

been approved and permitted and progress on the conservation strategy, such as acquisition of reserve lands, is actively underway.

The second research question is: are there explicit connections between the SCMs and the proposed adaptive management and monitoring program for each plan and, if so, how are they made? Beginning with the NCCP Act of 2003 each plan is required to contain an adaptive management and monitoring program (Atkinson et al. 2004). "Adaptive management" as defined in the NCCP Act "means to use the results of new information gathered through the monitoring program of the plan and from other sources to adjust management strategies and practices to assist in providing for the conservation of covered species" (NCCPA 2003).

This leads to our third research question: are there explicit connections between SCMs and the biological goals and objectives of each plan and, if so, how are they made? Goals, objectives, and conservation measures differ across plans in how they are used. Generally, however, goals are broad statements of desired outcomes that set the direction for an NCCP (e.g., conservation for a covered species in perpetuity), objectives are specific and measurable statements detailing how each goal can be achieved (e.g., a specified quantity of acres of some specific habitat type for a covered species) and conservation measures describe actions (e.g., acquire land in fee title). The term "conditions for coverage" is also sometimes used in the biological goals and objectives section of an NCCP to describe specific actions that must be taken for a species to be considered conserved and thus eligible for coverage under a plan.

Our final research question is: are there explicit connections between SDMs and the reserve design of each plan and, if so, how are they made? For the purposes of this study, the reserve design is defined to include both the measurable reserve acreage commitments in the biological goals and objectives and the spatial design of the reserve system for the entire plan area. As stated previously, NCCPs must provide a connected reserve system, with linkages between reserves inside the plan area and to adjacent habitat areas outside of the plan area (NCCPA 2003).

METHODS

The primary methodology used to explore and answer these questions was a keyword search of planning documents from 18 NCCPs in California that are either approved or in public draft form (Table 1.2). Nineteen NCCPs met this initial set of criteria, but one was dropped, the San Diego MSCP La Mesa Subarea Plan. The plan included only a brief statement describing its consistency to a programmatic NCCP, but otherwise contained none of the necessary elements to stand on its own as an NCCP. Of the remaining 18 plans, 15 have been approved and permitted and three are in public draft form, generally the final stage before public comments are reviewed and the plan is finalized and submitted to the state and federal wildlife agencies. Approved and permitted plans that are considered "Subarea Plans" to larger programmatic NCCPs were treated as unique plans. Programmatic NCCPs serve as "umbrella" plans. They do not receive permits and were not included as unique plans. However, they were considered as contributors of conservation analyses and modeling to their subarea plans. All documents were publicly available as downloads from the websites of organizations serving as lead entities for the plans. A lead entity is generally a local government with land use planning authority, but it is not required to be so; regional authorities for water and transportation and private companies also undertake NCCPs (Hopkins 2004).

Table 1.2. NCCP/HCPs in California, presented in order of permit year or public draft year. Plans with a permit year are approved and in the implementation phase. Those with a public draft year are still in the planning phase.

Plan #	Approved and Permitted NCCP/HCPs	Permit Year	NCCP Act Version	Scientific Advisor Report
1	San Diego Gas & Electric	1995	1991	n/a
2	County of Orange Central and Coastal Subregion	1996	1991	n/a
3	San Diego Multiple Species Conservation Program (MSCP) Poway Subarea Plan	1996	1991	n/a
4	Kern Water Bank	1997	1991	n/a
5	San Diego MSCP City Subarea Plan	1997	1991	n/a
6	San Diego MSCP County Subarea Plan	1998	1991	n/a
7	San Diego Multiple Habitat Conservation Program (MHCP) Carslbad Subarea Plan	2004	2001	n/a
8	Western Riverside Multi-Species Habitat Conservation Plan (MSHCP)	2004	2001	n/a
9	San Diego MSCP Chula Vista Subarea Plan	2005	2001	n/a
10	East Contra Costa County	2007	2003	Huntsinger et al. (2003)
11	Coachella Valley Multiple Species Habitat Conservation Plan (MSHCP)	2008	2003	Noss et al. (2001)
12	San Diego County Water Authority	2011	2003	Rahn et al. (2008)
13	Santa Clara Valley Habitat Plan	2013	2003	Spencer et al. (2006a)
14	Orange County Transportation Authority	2017	2003	Rahn et al. (2011)

Plan #	Approved and Permitted NCCP/HCPs	Permit Year	NCCP Act Version	Scientific Advisor Report
15	Yolo	2019	2003	Spencer et al. (2006b)
	NCCP/HCPs in Public Draft Form	**Draft Year**	**NCCP Act Version**	**Scientific Advisor Report**
16	Rancho Palos Verdes	2018	2001	n/a
17	Butte Regional Conservation Plan	2019	2003	Spencer et al. (2007)
18	Placer County Conservation Plan	2019	2003	Brussard et al. (2004)

To address the first question regarding the level of modelling done in the planning phase of an NCCP, we searched each plan document using model names, model types, and alternate terms for model structure as keywords, entries in columns 1-3 of Table 1.1, respectively. The goal was to determine which of the model inputs (Column 4 entries) were present for species in a plan. The criteria for including model inputs as present are listed in Table 1.3. Model inputs were considered present if they were included for one or more species in a plan. They were also considered present if, in the case of subarea plans, direct reference was made to a species model in a programmatic NCCP. Of the six subarea plans, three relied wholly on species models produced for a programmatic NCCP and three both referenced models in a programmatic NCCP and included models for species in the subarea plan that were not included in the programmatic NCCP.

To find explicit connections between the SCMs and the proposed adaptive management and monitoring program, our second question, we conducted a keyword search in the adaptive management and monitoring chapter of each plan for direct reference to the name and location of the species models in the documents for that plan. Only one plan was found to contain SCMs, so to determine intent to create SCMs among the remaining plans, we also searched for "concept" and "model." The search for explicit connections between SCMs and biological goals and objectives, our third question, was also limited because only one plan was found to contain SCMs. Therefore, to see how any level of species modeling may be influencing biological goals and objectives in the remaining plans, we looked at connections between the one SAM component that is in common with an SCM, namely, threats. "Threat" was used as a

Table 1.3. Criteria for including model inputs as present in NCCPs.

Model Inputs	Criteria for Including Model Inputs as Present
	Species Account Model (SAM)
Legal status	listing status as threatened or endangered under the California or federal Endangered Species Acts or rare under the California Native Plant Protection Act (FGC §§ 1900-1913) inclusion on any administrative watch lists such as California Species of Special Concern
Species description	physical description, growth habit in the case of plants, and/or any level of taxonomic information
Life history	pattern of survival, life cycle, and reproduction events for a species
Habitat associations	for terrestrial wildlife species, habitat types, natural community types, or landcover types known to be suitable for a species meeting one or more life history requirements; for fish, stream reaches or water bodies with the proper conditions, such as temperature or flow rate or connectivity, to support one or more stages of a species' life history; for plants, inclusion of plant associations, soil type, hydrology, slope, or elevation
Geographic range	description and/or map of the limits of distribution globally, in North America or in California
Home range or territory size	for terrestrial wildlife species, reference to the distance an individual travels in meeting life history requirements; for species that are also territorial, reference to the average territory size for an individual, or a range of sizes depending on habitat conditions or gender
Distribution of occurrences in the plan area	general description of population locations, often in the absence of surveys for the entire plan area
Threats	anthropogenic threats such as habitat loss or fragmentation, exotic species introduction, uncontrolled grazing, pollution, pesticide use, or noise disturbance
Population trends	globally, in North America, in California, or in the plan area (if known); located through keyword searches on "trend", "population", "declining", "stable", and "increasing"
Abundance estimates	globally, in North America, in California, or in the plan area (if known), expressed as a range of population size or as a density estimate

Measurable aspects of response	Identification of variables for measuring the response of natural communities, species or populations to management actions such as habitat quality, patch occupancy or population size, respectively

Management- oriented Species Conceptual Model (SCM)

Anthropogenic threats	threats such as habitat loss or fragmentation, exotic species introduction, uncontrolled grazing, pollution, pesticide use, or noise disturbance expressed as management issues in a conceptual diagram
Natural drivers	drivers of change such as fire or hydrologic regimes directly connected to response variables in a conceptual diagram
Management actions	mitigating actions directly connected to anthropogenic threats in a conceptual diagram
Critical uncertainties	outstanding research questions for completing or updating a conceptual diagram

Species Distribution Model (SDM), using discrete or continuous variables

Mapped occurrences or population locations	occurrences presented as points in vector format in a GIS, either as maps in a plan document or available digitally as GIS data

Population Viability Analysis (PVA), depending on available data

Known numbers of adults	count-based or other methods of determining the number of adults
Population growth rates	calculated rate based on a ratio between number of adults in any given year and number of adults one year later
Reproductive rates	fecundity, based on survival and fertility rates

Spatial PVA (SPVA), depending on available data

SDM (with habitat suitability)	one of more of the SDM components listed above
PVA parameters	one or more of the PVA components listed above
Movement parameters	one or more spatial components of a PVA that affect habitat suitability such as connectivity of habitat on a landscape or dispersal ability of a species

keyword in the search, as were “enhance” and “restore,” action words found among biological goals and objectives for reducing or mitigating threats.

Finally, to research explicit connections between SDMs and reserve design, we looked in two locations within each plan. First, for connections to reserve acreage commitments, we searched the biological goals and objectives section for direct reference to the name and location of the SDMs in the documents for that plan. If this yielded no results, the keywords “model,” “occurrence,” and “occupied” were used to query for the components of an SDM. Second, for connections between the SDMs and the reserve design strategy for a plan, we employed several keywords that lead to descriptions of how SDMs may be used together, all of which can be found among the collection of planning documents: “criteria,” “principle,” “concept,” “rule,” “consideration,” “design,” “assembly,” “synthesis,” and “process.”

RESULTS

Results for the level of modeling done in the planning phase of each NCCP are presented in Figure 1.2. All 18 NCCPs contained the full suite of components for text-based SAMs. Only one NCCP prepared SCMs for its covered species in the planning phase (Plan #18 of Table 1.2). Regarding SDMs, 17 of the 18 plans (94%) contained maps of known occurrences for each covered species. Fifteen plans or 83% also presented expert-based habitat suitability maps for each covered species as discrete polygons in a vector-based geographic information system (GIS), wherein each mapped polygon represents one habitat type on the ground modeled as suitable for a species and contains a single habitat suitability value. No plans presented habitat suitability maps as a composite of continuous environmental variables in a raster-based GIS, wherein each cell in a pixelated mapped surface has a habitat suitability value representing the

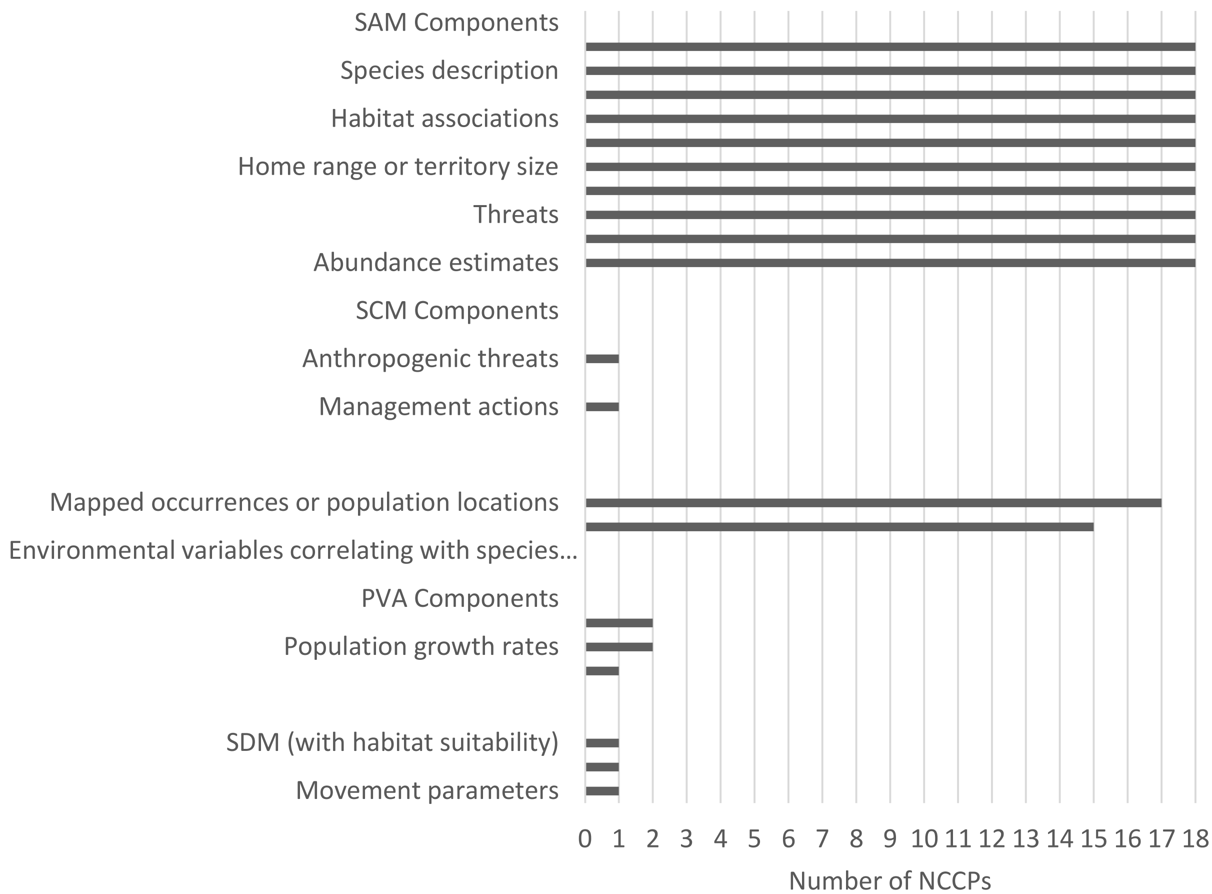

Figure 1.2. The model components and levels of species modeling found among existing NCCPs.

summed value of layers of environmental variables for that cell on the ground, creating a "surface" of habitat suitability that is continuous. (See Chang 2019 for a full comparison of vector and raster data formats in GIS.) Just two plans (#7, #13) contained some components of Population Viability Analysis (PVA) species models and, in each case, for a single species only. One of these two plans (#7) also had components of a spatial PVA.

Results for explicit connections between the SCMs and the proposed adaptive management and monitoring program are presented in Figure 1.3. A full 50% of the eighteen plans made no reference to SCMs. Only one plan (#18) prepared SCMs at the planning phase but did not declare intent to use and refine them until a future date. Two additional plans (#14, #15) prepared a single sample or framework SCM for use in preparing future species-specific SCMs. Six plans declared an intent to develop and use SCMs in their adaptive management and monitoring chapters (#8, #10, #11, #12, #13, #17). Significantly, eight of these nine collective plans referencing SCMs represent the plans in Table 1.2 subject to approval through the NCCP Act of 2003, which added the requirement for an adaptive management and monitoring component.

Beginning with a 2000 amendment to the NCCP Act, new NCCPs were also required to incorporate independent scientific input, although several plans already underway with signed Planning Agreements were "grandfathered" in and exempted from this requirement. A search of scientific advisory reports prepared at the start of the planning process for each NCCP required to prepare such an analysis (Table 1.2) revealed that seven out of eight recommended the use of SCMs in adaptive management and monitoring. One such report called for the

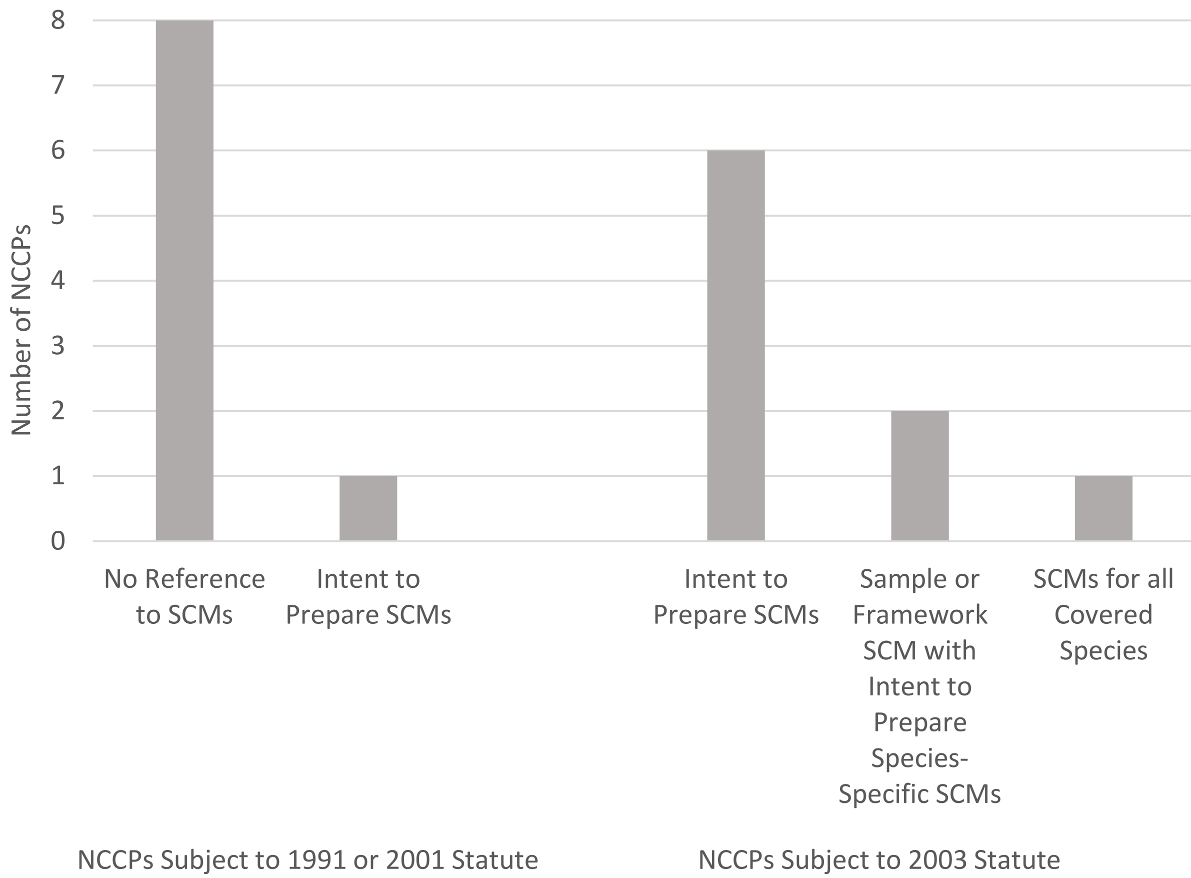

Figure 1.3. References to species conceptual models (SCMs) in NCCPs. Among early NCCPs (n = 9), only a portion reference species conceptual models (SCMs) in their adaptive management and monitoring chapters. Among NCCPs subject to the 2003 statute (n = 9), most plans present an intent to prepare SCMs in the future.

development of SCMs ideally up front, that is, in the planning phase (Rahn et al. 2008). It is worth noting that Atkinson et al. (2004) was published shortly after the NCCP Act of 2003,placing SCMs as necessary inputs to the adaptive management and monitoring process (Figure 1.1).

Results of the search for connections between threats described in SAMs and biological goals and objectives are shown in Figure 1.4, categorized and presented in order from least to most explicit connections. Six of the eighteen plans, or one-third, either made no direct reference or a very general one to the SAMS when presenting biological goals and objectives, indicating they were used but unclear about how. Two-thirds of the plans made direct references to SAMS in species-specific biological goals and objectives. The most explicit connections were made by eight plans (#5, #6, #7, #8, #9, #12, #16, #17), who chose to present an analysis of SAM components, such as threats, side-by-side with species-specific biological goals and objectives as a justification for them. Thus, it was transparent and immediate to see how the models and model assumptions were used.

Finally, we examined explicit connections between SDMs and reserve designs. Each of the 17 plans that contained SDMs made a direct reference to their use in the conservation strategy, which includes reserve design, and the one remaining plan (#4) made reference to text-based information in the SAMs it contained. However, it was not always explicit how SDMs and SAMs were used. Since modeled suitable habitat is used along with occurrence data as the basis for reserve acreage commitments by species, the next question to examine was how explicit the process was for using classified (expert opinion) suitable habitat in each SDM. The results are shown in Figure 1.5. Of the 15 plans that had this SDM component, five plans (#2,

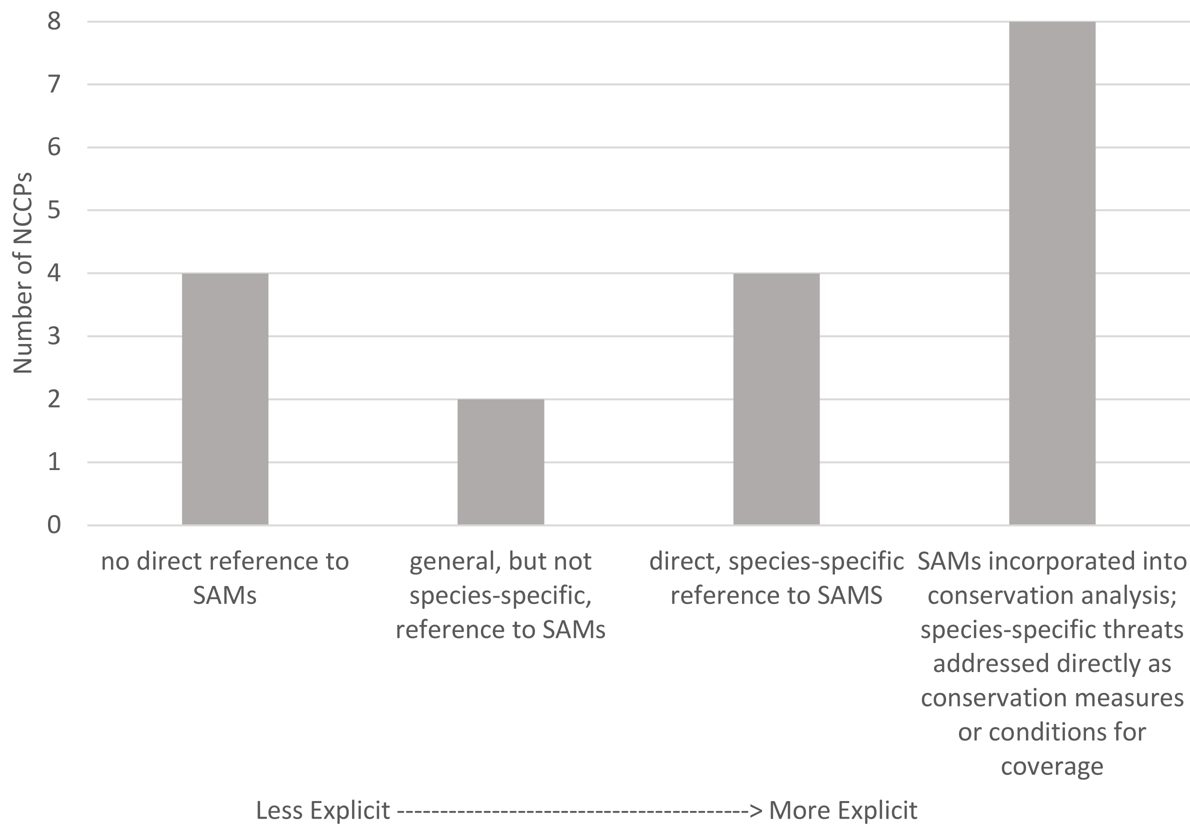

Figure 1.4. Explicitness in the use of species account models (SAMs) in NCCPs. There is a range of explicitness among NCCPs in how SAMs connect to biological goals and objectives.

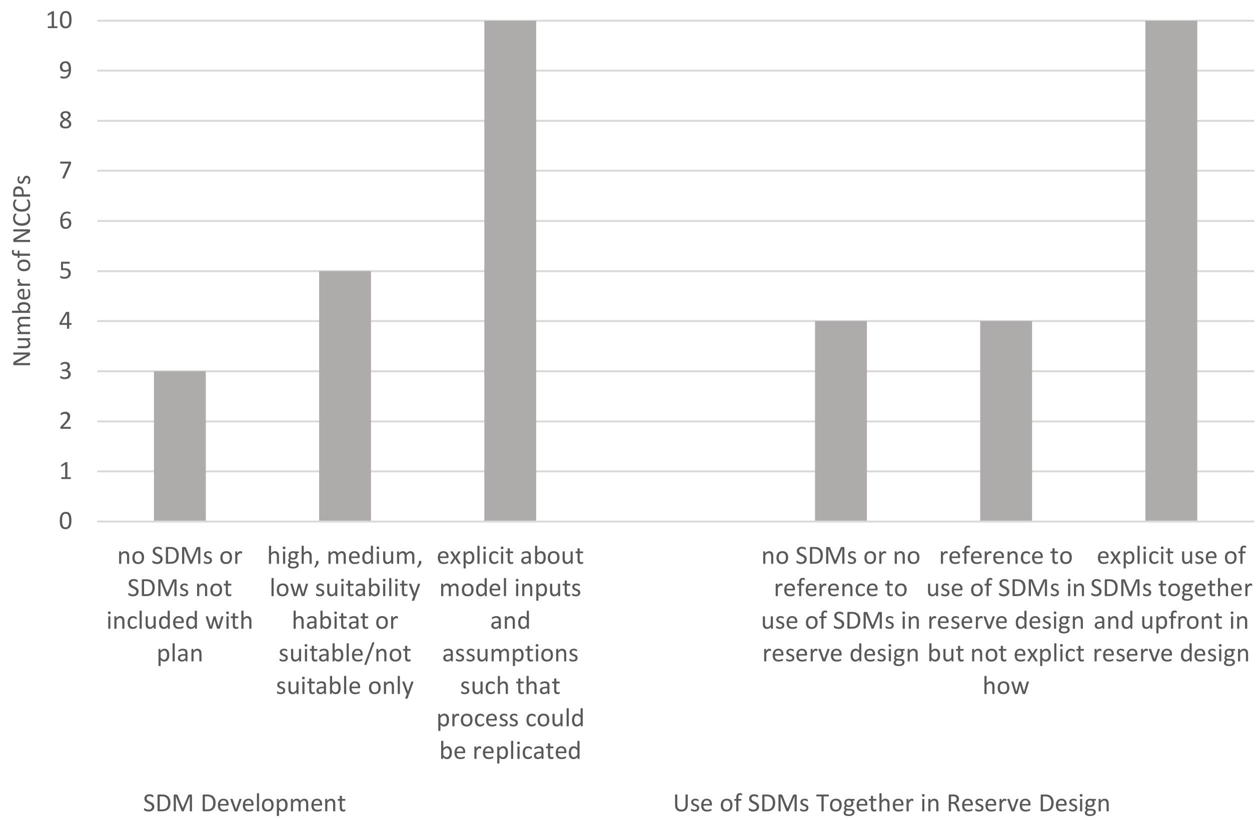

Figure 1.5. Explicitness of model inputs to species distribution models (SDMs) in NCCPs. In SDM development, not all NCCPs are explicit enough about model inputs such that the process can be replicated. In the use of SDMs together and upfront in reserve design, NCCPs vary in explicitness.

#9, #11, #15, #16) had habitats ranked as “high”/ “medium”/ “low” or “suitable”/ “unsuitable” for a species, without disclosing model inputs or assumptions, such as habitat types selected or minimum habitat patch size applied. Thus, these models could not be replicated just with the information contained in the plan. Ten plans were explicit about how each suitability map was created such that the process could be replicated in a GIS.

Regarding use of the models together in the creation of a reserve design, three levels have been distinguished and are shown in Figure 1.5 from the least to the most explicit. Three of the 17 plans containing at least one component of an SDM did not describe a process of using the models together in the reserve design (plans #9, #13, #14). Four plans made reference to using SDMs in their reserve designs but were not explicit about how their individual SDMs may have been used together and upfront (plans #10, #15, #17, #18). Ten NCCPs described processes for using SDMs together and upfront for prioritizing lands in a reserve system (plans #1, #15, #2, #3, #5, #6, #7, #8, #12, #16). Spatial analysis methods used by the 10 plans included: (1) “hotspot” analyses, in which landscape data are divided into standard units such as square or hexagon grid cells and point-based species occurrence data is assessed for each cell to locate areas of high density or “hotspots,” (2) formal and “informal” GAP analyses (USGS 2019), in which suitable habitat and/or known occurrences for one or more targeted species on a landscape is overlain with existing conserved lands to locate “gaps” in conservation, and (3) a composite habitat evaluation model (Ogden 1995), which consists of high priority habitat for selected covered species, wildlife corridor data, and a habitat value index. The habitat value index itself represents seven input data layers weighted and combined to assess relative biological value: soils known to support sensitive plant species, adverse edge effects, habitat element features (e.g., presence of cliffs, springs, or ponds), ecotone index, habitat diversity index, rarity of natural habitats, and potential to support covered species.

DISCUSSION

The results reveal that all plans create species models and reference them to some degree and most plans utilize SAMs in developing biological goals and objectives. Thus, there is a practice of connecting what is known about a species' life history, habitat use, geographic range, distribution, threats, and population trends to what would be appropriate objectives for that species in a strategy for conservation. Especially effective in conveying the reasoning behind a conservation strategy were those eight plans (44%) that presented an analysis of SAM components, such as threats, side-by-side with species-specific biological goals and objectives as a justification for them.

What is most concerning is the almost non-existent use of SCMs in the planning phases of NCCPs. Only one plan developed SCMs up front, and even this plan did not utilize these models in developing a framework adaptive management and monitoring program. It is strongly recommended that plans develop and utilize SCMs up front, so these models can inform key components of the plan, as indicated in Figure 1.1 (Atkinson et al. 2004). As stated previously, SCMs are a bridge between the goals and objectives of a conservation plan and the conservation measures or management actions assumed necessary for achieving them. They also serve to identify priorities for monitoring and critical uncertainties that still need research (Atkinson et al. 2004), information that would be beneficial, especially when scoping the long-term cost of a plan. Franklin et al. (2011), in prefacing a case study for developing a monitoring program for the San Diego Multiple Species Conservation Program (MSCP), acknowledge that conservation plan objectives can be set too broadly to identify monitoring priorities during plan development and that monitoring and management often require more resources than are acknowledged or even known at the planning stage. Without proper funding at the outset, effectiveness monitoring for an NCCP can be significantly delayed.

There may be any number of reasons for the underutilization of SCMs in the planning phase of an NCCP. One is simply a lack of specificity in the requirements of the NCCP Act related to adaptive management and monitoring. In approving an NCCP, the state must find that the plan "integrates adaptive management strategies that are periodically evaluated and modified based on the information from the monitoring program and other sources" (Section 2810(a)(2)) "contains a monitoring program" (Section 2810(a)(7)) and "contains an adaptive management program" (Section 2810(b)(8)). Author MP has worked as an agency scientist reviewing NCCPs and preparing findings and has found that these chapters are often very brief, with some planners considering that to define a management and monitoring program at the planning stage before reserve lands are acquired would be premature.

Although it would be premature to write individual management plans, SCMs with explicit assumptions are key to developing a management and monitoring framework to guide management planning across an entire reserve system. Managers of individual reserves must be able to translate the goals and objectives of a conservation plan into a work plan for management and monitoring – over time, in the context of a reserve network, and in the face of uncertainty. SCMs clarify assumptions regarding a species' relationship to ecosystem components, stressors, and its response to potential management actions (Atkinson et al. 2004; Hopkins 2004). If SCMs were to be developed while a conservation plan was still being written, the goals of the plan might be specified in a way that makes management targets and monitoring objectives obvious (Franklin et al. 2011).

Explicit assumptions included as part of a SCM are especially important in an adaptive management context, which necessarily treats assumed causal relationships between modeled ecological variables as hypotheses (Woodward et al. 1999, Barrows et al. 2005, Franklin et al. 2011, Runge et al. 2011). Wrote one participant as feedback in a San Diego workshop designed to develop SCMs: "... the way this modeling process was done, identifying stressors and using available life history information was a good approach. I think we came up with some interim management methods/tasks that could be used immediately… to help protect occupied Hermes [a butterfly species] habitat from fire while we wait for research questions to be answered about dispersal and other unknowns." (Lewison et al. 2012)

Plans varied in describing the creation of SDMs and their use together and upfront in reserve design. In creating SDMs, the five plans that simply ranked habitats as "high"/ "medium"/ "low" or "suitable"/ "unsuitable" for a species, without disclosing model inputs or assumptions may indeed have engaged in an explicit modeling process among scientists without publishing details of the process in the plan, but this should be discouraged as a planning practice for NCCPs. More explicitness makes the planning process more transparent and inclusive to other stakeholders because interested parties are able to replicate the models and understand the assumptions made in using them. It is strongly recommended that metadata accompany each SDM. Ideally, it would include all input data sets, their sources, their limitations of use as described by their creators, and the assumptions modelers made in assembling them to create a SDM. Because knowledge of a species distribution is often coarse or incomplete, understanding data available and methodological choices used to create a model is key to its appropriate use (Sofaer et al. 2019).

When it comes to using SDMs together and upfront in reserve design, it is significant that two of the three plans that did not conduct such an analysis are led by regional authorities with the ability to commit their own lands to a reserve system, and this factor is what likely drove the initial design. Among the remaining fourteen plans, one might have expected more spatial analysis among newer plans, with greater GIS capacity and access to more spatial data layers than were available to planners in the 1990s, but there does not appear to be a trend related to the year of plan approval. Researchers have acknowledged the difficulty in selecting an appropriate modeling method for multiple species, known as an ensemble modeling strategy (Lin et al. 2018). It is significant that two thirds of plans employed an ensemble strategy upfront in reserve design. Once again, it is recommended that modelers disclose any assumptions made or data limitations noted in the process of compiling multiple SDMs. For example, several NCCPs employed a process similar to that of the California Department of Fish and Wildlife (CDFW) Areas of Conservation Emphasis (ACE II) – which includes indices of biological value by hexagonal unit across the state, derived from occurrence data and range maps of multiple species. The metadata for ACE II not only discloses reasoning for the unit (hexagon) and scale (hexagon size) of analysis chosen, it also acknowledges that values are influenced by the data (or lack of data) available for any given species in any given region of the state. Included with the data are recommendations for appropriate use (CDFW 2015).

The intent of this paper has been to understand current practice regarding the integration of species models in systematic conservation planning, with an aim to improve practice overall, rather than to highlight the shortcomings of any individual plan. With a powerful and far-reaching statute to guide them and only fifteen plans approved statewide, NCCPs are in many ways still experimenting with best practices. Early publications have taken the form of case studies (Pollak 2001, for example) or guidance documents with "lessons learned."

Universally, plans were strong in including detailed SAMS, while they varied in their ability to connect models directly to biological goals and objectives. Two-thirds of plans were explicit in SDM creation such that individual species models could be replicated in a GIS with the information provided in the plan and two-thirds of plans demonstrated ways that SDMs can be used together in reserve design. We found the greatest room for growth in the use of SCMs for adaptive management and monitoring planning, which may be facilitated by more detailed requirements in statute regarding the adaptive management and monitoring component of a plan. Professional training in the creation and use of SCMs may also help. To this end, NCCPs in the implementation phase that have developed SCMs for monitoring would be an ideal resource.

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Chapter 2. Species Conceptual Models in Decision-Making for Systematic Conservation Plans: A Grounded Theory Analysis and Case Study in San Diego County, California

ABSTRACT

Scientists play a central role in systematic conservation planning for plant and animal species at risk in California and they must make decisions regarding management and monitoring in the face of many biological and ecological uncertainties. Species conceptual models (SCMs) are a way for species experts and other stakeholders to share knowledge and document these uncertainties as they determine the most effective conservation strategy for a species. Using San Diego County, California as a case study, this study examines when, how, and by whom SCMs are created and later refined. Keyword searches of planning documents and interviews with scientists revealed that many SCMs have been created but have not yet been formally refined based on monitoring data and stakeholder input. A grounded theory analysis of SCM workshop proceedings and interviews with scientists to determine how and by whom yielded the emergent theory "A Collaborative Ideal: Personalities and Attitudes of Individuals Affect Outcomes and Consensus is Reported". The paper concludes with a discussion of best practices for ensuring useful SCMs that reflect species expertise and the input of other stakeholders.

Keywords: systematic conservation planning, environmental decision-making, species conceptual models, adaptive management and monitoring, grounded theory

INTRODUCTION

Scientists have a vital role to play in planning and managing for the conservation of plant and animal species in California, a critical and ongoing need for the state. California has more than 2,000 plant species and more than 900 animal species that are considered to be at risk – meaning they are already state or federally listed as threatened or endangered or are at risk for becoming so (California Department of Fish and Wildlife 2022). The state's population is 40 million and is expected to reach 43 million by the year 2040 (California Department of Finance 2022).

Moreover, decisions on how best to monitor and manage conserved species and their associated natural communities must often be made in the face of many biological and ecological uncertainties. This study examines the creation and use of management-oriented species conceptual models (SCMs), one process by which scientific knowledge regarding a species, a natural community, or a management strategy affecting multiple species is codified by a group of species experts and other stakeholders and utilized to affect management and monitoring decisions. SCMs clarify assumptions regarding a species' relationship to ecosystem components, stressors, and its response to potential management actions (Atkinson et al. 2004). They are a tool for documenting the assumptions made about the main drivers affecting status and trends of a species (Franklin, et al., 2011). It should be noted that the term species conceptual model is used herein, although the focus of a model may be a natural community (e.g. coastal sage scrub) or, less commonly, a management strategy affecting multiple species (e.g. invasive weed control). In this case study of San Diego County, California, SCMs and associated management and monitoring strategies take place within the context of large scale, regional conservation planning. Such planning is a tool for resolving potential conflicts between urbanization and threatened and endangered (listed) species, especially in biologically rich areas of the state that face high levels of growth and development (Atkinson et al., 2004).

Federal and state wildlife agencies in California have two primary tools in statute to accomplish regional, multi-species conservation planning – federal Habitat Conservation Plans (HCPs) under the Endangered Species Act Section 10(a)(1)(B) and state Natural Community Conservation Plans (NCCPs) under California Fish and Game Code Section 2800 et. seq. These plans establish large-scale reserve networks of permanently protected lands and long-term programs designed to conserve and manage species legally "covered" by the plan while they allow compatible and appropriate development. Several joint NCCP/HCPs have been approved in southern California, and more are being planned throughout the state. These plans include large numbers of species, more than 80 in some cases, and hundreds of square miles of land. In California, an HCP can be implemented without an NCCP. However, all NCCPs are joint state and federal NCCP/HCPs. NCCP/HCPs in California may also be thought of as systematic conservation plans, the term "systematic conservation planning" having come from the seminal and highly cited work of the same name published in *Nature* by Christopher Margules and Robert Pressey (2000).

SCMs may be developed in a number of ways, but in the NCCP/HCPs of San Diego County, they have at times been created or modified by convening a group of scientists from state and federal wildlife agencies, universities, and non-governmental organizations (NGOs) in both conservation research and land management. It has been this author's observation, as a past participant and agency scientist, that one thing is clear. Species experts and other stakeholders are sometimes not aware that they have different perspectives on a model and erroneously assume they have consensus. In other words, a working model is treated as if it is the state of knowledge on a species or natural community shared and understood by all; then, stakeholders new to the model demonstrate this is not the case by suggesting changes. If model assumptions are to be used explicitly to affect management and monitoring decisions, it is significant that they be shared assumptions.

The need for shared, explicit conceptual models or learning processes among conservation planning participants has been identified in the literature (Margoluis et al. 2009, Grantham et al. 2010, Schmolke et al. 2010, Biggs et al. 2011, Franklin et al. 2011, and Pressey et al. 2017). Schmolke et al. (2010) looked for consensus on the elements of good modeling practice in a literature review of 41 publications, going back to 1995 and in various fields including biological conservation. The authors found 13 convergent elements of the modeling process considered critical to the role of models in environmental decision making. One such element was a conceptual model, for formulating assumptions about a system and a preliminary understanding of its internal organization and operation.

Conceptual models have been identified as central to monitoring (Noon 2003), especially in an adaptive management context, which necessarily treats assumed causal relationships between modeled ecological variables as hypotheses (Woodward et al. 1999, Barrows et al. 2005, Franklin et al. 2011, Runge et al. 2011). Where there is uncertainty regarding causal relationships, conceptual models represent a baseline of current knowledge that can be updated as new information becomes available. However, despite authors acknowledging the revision of conceptual models as a stage in an adaptive management feedback loop (see Figure 2.1 as a sample), no studies have been found that elucidate the actual process of revision, although observations on the initial creation of conceptual models in workshop settings have been reported in the literature (Heemskerk et al. 2003).

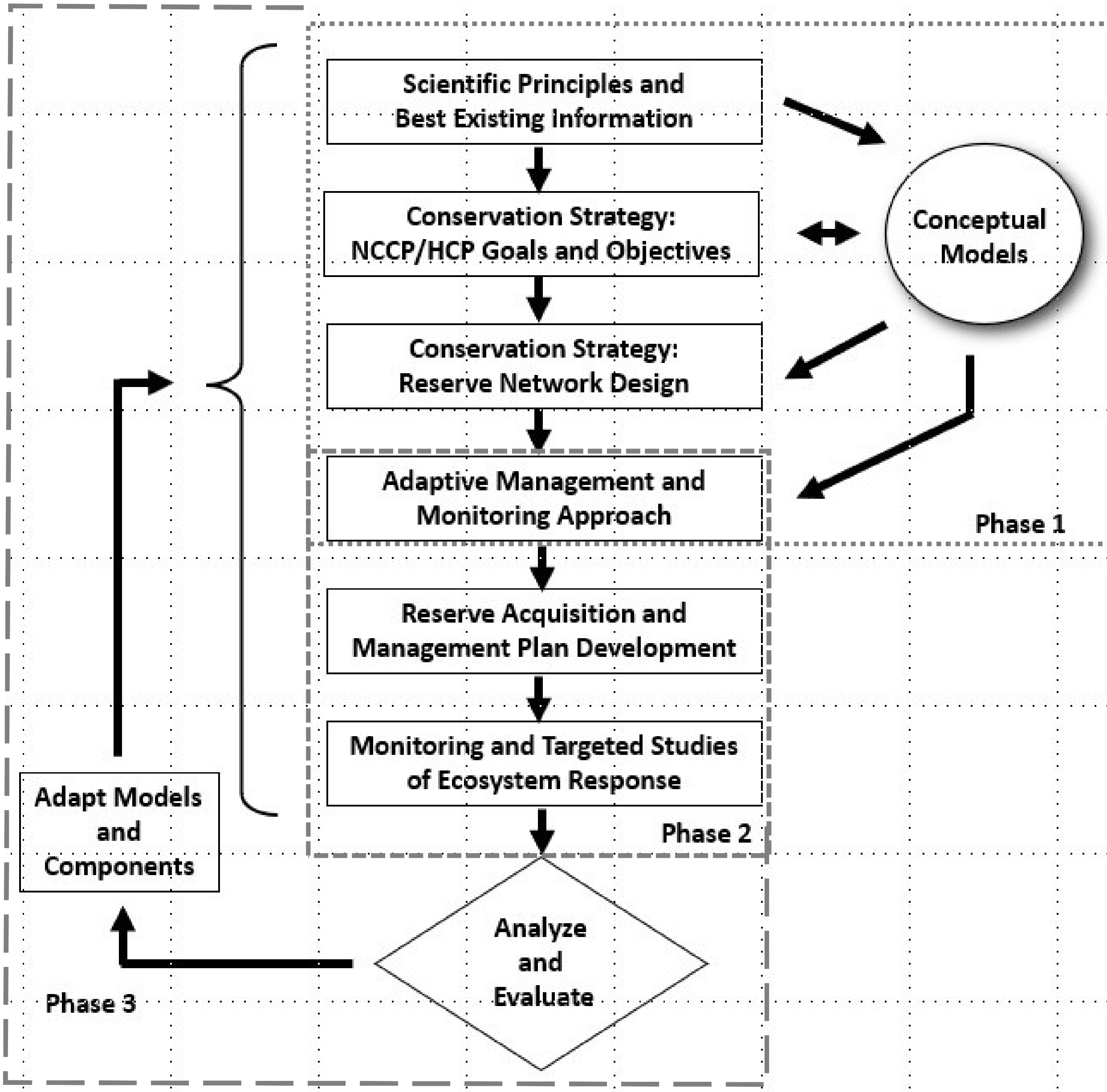

Figure 2.1. Phases of the adaptive management feedback loop (adapted from Atkinson et al. 2004) as defined for this study. Phase 1 involves creating and editing conceptual models in the planning phase of an NCCP/HCP. The focus of Chapter 1 of this dissertation, also published as a study (Parisi and Greco 2021), Phase 1 includes applying the best available science to the conservation strategy and adaptive management and monitoring approach of a plan. Phase 2 involves creating and editing conceptual models in the implementation phase of an NCCP/HCP, after the plan has been approved. One focus of this study, Phase 2 includes using the models to develop management plans and identify key uncertainties for targeted studies related to monitoring. A second focus of this study, Phase 3 involves adapting conceptual models to refine an NCCP/HCP during implementation. This phase includes analyzing and evaluating monitoring and targeted studies data and adapting the models to refine the NCCP/HCP for effectiveness.

A review of the literature also supports the need for interdisciplinary studies that include the socio-political aspects of conservation planning as well as the biological-ecological (Heemskerk et al. (2003), Balmford & Cowling (2006), Christie (2011), Ban et al. (2013), and Mair et al. (2018). Notably, the first major contributions to Margules & Pressey's original (2000) protocol for systematic conservation planning go beyond analyzing biological and ecological data as they relate to achieving conservation targets, the original six steps outlined by the authors. In 2008, Pressey & Bottrill added five steps, recognizing the value of social, political, and economic data. Such data determine opportunities and constraints for planning in a political context, conservation goals as they relate to stakeholder values, and cost. Cowling and Pressey (2003) were the first to recognize the value of defining stakeholders. Sarkar & Illoldi-Rangel (2010) qualified this contribution by observing that conservation plans have little chance for successful implementation if they do not manage to negotiate socio-political issues in a planning region and by adding that stakeholders include biological experts.

This is a study of the process of creating and revising conceptual models, to gain both ecological and sociological insight. There are two primary research questions. First, when, how and by whom are species conceptual models for a science-based monitoring program initially developed? (Phase 2 of the adaptive management feedback loop, Figure 2.1). Second, when, how, and by whom are species conceptual models for a science-based monitoring program revised? (Phase 3 of the adaptive management feedback loop, Figure 2.1). The term "science-based" is used here to reflect language in statute that requires NCCPs to be based on the best available scientific information regarding the status of covered species and the impacts of permitted activities on those species (Fish and Game Code Section 2820(a)(6).

METHODS

A number of sources were consulted to determine when SCMs are created and later refined. Strategic documents were consulted to understand when and how often SCM creation and adaptation are recommended to occur (Lewison and Deutschman 2014, San Diego Management and Monitoring Program (SDMMP) and The Nature Conservancy 2017). The SDMMP web portal page devoted to reports was searched for management planning documents using the keywords “management plan”, “monitoring plan”, “strategy” or “strategic plan” and “framework”. This yielded a total of 48 management planning documents available for download, 36 of which were for individual reserves in San Diego County and 12 of which were for species or natural communities that occurred on one or more reserves throughout the county. These documents were searched using the keywords “concept” and “model” to determine whether they referenced a SCM.

The primary methodology applied to understanding how and by whom SCMs for a science-based monitoring program are created and later refined was grounded theory analysis (Corbin and Strauss 2015), a systematic way of constructing theory through observation, coding, researcher self-reflection, and inductive reasoning. Grounded theory studies in the context of regional conservation planning are not common in the literature. However, grounded theory studies successfully codifying decision-making in the face of complexity and uncertainty are, and they abound in fields such as health sciences (see Gillespie et al. 2015 for an example). Designers of adaptive management and monitoring programs similarly face both complexity and uncertainty and they are engaged in making management decisions that may carry some risk, in this case for populations of endangered or threatened species. A grounded theory approach showed promise in this context for yielding insight into decision-making.

San Diego County (Figure 2.2) was chosen as a case study area for several reasons, although regional conservation planning occurs statewide in California. First, the state's NCCP program originated there in the early 1990s and so the county has the oldest plans with the longest histories of adapting management and monitoring to the best available science and the most well-established process for doing so. Second, San Diego is the first known county in California to have organized a region-wide management and monitoring program for species and natural communities that spans across individual reserves. In 1987, voters approved a 20-year half-cent sales tax on various transportation projects. The tax was extended by ordinance in 2004 to the year 2048. With this funding, the San Diego Association of Governments (SANDAG) established an Environmental Mitigation Program to fund the San Diego Management and Monitoring Program (SDMMP), which contracts with scientists from the United States Geological Survey (USGS). In the same region, the San Diego State University Institute for Ecological Monitoring and Management (SDSU IEMMP) also provides scientific expertise for land managers and planners. Finally, limiting the study to one region was likely to result in a relatively large sample out of the population of potential study participants. Results may be generalizable or of interest to conservation plans much newer to the process.

Data sources for analyzing the creation and adaptation of SCMs in Phases 2 and 3 of the adaptive management feedback loop are presented in Table 2.1. The analysis was applied to both semi-structured, audio-video interviews with study participants via coding of interviewed transcriptions and to text documents via keyword searches. Fifteen individuals were

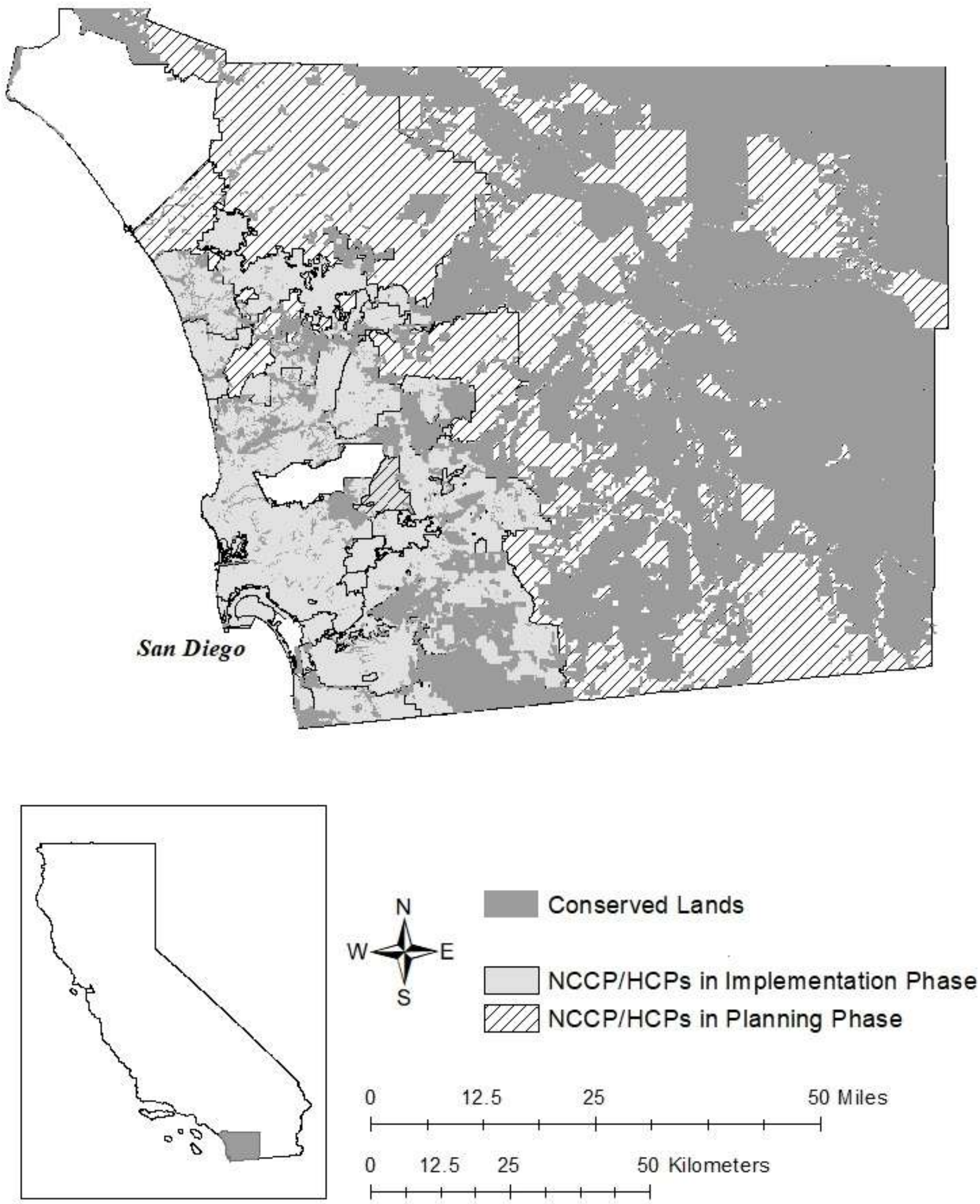

Figure 2.2. Study area of San Diego County, California. NCCP/HCPs in the planning phase have not yet been permitted. NCCPs in the implementation phase have been permitted and are actively acquiring new reserve lands. Conserved lands occur throughout the county.

Table 2.1. Data sources for a grounded theory analysis on how and by whom species conceptual models (SCMs) are created and later refined.

Audio-Video Semi-structured Interviews, December 2021 – April 2022 (*n = 16*) *		
Category	**Role in Planning or Implementing NCCP/HCPs**	**Role in Species Conceptual Modeling**
Wildlife Agency Scientists (*n = 4*) Scientists from the US Fish and Wildlife Service or California Department of Fish and Wildlife whose primary role is planning and permitting NCCP/HCPs	Ensuring compliance with federal or state endangered species acts	Ensuring the best available science is applied to planning and implementation, at times serving as a species expert
Monitoring Research Scientists (*n = 6)* Scientists from non-governmental organizations or academic institutes who facilitate model development or serve in a coordinating function with monitoring and management	Developing science and applying it to planning or adaptive management and monitoring	Facilitating model development among species experts and other stakeholders, at times serving as a species expert
Private Consulting Planners (*n = 2*) Scientists from for-profit consulting firms specializing in regional conservation planning	Developing NCCPs and HCPs and preparing management documents, at times collecting field data or developing science	Facilitating model development among species experts and other stakeholders, at times serving as a species expert
Land Managers (*n = 4*) Scientists whose primary role is on-the-ground reserve management; may include individuals from wildlife agencies or non-governmental organizations	Implementing management actions on the ground to achieve the biological goals and objectives of a regional conservation strategy for a species or natural community; may or may not be affiliated with an NCCP/HCP	Translating model components into realistic management actions (e.g. eradicating a known anthropogenic threat such as an invasive species), at times facilitating model development as a species expert
**Notes: All interviewees have education and experience in the biological sciences; they are distinguished here by their primary roles in planning or implementing NCCP/HCPs and in developing species conceptual models. Individuals not currently developing models were asked to respond from the perspective they had when they did. One individual responded from two distinct perspectives and is included in two categories.*		

Conceptual Model Workshop Written Materials (February 2012)
Communications to Workshop Participants: • Initial and final invitations to attend the workshop • E-mails to invitees providing background information on the modeling process • Plenary presentation Reports: • Deutschman, D. and S. Strahm. 2012. Monitoring and management in the San Diego Multiple Species Conservation Program: results from a structured workshop. Prepared by San Diego State University for San Diego Association of Governments. • Lewison, R. L., D. H. Deutschman, E. Marnocha, C. Tredick, P. McIntyre. 2012. Developing conceptual models: translating knowledge into action: building and implementing an integrated framework for monitoring and management in San Diego County. Proceedings from a workshop held February 29, 2012. Mission Trails Regional Park. Prepared by San Diego State University Institute for Ecological Monitoring and Management for San Diego Association of Governments. Participant Feedback: • Appendix II of Lewison et al. 2012. Question 1: Which of the following best describes your job? (*n=23 respondents*)* Planner (*n = 2*) Land/Resource Manager (*n= 3*) Research/Monitoring (*n = 4*) Boots on the ground (*n = 2*) A little bit of everything (*n = 10*) Other (please specify) (*n = 2*) Question 7: How would you rate the breakout session you participated in? (*18 responses or a 78% response rate*) Question 8: Please comment on the workshop content. What was most relevant and useful for you? What was least relevant and useful? (*17 responses or a 74% response rate*)
*****_Notes: Sample may not be mutually exclusive with that of audio-video interviewees (above); workshop survey was anonymous and so some individuals are likely represented in both data sets. Only open-ended responses from Question 7 and Question 8 were used in the grounded theory analysis._

audio-video interviewed for the study, representing a diversity of roles in both planning and implementing NCCP/HCPs and in species conceptual modeling: wildlife agency scientists (*n = 4*), monitoring research scientists (*n = 6*), private consulting planners (*n = 2*), and land managers (*n = 4*). Individuals not currently developing models were asked to respond from the perspective they had when they did. One individual responded from two distinct perspectives and is included in two categories, for a total sample size of 16.

Initially, such categorical sampling was purposive. Open-ended responses from an anonymous survey following a conceptual modeling workshop held in 2012 (Lewison et al. 2012, Appendix II) revealed differences in experiences of and attitudes toward group model-building, which may have been due to different roles in planning and implementing NCCP/HCPs, especially between monitoring research scientists and land managers. Then it was discovered during audio-video interviews that there is a great deal of overlap in roles during model development among the categories. For example, there were individuals in every category who sometimes served as a species expert on a model. Thus, results to distinguish among the categories would prove to be inconclusive. Readers will also note from Table 2.1 that the largest category of respondents in the 2012 conceptual modeling workshop were those who described their jobs as "a little bit of everything."

Interview questions are presented in Table 2.2. Interviews were semi-structured in that they were guided by the interview questions but also allowed for follow-up questions by the researcher or additional insights freely offered by interviewees. All interviews were conducted by the author, aka the researcher, in subsequent text. Prior to each interview, the participant was read a consent script describing the study and asking for verbal agreement to

Table 2.2. Semi-structured interview questions.

Initial Questions

- What is your job title?
- Is your education or training reflected in your job title? If not, can you clarify?
- Is your job function (e.g. scientist, planner, ranger, land manager) reflected in your job title? If not can you clarify?
- What is your role in planning or implementing NCCPs or HCPs in the San Diego area?

Concept-related Questions

I am studying the process of creating and refining management-oriented species conceptual models (show sample model) in both NCCP planning and in adaptive management and monitoring (show figure representing the adaptive management feedback loop).

- Have you participated in creating a species conceptual model in your work? If so, what role did you play? Please identify if your job title or affiliation was different than it is now.
- What process did you engage in? (e.g. working alone or with a small group of species experts, in a workshop setting with both scientists and land managers)
- Have you participated in refining a species conceptual model based on monitoring data? If so, what role did you play? Please identify if your job title or affiliation was different than it is now.
- What process did you engage in?
- Did you ever disagree with other experts on a model? If so, what was the process for resolving differences?
- Were you ever surprised to discover there was not consensus on a model? Can you explain the experience?
- Do you have anything to add?
- Is there anyone else you recommend that I interview?

participate. The consent script included a disclaimer from the researcher to address a potential ethical concern: “Although my career includes having managed NCCPs statewide for the California Department of Fish and Wildlife, my role here is strictly as a graduate researcher with UC Davis and I no longer have influence over funding for the work we will be discussing.” Participants were asked for consent to having the interview audio-video taped and transcribed and offered the alternative of the researcher taking notes without recording. All participants agreed to both taping and transcription. They were also offered the chance to preview any resulting reports or publications, to verify both anonymity of their contributions as well as accuracy of results.

All audio-video interviews were conducted using Zoom©, with post-processing files from the recorded session saved to an off-line hard drive. Audio tapes were then uploaded to Rev.com© for an automated transcription, which was later edited by the researcher. Immediately following an interview, any characteristics of the interview believed to lend context to what was said were noted by the researcher. Paper field notes from each interview were encoded as to the identity of each participant and stored in a private archive.

Research questions revolve around decision-making at various stages of the process conceptualized in Figure 2.1. Transcripts, field notes, and text data sources were analyzed for emergent categories and coded, initially openly. Similar codes were grouped together through axial coding to identify subcategories and dimensions of each subcategory. As new categories, subcategories, or dimensions emerged, all notes taken prior were reevaluated and recoded to reflect the changes. This iterative process continued until no new categories, subcategories, or dimensions emerged; the data had become saturated. Also constant were researcher reflections on how personal thoughts or experiences could be shaping interpretation of the data.

RESULTS

In terms of when and how often SCMs are created and later refined (Phases 2 and 3 of the adaptive management feedback loop, Figure 2.1), the framework management plan guidelines authored by Lewison and Deutschman (2014) recommend two temporal scales for a process that includes SCMs – one that involves rapid updates to management and monitoring that occurs every one to five years, for example, and one that involves a reassessment of biological goals and objectives that occurs every 10 years or so.

The document search of management and monitoring reports showed that SCMs come into play mostly when species-specific management and monitoring plans are developed. A portion of these plans are labeled “framework” plans, intended to apply as regional strategies for species or groups of species that transcend reserve boundaries. Nine out of 12 or 75% of these plans referenced or contained SCMs. SCMs are less likely to be referenced when reserve-specific management plans are developed. Eight out of 36 or 22% of these plans referenced or contained an SCM. Interviewees were able to confirm the timing of conceptual model building in Phase 2.

However, it appears that conceptual model adaptation following analysis of monitoring data, Phase 3 in the adaptive management feedback loop (Figure 2.1), may not yet be happening in a formal way with species experts and other stakeholders. “I'm thinking that we never went back to any of these models to update them based on our research and management. That needs to happen,” reflected one interviewee. Some noted that it was happening internally, in their own minds, as they considered what a set of monitoring data was telling them. Others hinted at the idealistic nature of the adaptive management feedback loop itself even as they supported the process: "… that beautiful diagram" or something to which "lip service" is paid are two examples.

Results of the grounded theory analysis to understand how and by whom SCMs are created and later refined is presented in Figure 2.3: "A Collaborative Ideal: Personalities and Attitudes Affect Outcomes and Consensus is Reported." A successful outcome is defined here as producing a model that has utility for species experts and other stakeholders in meeting the biological goals and objectives of a conservation plan. Results indicate stakeholders other than species experts are included in species conceptual model building, but it varies as to how they are brought in. In some cases, species experts work together on an initial model and later share it, possibly in stages, with ever larger groups of stakeholders, as reported by one interviewee. In other cases, such as the 2012 conceptual modeling workshop (Lewison et al. 2012) a formal and region-wide effort to review models involves the broadest possible array of stakeholders all at once. It appears that the 2012 workshop was the first of its kind in the region, although individual organizations were building models for habitat management plans well before 2012 (see Spiegelberg [2005] for example). Components of the Figure 2.3 model are described below.

<u>A Collaborative Ideal</u>. There is an expectation or a standard of collaboration for participants in this work, and meeting moderators are employed to facilitate it. The ideal is communicated in written materials and held as a standard in workshops. The web portal for the

A Collaborative Ideal: Personalities and Attitudes of Individuals Affect Outcomes and Consensus is Reported

There is an expectation or a standard of collaboration, and meeting moderators are employed to facilitate it. More collaborative or less collaborative circumstances (columns below) mostly describe personalities and attitudes of individual participants and have different outcomes. Consensus is reported, generally without disclosing any difficulties in achieving it.

More Collaborative

Participants place a value on collaboration.

Participants are characterized as:

- transparent
- open-minded
- inclusive
- respectful
- willing to participate
- aware of a common goal
- facilitator oriented themselves

Inclusiveness of stakeholders is considered a strength.

- Builds trust
- Promotes buy-in and ownership
- Increases the chances that a model will be used
- A mixed group is real life.

Diversity of expertise is acknowledged.

- Unique areas of expertise are acknowledged – science, land management practices, concept modeling, regulation.
- Unique forms of data input are acknowledged – systematic academic science, anecdotal field observations.

Resolution occurs.
Disagreements are treated as critical uncertainties in the model or the group reaches a solution acceptable to all.

Less Collaborative

Meeting moderators facilitate collaboration when personalities or roles initially inhibit it.

- One or more strong personalities dominate, each with a need to be right.
- One or more scientists are invested in a model, set of data, or way of doing things.
- Knowledgeable participants are shy about speaking up.
- Participants are aware of a power imbalance and are hesitant to speak.

Inclusiveness of stakeholders is considered a limitation.

- Too many people and not all the right people.
- Time is too limited for a variability of knowledge.
- A mixed group is not real life.

Diversity of expertise is ignored.

- A higher value is placed on some areas of expertise.
- A higher value is placed on some forms of data input.
- A higher status is given to some scientists.

Resolution occurs.
Some voices may not be included or the solution is written broadly and generally so that consensus can be reported.

Consensus is reported.
Difficulties in achieving resolution are generally not reported.

Figure 2.3. Diagram of a collaborative ideal, showing how personalities and attitudes of individuals affect outcomes and how consensus is reported.

San Diego Management and Monitoring Program bears the subtitle “Applying science to conservation through collaboration." The San Diego State University Institute for Ecological Monitoring and Management based its 2012 workshop on a model of scientific collaboration, the Dahlem Konferenzen model (Freie Universität Berlin 2007). Dahlem conferences are a structured way to foster the exchange of information and ideas among scientists and the development of new theses. To this end, they are designed to identify areas of broad consensus as well as expose areas of contention and disagreement. Participation is by invitation and participants prepare by reading background papers prepared for the workshop, such that the workshop can begin with discussions, debate, and collective thinking.

Collaboration is a characteristic of conservation science, planning, and management across multiple organizations with common goals. It does not necessarily characterize any one organization or any given group of professionals with the same job title. States one interviewee: “I would expect more consensus under the umbrella of my peers, the SDMMP. It would never, ever occur to me I’m going to get consensus if I walk into the conference room of my own department in my own region and have everybody go ‘Yeah, that’s clearly what you should do.’”

<u>Personalities and attitudes of individuals affect outcomes</u>. More collaborative or less collaborative circumstances have mostly to do with the personalities and attitudes of individual participants. There is no consistent pattern of either circumstance applying to one type of organization or one category of participants interviewed. Do participants place a value on collaboration or do they have personalities or roles that initially inhibit it? Are stakeholders

other than species experts considered a strength or a limitation? Is diversity of expertise acknowledged or is it ignored?

In more collaborative circumstances, individuals place a value on collaboration itself. Interviewees used several different phrases to allude to this value, including “the importance of having a group,” “going through the group thinking process,” “the more brains you could have involved the better,” and “getting people together, it doesn’t matter if they finish the model … together, face to face.” Individuals in these groups characterize other participants as transparent, open-minded, inclusive, respectful, willing to participate, aware of a common goal, and facilitator oriented themselves. There is a will to collaborate, even as some participants recognize different perspectives in the room and the work involved in pulling them together. One monitoring research scientist described working with a land manager this way: “I realized we were approaching things from different backgrounds and different places. So what made sense to her and how she was thinking of it was not what made sense to me. I usually came at it from the land management perspective that a land manager doesn't think the way a scientist often does. You … just have to either put yourself in the middle and try to bring the two together or, as a scientist, you really need to think as a land manager, if they're the ones that are going to be implementing the management and then the monitoring and then doing the feedback loop.“

In circumstances where some personalities or roles may initially inhibit collaboration, moderators have been reported to play a role in facilitating it. Dominant personalities, each with a need to be right, were perhaps the most difficult to overcome. “There were definitely some folks who needed to have it their way,” said one interviewee with experience moderating. Similarly challenging were situations where one or more scientists were either invested in a model, felt ownership over a set of data, or were accustomed to a certain way of doing things and so were resistant to compromise.

Several interviewees described situations where knowledgeable individuals were shy about speaking up and a moderator helped. Said one experienced moderator, “I get the feeling that people are going through that sort of high school ‘Uh, I'm nervous. I don't wanna seem dumb.’“ Another interviewee described this same moderator: “[Name] sort of took the lead on it. And, I think [they] did an excellent job of keeping everybody in check and making sure that we went through the list of questions and heard everybody's opinions and everything.” This moderator also stepped in when participants were hesitant to speak because of a perceived power imbalance between them and an individual who controlled funding for the work: “I wanted [name] to understand that [they] held purse strings for everybody's fate … and so, [they were] hugely influential … I just felt like it was really important for us to know who, where the power dynamic was in each group.”

Interviewees as well as participants from the 2012 workshop varied in their attitudes towards stakeholders who were not species experts. Note in Table 2.1 that all categories of interviewees had individuals who at times served as a species expert. Research monitoring scientists primarily provided expertise and land managers primarily planned and executed management actions but there was still overlap between the two groups. Species expertise was also found among wildlife agency scientists and private consulting planners. Most workshop participants and interviewees considered broad stakeholder inclusion a strength – building trust, promoting buy-in and ownership, and increasing the chances that a model would be used. One workshop participant considered such inclusion to be real life: “The experience of having a diverse group of well-intentioned, but uneven in experience/knowledge was challenging. But it could be close to what happens in the future as reserve managers find they have to use a small, perhaps not fully-informed/experienced staff to develop/modify models so they can then prepare their work plans for reserve monitoring and management.” Conversely, one workshop participant considered a mixed group not to be real life, with an understanding that “… a lot of the models are being done by paid groups.” Just one additional workshop participant and one additional interviewee cited the drawbacks of broad stakeholder inclusion – too many people and not all the right people or too wide a variability in knowledge given the time limitation.

Interviewees and workshop participants also varied in recognizing expertise other than scientific expertise as essential to developing a successful working model. Those who considered such diversity a strength cited knowledge of land management practices (e.g. “what’s feasible to do on the ground”), conceptual model building itself (e.g. “abstraction and conceptualization … scaling, prioritizing, ordering, categorizing”), and regulation (e.g. “… is this process going in a way that's valid that we can defend it?”) as unique areas of expertise. They also acknowledged the value of forms of data input other than systematic academic science, such as on-the-ground observation. One interviewee noted: “… you would think that the anecdotal data would be good clues about what a kind of science needs to be collected to go into one of those conceptual models.“

There is evidence from workshop feedback and interviewees that there are situations where different areas of expertise are simply ignored. Three workshop participants made comments to suggest that they only recognized the species experts in the room. “I think we would have come up with a more useful conceptual model for Hermes copper if perhaps 2 or 3 of us had worked up full models, then submitted them to the group for review and refinement”, is one example. A few interviewees observed a disparity in how different forms of data input were recognized and different types of scientists were given status, generally with the analysis of a research monitoring scientist, especially one with an advanced degree, recognized more than the field observations of a land manager. “There could be somebody on the ground who's very, very knowledgeable about the species … but because they don't hold, you know, a higher degree, their opinion is discounted or because it's based on observation and anecdotal information rather than a publication”, said one interviewee.

Resolution occurs in both more and less collaborative circumstances, but the outcomes are different. Individuals in more collaborative groups did report disagreements, yet they characterized these interactions as “good, healthy disagreement,” “healthy debate,” or reaching “some conclusion that everyone can live with.” Resolution in some cases included treating disagreements as critical uncertainties in a model. In less collaborative situations, there is a risk that some voices may simply not be included or that, to achieve consensus among a group that has multiple points of view, a model is written in a way that limits its utility. One land manager stated, “… either I'm not gonna get a consensus or I'm going to write something so broad and general so that everybody sort of feels happy about It … and it's going to be worthless.”

Regardless of circumstance, it is consensus that is reported. Difficulties in achieving it are generally not reported. A keyword search of the 2012 workshop proceedings yielded 101 instances of the word "group" or "participants" followed by a verb suggesting collaboration. There were 28 such verbs in total (Table 2.3). A lack of consensus on a portion of a model only appears once when describing group findings. No versions of the words "controversy" or "disagreement" appear anywhere in the document. There appear to be some strong incentives to formally report consensus. One is funding. One interviewee reflected, "…maybe that's a reason subconsciously or consciously we leave things out of our reports because we think it's bad ... I think particularly for people who are on soft funding, there's also this desire, this motivation to make it look like everything went your way." Another interviewee who served as a facilitator described situations where group members did not want to initiate a controversy with one or more strong personalities and so let it appear as though there was consensus by the end of a meeting, only to send private follow-up correspondence suggesting otherwise.

A final result worth noting is a theme that emerged regarding model utility as it relates to model complexity, although interviewees were not asked about this issue directly. Hierl et al. (2007) reported a tendency to create highly complex models when there is a desire to include the opinions and expertise from a broad array of stakeholders, who come to the table with different experiences and perspectives. A number of interviewees shared their experiences

Table 2.3. Verbs to suggest group collaboration – 2012 workshop proceedings (Lewison et al. 2012).

Accepted	Decided	Focused	Ranked
Achieved (consensus)	Deemed (too complex)	Identified	Recognized
Acknowledged	Determined	Included	Reviewed
Agreed	Developed	Listed	Started (from scratch)
Chose	Discussed	Noted	Understood
Created	Evaluated	Preferred	Used (draft models)
Debated	Felt	Progressed	Viewed

with overly complex models. “In the early days of making models, they were just polygons or squares or rectangles on a path, arrows going all over the place. … And, I did not like those. And I remember that [name of species] looked like that when we were done. … There was nothing to follow. There was no beginning and no end or really telling you what to do,” said one interviewee. Another reported, “We had for [name of species] … one early draft of a conceptual model. … It just looked like a bowl of spaghetti, you know, there was just lines going everywhere.”

DISCUSSION

Most significant among the results of when and how often SCMs are created and later refined is that species experts interviewed could not recall formal, group efforts to update their SCMs based on monitoring data. However, the timing of such updates recommended by the strategic document authored by Lewison and Deutschman (2014) would place those updates for several species as just now coming due, 10 years past their creation in 2012.

Results of the grounded theory analysis of how and by whom SCMs are created and later refined are consistent with reports in the literature in several ways. First, collaboration is often the stated or implied standard for environmental planning and management decision-making that involves multiple stakeholders (Gutrich et al. 2005, Manring 2007, Koontz and Bodine 2008, Mauz and Granjou 2013, Goggin et al. 2015). Mauz and Granjou (2013) demonstrated that scientists with different ways of knowing, such as modelling ecologists and field naturalists, can establish close collaboration. Second, scientists in this study share many of the characteristics associated with a culture of research scientists in the public realm (Lacy et al. 2014), including a commitment to problem-solving, open communication, and inclusiveness or egalitarianism. Even the private consulting planners working in for-profit organizations that were interviewed have public agencies as clients and have worked in the public realm themselves.

Finally, personalities and attitudes of individuals do affect outcomes. For example, a study in New South Wales, Australia, documented the factors that produced successful partnerships between a culture of environmental scientists and the cultures of practitioners such as regulators and land managers in leaving an enduring legacy for the environment (Goggin et al. 2015). Practitioners noted nine common attributes of scientists, most of which have to do with personality or attitude or forms of expertise other than scientific: a committed, dedicated and passionate person; a leader or champion; a rigorous expert; well connected to universities or other organizations; a clear and effective communicator; who understood the practitioner's aims, needs and constraints; who was accessible and flexible; could function as a knowledge broker and translate complex and technical information into simple terms; and was pleasant, personable and "easy to get along with." Also of note here is an ability to understand and bring together multiple perspectives.

There are some limitations to this study. Were it not for a global pandemic, the study may have included direct observations of individuals engaged in group model development. One-on-one audio-video interviews only allow for second hand reporting of group dynamics. It is also possible that results are skewed towards representing the most collaborative scientists, those with a willingness to be interviewed and an active interest in the study results. Grounded theorists and other qualitative researchers may note that the sample size of interviews (n = 16) is relatively small. Corbin and Strauss (2015) admit that it is difficult to set a number, although they caution that extremely small samples such as five or six are unlikely to provide enough data for saturation. Other grounded theorists have recommended a minimum number of interviews, such as 30 (Thomson 2011), even as they report research findings indicating that the point of theoretical saturation can be affected by the scope of the research question, the sensitivity of the phenomena, and the ability of the researcher. As stated previously, in this study, efforts to distinguish categories of individuals based on their roles in planning and implementing NCCP/HCPs would prove to be inconclusive. With a great deal of overlap among the categories in roles during model development; the sample proved to be more homogenous than was anticipated. Saturation of the data was based on emergent categories as they related to the entire sample and was simpler to achieve than if each initial category of individuals were treated as a separate condition.

In conclusion are some recommendations for best practices. First, species experts should continue to include a broad array of other stakeholders in SCM creation and refinement, for both model utility and buy-in. Second, it is strongly recommended that groups always employ an experienced facilitator, one cognizant of multiple perspectives and skilled at bringing them together and one who can help keep focus on tasks rather than personalities. One interviewee described his strategy this way, “I would try and structure the discussion to, you know, stay focused on the problem, not the personalities. … So, context matters. And if you facilitate the discussion to focus on what matters rather than extreme positions, then maybe you can make progress.” The ideal meeting facilitator may or may not be the species expert who convenes the meeting.

Third, attitudes toward broad stakeholder inclusion and diverse forms of expertise could be aided by managing expectations in workshop settings. The Initial Announcement (Save the Date) of the 2012 conceptual modeling workshop (Lewison et al. 2012, Appendix IV) was clearly intended to purposely attract a broad array of stakeholders, yet this intent highlighting the value of stakeholder input appears much less so in the Final Invitation (Appendix V) and the Conceptual Model Workshop – Plenary Presentation (Appendix III). It is clear some workshop participants focused almost solely on species expertise. Wrote one participant, "I think that having sample conceptual models created may have put some participants off – that is, we are considered the 'experts' in the room, and it might have been more streamlined to first have the group take a crack at developing a conceptual model on our own vs. [sic] responding to an existing model."

These recommendations are supported in the literature. A grounded theory literature review of best practices for stakeholder participation in environmental management conducted by Reed (2008) lists these: 1) a philosophy that emphasizes empowerment, equity, trust, and learning; 2) a practice of considering stakeholder participation as early as possible and throughout the process; 3) a systematic representation of relevant stakeholders; 4) clear objectives for the participatory process agreed to at the outset; 5) methods that consider the objectives, types of participants, and appropriate level of engagement; 6) highly skilled facilitation as essential --especially in handling dominant individuals, encouraging participants to re-evaluate entrenched positions, and getting the most from reticent individuals (all circumstances that showed up in this study); 7) an integration of local (implicit, informal, and observational) and scientific (explicit, systematic, and decontextualized) knowledge; and, 8) an institutionalization of the participatory process. A review of scientific and grey literature conducted by Addison et al. (2013) listed common objections to the use of models in conservation decision-making and several solutions for overcoming them. In modeling practice, especially, when decision-makers do not believe a model represents their conceptual understanding or is too complex to be useful, the authors recommend a number of solutions to improve communication. They include developing clear objectives and management alternatives for the decision context, engaging with stakeholders and experts in participatory decision-making, using a skilled facilitator, and building trust.

Finally, and beyond the scope of this paper to fully explore, is the consideration of how best to share and make explicit the process of adapting models to refine management and monitoring actions (Phase 3 of Figure 2.1). SDMMP and The Nature Conservancy (2017) have developed a strategic roadmap - a comprehensive, landscape-level, adaptive management and monitoring framework for prioritized species and vegetation communities in western San Diego County. Included with the strategic roadmap is an on-line portal (https://sdmmp.com/portal.php) for accessing databases, viewing maps, and tracking progress towards goals, objectives, and conservation actions. Tracked updates to SCMs based on monitoring data and broad stakeholder input would be well placed here.

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Chapter 3. Assessing Conservation Outcomes and Maximizing Habitat Connectivity for Multiple Species in Systematic Conservation Plans: A Case Study in Yolo County, California

ABSTRACT

Context

Habitat connectivity is key when designing reserve networks for conservation of species at risk. Acquiring land over time to achieve connectivity for multiple species in a systematic conservation plan can pose a data challenge because of limited species occurrence data and complexity in using multiple species models.

Objectives

We evaluated four land acquisition strategies in a data-challenged plan in their ability to meet each of three objectives: 1) meet conservation targets, 2) maximize structural habitat connectivity, and 3) maximize connectivity for multiple focal species.

Methods

For this case study in Yolo County, California, we compared the efficiency of strategies to meet conservation targets using MARXAN. We compared structural connectivity of MARXAN solutions for each strategy using 'Contiguity Index' and 'Perimeter-Area Ratio' in FRAGSTATS and 'Nearest Neighbor' in ArcGIS. We compared focal species connectivity by using 'Cost Connectivity' in ArcGIS to define species-specific least cost networks and then assessing each network's conformity with MARXAN solutions.

Results

Although the study plan defines 'Priority 1', 'Priority 2', and 'corridor' lands, it is Priority 1 parcels and corridor parcels together that provide 1) the best combination for attaining conservation targets with efficiency, 2) the highest structural connectivity, and 3) high connectivity for the greatest number of focal species. Priority 1 lands alone do not meet

conservation targets, yet Priority 2 lands are a less effective adjunct to Priority 1 lands than are Corridor lands.

Conclusions

Because land acquisition patterns are time sensitive and data may be limited, we recommend using spatial prioritization software often and employing several measures of connectivity in decision-making.

Keywords

habitat connectivity, endangered species, systematic conservation planning, reserve selection, MARXAN

INTRODUCTION

Connectivity of suitable habitat is a key consideration when planning for species conservation, particularly the long-term survival of a species. A desired conservation outcome for a species would be one in which critical portions of its range have been conserved and there is high connectedness in a reserve system between areas of suitable habitat. Classic works in landscape ecology and conservation highlight the importance of this landscape-level approach to species protection (Noss et al. 1997, Beier and Noss 1998, Wiens 2009). Landscape connectivity has been defined as both structural and functional. Structural connectivity is based on the spatial arrangement of broad structural habitat types or land cover types, such as forests or grasslands, in a landscape while functional connectivity takes species-specific needs into account, such as dispersal behavior (Theobald 2006).

Designing reserve networks to achieve connectivity for multiple species can pose a data challenge to regional conservation planners. Plans are often forced to rely on suitable habitat as a surrogate for species protection because actual species location or occurrence data is limited (Noss et al. 1997, Rondinini et al. 2006, Winchell & Doherty 2008). Thus, suitable habitat forms the basis for a species distribution model (SDM) that informs reserve design. Moreover, empirical evidence shows that patterns of species distribution are often constrained by dispersal limitation (Nathan, 2001). Yet, even novel approaches that reduce uncertainty in reserve selection by incorporating known species' dispersal distances in predictive modeling (e.g. Underwood et al. 2010) rely on occurrence records.

Regardless of the level of data supporting a species distribution model (SDM), it can also be a challenge to use multiple SDMs together in reserve design. A search of the literature reveals the complexity involved in using SDMs collectively for this purpose. Some have noted the difficulty in selecting the best SDM for a specific species, let alone an appropriate ensemble modeling method for multiple species (Lin et al. 2018). Others have shown how the vast majority of research on SDMs focuses on methods rather than application to decision problems such as reserve selection (Guisan et al. 2013, Mair et al. 2018).

Here we evaluate the relative efficiency of four different land acquisition strategies in both meeting conservation targets and attaining connectivity for multiple species within the context of a systematic conservation plan that has limited species occurrence data, the Yolo Habitat Conservation Plan / Natural Community Conservation Plan (hereafter "Yolo HCP/NCCP" or "plan"). The term "systematic conservation planning" comes from the seminal work of the same name published in *Nature* by Margules and Pressey (2000), who outlined a systematic approach to locating and designing reserves and meeting conservation goals. In California, both Natural Community Conservation Plans (NCCPs) under California's Endangered Species Act (Fish and Game Code Section 2800 et seq.) and federal Habitat Conservation Plans (HCPs) under the Endangered Species Act Section 10(a)(1)(B) may be considered systematic conservation plans (SCPs). Both are intended to establish large reserve networks of permanently protected lands and long-term programs designed to conserve, mitigate for, and manage species legally "covered" by a plan while they allow compatible and appropriate development (Presley 2011). They offer an alternative to traditional approaches to endangered species conservation, which often mitigate or offset impacts to, or "incidental take" of, species on project-by-project basis (McKenney and Kiesecker 2010), a practice that results in uncoordinated, "piecemeal", and far less effective conservation (Underwood 2010).

Going beyond the requirements of federal HCPs, NCCPs must provide recovery – "methods and procedures within the plan area that are necessary to bring any covered species to the point at which the measures provided pursuant to Chapter 1.5 (commencing with Section 2050) [The California Endangered Species Act] are not necessary'" (Section 2805(d)). They and must also provide connectivity – "the establishment of one or more reserves or other measures that provide equivalent conservation of Covered Species within the Plan Area and linkages between them and adjacent habitat areas outside the Plan Area" (Section 2820(a)(4)(B)). In several ways, NCCPs also fit the decision-making framework of SCP as it is defined by Schwartz et al. (2018). First, theoretical foundations for NCCPs are in the fields of landscape ecology and land use planning, what Schwartz et al. term "geospatial planning".

Second, core tools for decision-making include spatial prioritization tools, such as those used in this study. Finally, core tools are applied to designing reserve systems, a key feature of NCCPs.

Species distribution models in the Yolo HCP/NCCP are not unlike those of other NCCPs in California in both type and level of data supporting them. In a study of eighteen NCCPs approved or in preparation, Parisi and Greco (2021) found that 17 out of 18 contained mapped occurrences and 15 out of 18 included classified (expert opinion) suitable habitat in vector format. The main source of occurrence data for species at risk is the California Natural Diversity Database (CNDDB), a "natural heritage program" data set overseen by NatureServe that has an equivalent in every state (CDFW 2021).

The Yolo HCP/NCCP is also like other systematic conservation plans in identifying top priority lands in the planning phase, before the plan has been approved. In this case, Priority 1 lands are clustered around existing public and easement lands and Priority 2 lands clustered around these (Figure 3.1). In looking at the amount and pattern of priority lands, one general question arose immediately: Is it possible to meet conservation objectives for species in a plan – i.e. meet target acreages of defined suitable habitat – and still not achieve a highly-connected system over the plan's permit term? Priority 1 lands alone total 90,170 acres. At the rate of land acquisition needed to meet the plan's 24,406-acre commitment in 50 years, an average of 488 acres per year, it would take an additional 135 years to acquire all of them. There are an additional 136,000 acres of Priority 2 lands plus lands within identified corridors (Figure 6-3 of the plan). Given this, what is the best land acquisition strategy? Our analysis centers around three research questions: 1) What is the most efficient strategy for meeting conservation

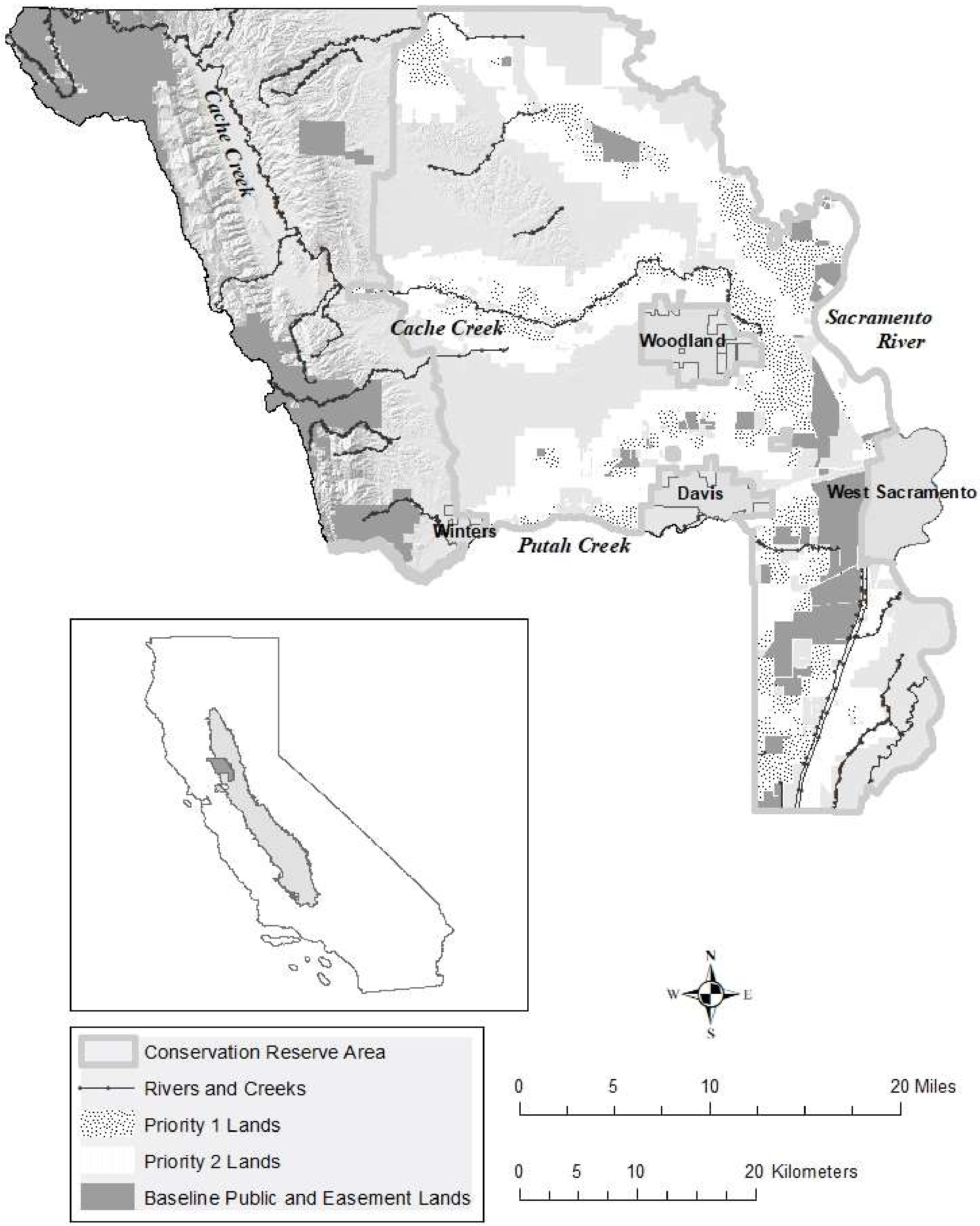


Figure 3.1. Study area of Yolo County, California. The inset shows Yolo County (dark gray) within California's Great Central Valley (light gray).

targets?, 2) What is the most efficient way to maximize structural habitat connectivity in the plan?, and 3) Is there a way to maximize connectivity for multiple focal species in a single plan?

METHODS

The Yolo HCP/NCCP plan area covers the entirety of Yolo County, California. However, the parcels eligible for analyses and acquisition reside only in the Conservation Reserve Area, which the plan defines as the valley floor (Figure 3.1). Yolo County is located within California's Great Central Valley (Figure 3.1) and is characterized by a Mediterranean-type climate, with cool, wet winters and hot, dry summers. Elevations in the county range from less than 100 feet above mean sea level on the valley floor in the eastern side of the county to approximately 3,100 feet above sea level within the mountains forming the county's northwest corner (Figure 3.1). Major hydrologic features include Cache Creek in the northern part of the county; Putah Creek, which forms much of the southern edge of the county; and the Sacramento River, which forms much of the county's eastern border. The valley floor is a matrix of agricultural lands and grasslands, some with seasonal wetlands, surrounding the county's four incorporated cities – Woodland, West Sacramento, Davis, and Winters. The highest elevations are characterized primarily as oak woodlands while riparian habitat lines the creeks and is found in remnants along the Sacramento River.

The Yolo HCP/NCCP (2018) was selected from among 17 NCCPs approved and being implemented (CDFW 2021) for several reasons. First, it was permitted relatively recently (2019), which means it is early in its implementation phase, before reserve lands have been purchased and when an analysis of potential land acquisition strategies may have the greatest effect on land purchase decisions. Second, although habitat connectivity is required of all NCCPs, this plan faces some unique challenges in not having a large base of public lands within its Conservation Reserve Area upon which to build a connected reserve network. Also, unlike many other NCCPs, the matrix of land cover is not sharply divided between urban or semi-urban parcels and natural habitat but contains agricultural land cover types, which have direct habitat value for some of the covered species and are semi-permeable for others attempting to move through them. Finally, the results are of immediate interest to conservation practitioners. Researchers in conservation have recommended bridging an existing gap between research and practice by sourcing research questions from such practitioners (Knight et al. 2008, Schwartz et al. 2018).

To determine efficient solutions for meeting conservation targets, we employed a widely used semi-optimization software package called MARXAN (Ball et al. 2011) to compare four possible land acquisition strategies (Figure 3.2), all within the Conservation Reserve Area depicted in Figure 6-5 of the plan. MARXAN is a spatial prioritization software tool that uses an algorithm for selecting reserves with maximal conservation benefits and minimal cost. Cost is defined by the user and can be both economic and ecological. Scenario A considers all parcels within the Conservation Reserve Area in selecting reserves. Scenario B includes only parcels identified as “higher priority” in Figure 6-6 of the plan (Priority 1). Scenario C is comprised of parcels identified as “higher priority” and “lower priority” (Priority 1 and 2, respectively). Scenario D includes both “higher priority” (Priority 1) parcels and parcels inside the ecological corridors shown in Figure ES-2 and Figure 6-3 of the plan. All input data for identifying conservation targets was vector-based geographic information system (GIS) data available from the Yolo Habitat Conservancy (2020b) and all data preparation for MARXAN was done in ArcGIS Desktop 10.7.1 (ESRI Inc.© 2019).

We chose land ownership parcels as a planning or reserve selection unit for MARXAN, considering this the most realistic way to identify reserve network solutions, as land will be acquired in whole parcels. The alternative would be to create a regularly- spaced planar tessellation surface, composed of hexagons for example. For parcel boundaries in Scenario A, we downloaded publicly available tax assessor data from Yolo County (2020) and, using the ArcGIS extraction analysis tool 'Clip,' we clipped it to the Conservation Reserve Area boundary. Priority 1 and 2 lands layers for scenarios B, C, and D were available from the Yolo Habitat Conservancy (2020a) as selected parcels. For the ecological corridor portion of Scenario D, we intersected the downloaded parcel data with a boundary layer we created to represent ecological corridors. To create this boundary layer, we selected ecological corridor polygons (planning units 7, 9, 17 and 18) from the Planning Units layer depicted in Figure ES-2 and Figure 6-3 of the plan (Yolo Habitat Conservancy 2020b). The plan also includes a corridor for the Sacramento River. To create this polygon, we buffered a GIS line feature of the river by 0.25 miles or 1,320 feet on each side, giving it initially the same width as the Cache Creek Corridor, and then clipped the buffered feature to exclude that portion of the river in neighboring Sacramento County. Once the ecological corridor layer and parcel layer were intersected, any polygon slivers without an identifying assessor's parcel number, often those labeled "road" or "river", were deleted.

To prepare biological data for MARXAN, we first identified the total conservation commitment acreage (24,406 acres) from the Yolo HCP/NCCP within the conservation reserve area and then each unique conservation target (Table 3.1, based on Table 6-2 [a] of the plan). A target may be a single element, such as a natural community type, or a combination of elements, such as a natural community type that is also modeled habitat for a species or also in a particular location in the planning area. The source for natural community types was land cover data mapped in figures 2-5 through 2-10 of the plan. For species modeled habitat, we used the data depicted in the species maps in Appendix A: Covered Species Accounts. Location data are the planning units shown in Figure ES-2 of the plan. Where a conservation target represented the intersection of two elements, the two element layers were intersected and the polygons from the resulting layer dissolved into one. The dissolved polygon was then intersected with the parcel layers representing the four scenarios (Figure 3.2) and the acreage by parcel of a conservation target calculated for each scenario. English units have been used here for both analysis and reporting of results as these are the sole units utilized in the plan.

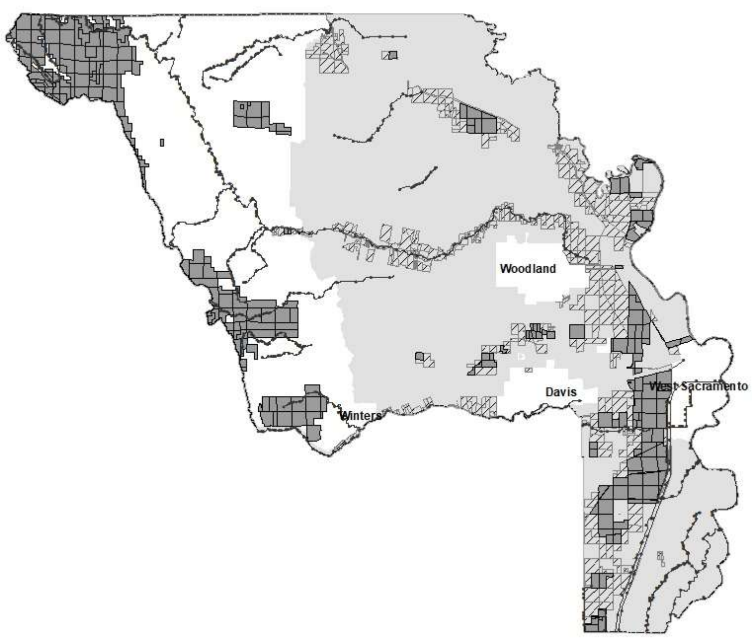
The data representing conservation targets and their values by planning unit (parcel) were then reformatted into a tab-delimited Planning Unit versus Conservation Feature, one of several input files required by MARXAN. In the Planning Unit input file, we set the cost for each parcel as its calculated acreage. The status was set at “0” for parcels potentially selected as new reserves, allowing these parcels to be in the initial (or seed) reserve system. The status of existing reserves was set at “2”, forcing them into selection as the initial part of a reserve system, although their conservation values do not appear in any input files because they do not contribute to new conservation targets.

Table 3.1. Twenty-one unique targets for MARXAN analysis, based on newly protected lands commitments listed in Table 6-2 (a) of the Yolo HCP/NCCP. Numbers in parentheses used here for identifying each unique element or unique combination of elements are not synonymous with coding numbers used to identify targets within MARXAN. Species modeled habitat commitments or location commitments are not mutually exclusive to one another relative to their shared natural community. For example, if an acreage commitment for species modeled habitat is the same as that for a natural community, then all acres for that natural community must also be modeled habitat for the species.

Natural Community	Natural Community Acreage Commitment (Inclusive)	Species Modeled Habitat	Location
Cultivated Lands (non-rice)	14,362	(1) 14,362 acres also Swainson's Hawk habitat (2) 2,500 acres also Western Burrowing Owl habitat	
Rice	2,800	(3) 2,800 acres also Giant Garter Snake habitat	
Grassland	4,430	(4) 4,430 acres also Swainson's Hawk habitat (5) 2,155 acres also Western Burrowing Owl habitat (6) 2,000 acres also California Tiger Salamander habitat	(7) 3,000 acres also in Planning Unit 5
(8) Valley Oak Woodland	10		
(9) Blue Oak Woodland	20		
(*) Alkali Prairie	33.7		33.7 acres in Woodland Regional Park

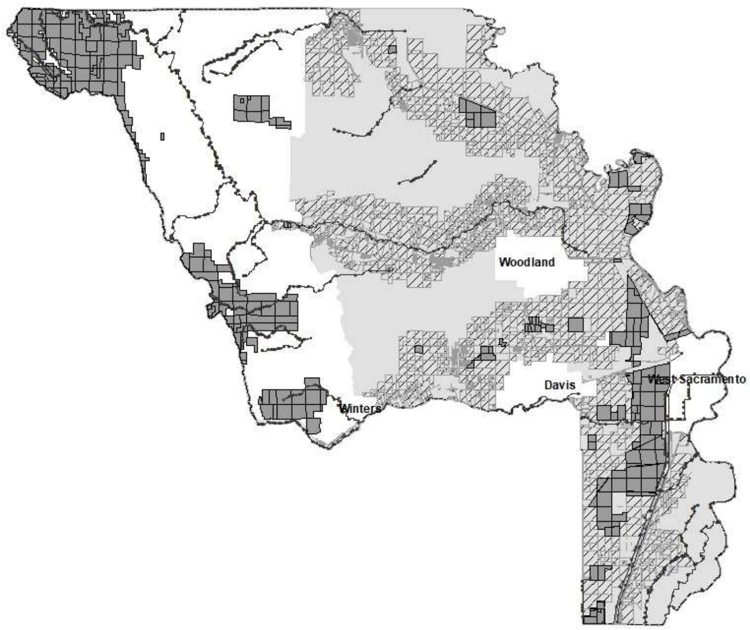
Natural Community	Natural Community Acreage Commitment (Inclusive)	Species Modeled Habitat	Location
Fresh Emergent Wetland	500	(10) 500 acres also Giant Garter Snake habitat (11) 200 acres also Tricolored Blackbird habitat	
Valley Foothill Riparian	1,600	(12) 500 acres also Yellow-billed Cuckoo habitat (13) 600 acres also Least Bell's Vireo habitat	(14) 1,600 acres also primarily in planning units 5 and 7
(15) Lacustrine_Riverine	600	(16) 36 acres also California Tiger Salamander habitat (17) 420 acres also Giant Garter Snake habitat	
Other	50	50 acres Bank Swallow habitat	(18) 50 acres also in Planning Unit 7
Any Protected Natural Community		(19) 1,160 acres also Giant Garter Snake active-season upland movement habitat (20) 2,315 also Giant Garter Snake overwintering habitat (21) 18,865 also White-tailed Kite foraging habitat	
Total	**24,406**	*Alkali Prairie was not included in the analysis as it exists in only one location. However, the 34 (rounded) acres are included here as part of the acreage total.	

(a)
Scenario A –
All Parcels

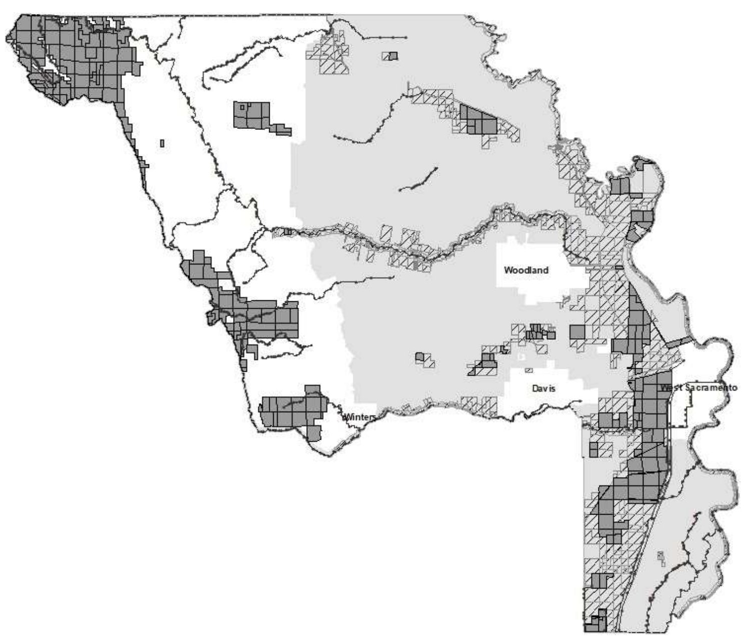


(b)
Scenario B –
Priority 1 Parcels Only

Figure 3.2a,b. Four land acquisition scenarios analyzed in MARXAN.



(c)
Scenario C – Priority 1 and 2 Parcels



(d)
Scenario D– Priority 1 and Corridor Parcels

Figure 3.2c,d. Four land acquisition scenarios analyzed in MARXAN.

Because a connected reserve system with minimal edge is a desired outcome for this plan, an optional 'boundary length' input file and 'boundary length modifier' (BLM) were used in this analysis. A BLM improves the compactness of reserve system solutions by accounting for a connectivity cost between reserves based on the effective length of their shared boundaries. The BLM value is set by the MARXAN user and represents a tradeoff between reserve cost and the desire for compactness. Boundary length between parcels included in each scenario was calculated using the 'Polygon Neighbors' tool in ArcGIS and the results were reformatted for input to MARXAN. The BLM was determined using a method from Stewart and Possingham (2005) as cited in Game and Grantham (2008). Total reserve system boundary length was plotted against total cost in area for repeated MARXAN runs, at 100 iterations each, with different BLM values. The selected BLM value of 0.08 was at the inflection point in which both total boundary length and total cost were at a minimum.

For each scenario, we conducted 10 MARXAN runs of 100 repetitions each and recorded the MARXAN "best" single solution in a run as well as the "summed" solution, which includes the selection frequency of each parcel calculated across all repetitions in that run. Using both solutions is recommended as a best practice for interpreting and refining MARXAN outputs as well as communicating them spatially (Ardron et al. 2010).

We calculated average cost in acres and planning units of the "best" single solutions among the 10 runs. As a way of identifying the "best of the best" parcels for each scenario, or a best summed solution, we also averaged selection frequency values for each parcel across the 10 runs, classified the averaged values using natural breaks, and chose a cut-off point based on a natural break for including a parcel in the solution for that scenario. For example, in Scenario

A, which includes all parcels in the Conservation Reserve Area, the parcels retained as part of the best summed solution were selected at least 40% of the time. Conservation targets not met in each scenario were taken from MARXAN output files that report these data.

To determine efficient solutions for maximizing structural connectivity, we compared connectivity of the MARXAN solutions for each scenario using FRAGSTATS (McGarigal et al. 2013) and the 'Nearest Neighbor' tool in ArcGIS. Analyses were performed on both the summed solution for each scenario, featuring the most frequently selected parcels, and a randomly selected single "best" solution from among the 10 runs in MARXAN. We chose to analyze single best as well as summed solutions, reasoning that a summed solution with only the most frequently selected parcels from many repetitions is likely to be larger and more contiguous than any one single solution and may show a different level of structural connectivity.

To prepare data for FRAGSTATS, we first converted parcel polygons from each solution layer from vector to raster format in ArcGIS, with a cell (pixel) size of 30 feet (900 square feet). Slivers – residual single pixels or strings of raster cells a single pixel wide – were eliminated. To analyze patch shape and spatial connectedness within each of the eight solution layers, we selected Perimeter-Area Ratio (PARA) and Contiguity Index (CONTIG) from among the patch shape metrics in FRAGSTATS using an eight-cell neighbor rule and averaged the resulting values across all patches. FRAGSTATS identifies unique patches of contiguous pixels as a part of calculating these statistics. PARA equals the ratio of a patch perimeter to its area. CONTIG convolves a 3x3 pixel template as a moving window and assigns values to pixels based upon class (patch type of interest versus background) and spatial relationship to surrounding pixels (horizontal and vertical weighted higher than diagonal). The value of each pixel in the output image, computed when at the center of the moving template, is a function of the number and location of pixels, of the same class, within the nine-cell image neighborhood. Thus, large contiguous patches result in higher values (McGarigal 2015). The average contiguity value is divided by the sum of template values minus one to yield an index value between 0 and 1.

As a measure of patch distribution, we used the 'Nearest Neighbor' tool in ArcGIS on the vector versions of each solution layer. This tool reports the mean distance between polygon centroids.

To assess connectivity for selected focal species, we used the 'Cost Connectivity' tool in ArcGIS. We chose the most dispersal-limited covered species in each of two major landscape matrices within the plan – burrowing owl (*Athene cunicularia*) and California tiger salamander (*Ambystoma californiense*), within the agricultural landscape, which includes grasslands and some seasonal wetlands such as vernal pools, and western pond turtle (*Emys marmorata*) and valley elderberry longhorn beetle (*Desmocerus californicus dimorphus*) in the riparian/wetland landscape. In a report of independent science advisors for the Yolo HCP/NCCP (Spencer et al. 2006), the authors recommend the use of focal species to help achieve the biological goals of the plan, and one such way to categorize species is by a combination of functional category such as dispersal limitation and major community type.

The 'Cost Connectivity' tool focuses on defining the optimum network of least-cost paths between regions, defined as core habitat patches for the purposes of this study. For each species, we considered a core habitat patch to be any patch of suitable habitat with a recent occurrence of a species (Source: CDFW 2021) or any patch of suitable habitat within public or easement land, considering this habitat to be already protected. Recent occurrences for a species and suitable habitat are the data depicted in its species map in Appendix A: Covered Species Accounts of the plan. The goal was not to define a single movement path for each species to disperse through from its point of occurrence, but to look at what the pattern of dispersal might look like through the most highly suitable habitat and see how well it conforms with the four scenarios or land acquisition strategies of this study. So as not to limit the analysis to within-plan boundaries that would be artificial to species, we chose habitat patches rather than parcel boundaries as cores and extended the initial scope of the analysis to public lands beyond the Conservation Reserve Area.

After converting each composite layer of patches for a species from vector to raster format, we used the 'Region Group' tool in ArcGIS to create an input regions layer for the 'Cost Connectivity' tool. To create an input cost surface layer for the same tool, we assigned cost values to polygons in the land cover data layer or individual species distribution model (Yolo Habitat Conservancy 2020b) per the rules in Table 3.2 and then rasterized and merged the input

Table 3.2. Land cover costs assigned in least cost network analysis.

Cost Value	Rules for Selecting Polygons
20	Vegetation Name = "Barren" or Habitat Association = "Urban" or Natural Community = "LAC/RIV" (except for the Western Pond Turtle)
10	Any natural or semi-natural habitat (Natural Community = "Cultivated Lands") not modeled as suitable for a species
2	Modeled suitable habitat for a species labeled "Other" or "Secondary"
1	Modeled suitable habitat for a species labeled "Primary" and part of a conservation target

data sets. The highest costs are for the least permeable forms of land cover and the lowest costs for the most highly suitable habitat for a species.

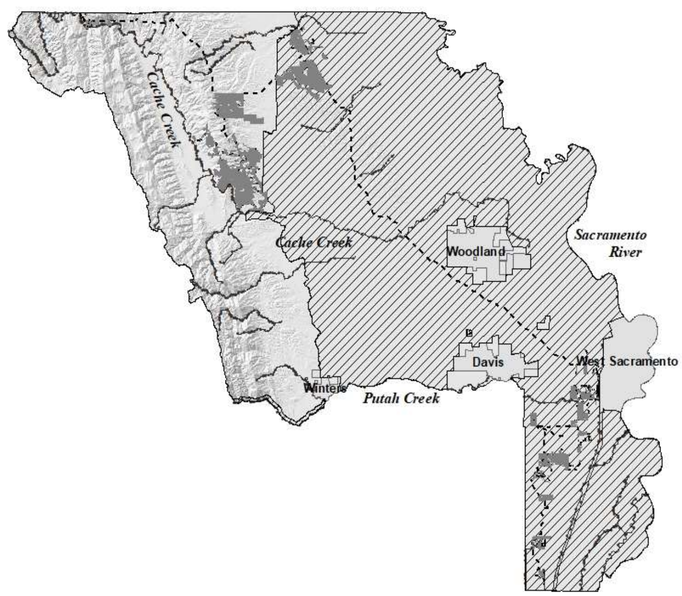
We then assessed conformity of the least cost network solution for each species (Figure 3.3) with the best summed solution for each of the four scenarios (Figure 3.4). Each least cost network was first clipped to the Conservation Reserve Area so it could be compared directly with the selected parcels for each best summed solution, which are limited to this portion of the plan area. Percent of least cost network segments intersecting each best summed solution was determined using the 'Select by Location' function in ArcGIS and calculating the percentage of path segments selected. We then determined the median path cost value of selected path segments. The distribution of path cost values was often highly skewed or bimodal; thus, we selected median rather than mean as a preferred measure of central tendency.

RESULTS

Results regarding the most efficient strategy for meeting conservation targets are presented in Table 3.3. Scenario A, which considers all parcels in the Conservation Reserve Area, hits the highest number of conservation targets (20/21), but is also the least efficient in doing so, with an average of 2,241 planning units to meet these targets. Scenario B, which considers only Priority 1 parcels, hits the fewest number of conservation targets (15/21), but is also the most efficient in doing so, with an average of 404 planning units. The best combination of attaining conservation targets (18/21) and doing so with efficiency (an average of 422 planning units) appears to be Scenario D, which considers Priority 1 lands and corridors. Scenario C, which considers Priority 1 and 2 parcels is also relatively effective and efficient with

(a)
Burrowing Owl
(*Athene cunicularia*)

(b)
California Tiger Salamander
(*Ambystoma californiense*)



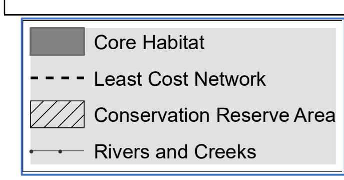


Figure 3.3a,b. Least cost networks of four selected dispersal-limited species.

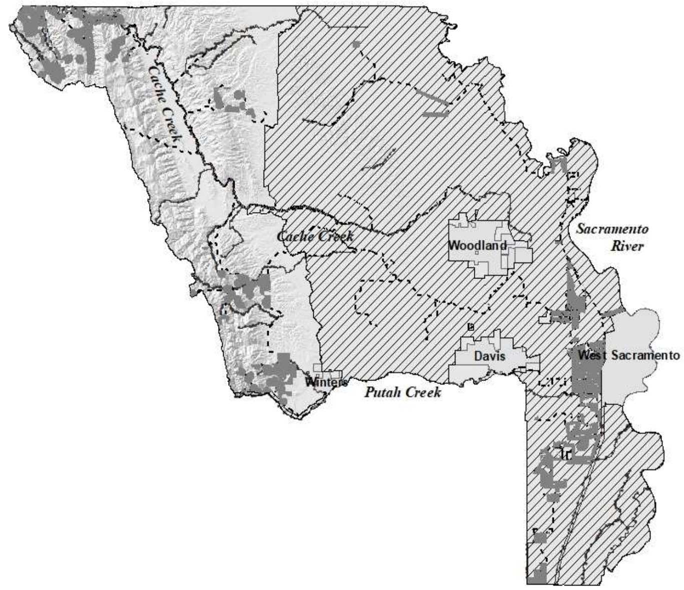
(c) **Western Pond Turtle** **(*Emys marmorata*)**	
(d) **Valley Elderberry Longhorn Beetle** **(*Desmocerus californicus dimorphus*)**	

Figure 3.3c,d. Least cost networks of four selected dispersal-limited species.

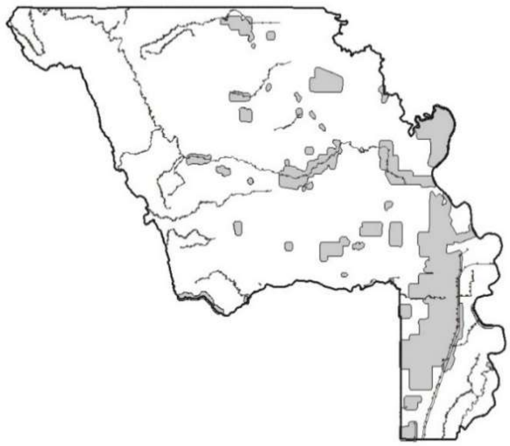
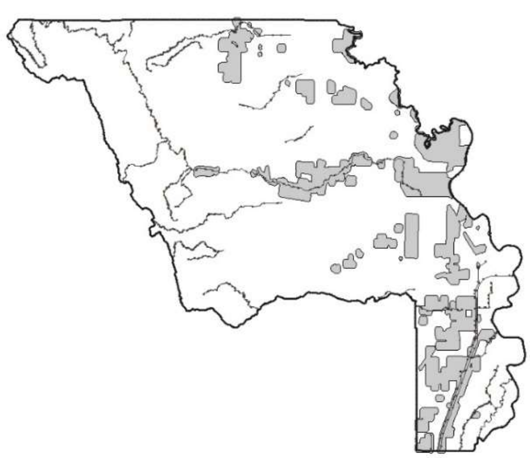
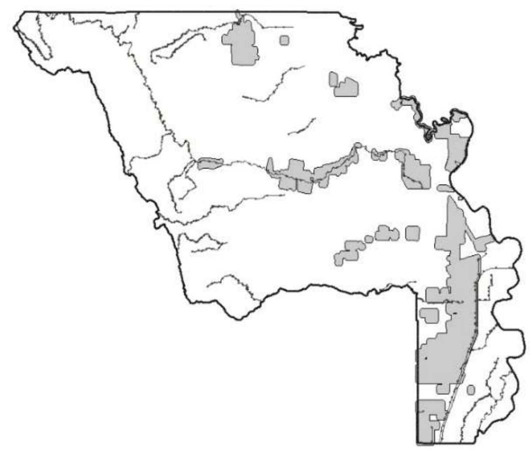
(a) 	(b) 
Scenario A – All Parcels – results in habitat patches that are closest together on average, but they are many and small, with the highest perimeter-area ratio and the lowest within-patch contiguity.	**Scenario B – Priority 1 Lands Only** -- results in fewer, larger habitat patches with low perimeter-area ratio and high within-patch contiguity, but also the largest average distance between patches.
(c) 	(d) 
Scenario C – Priority 1 and 2 Lands – results in habitat patches closer together than Scenarios B or C, with a moderate perimeter-area ratio and relatively high within-patch contiguity.	**Scenario D – Priority 1 Lands and Corridors** -- as with Scenario B, results in fewer, larger habitat patches with low perimeter-area ratio and high within-patch contiguity, but also the second largest average distance between patches.

Figure 3.4. Most frequently selected parcels by MARXAN in four land acquisition scenarios.

Table 3.3. Costs and acreage targets for four land acquisition scenarios.

	Scenario A - All Parcels	Scenario B - Priority 1 Parcels Only	Scenario C - Priority 1 and 2 Parcels	Scenario D - Priority 1 and Corridor Parcels
Average Cost in Acres of MARXAN Single Best Solutions	84,976 ±3,099	66,663 ±245	56, 494 ±937	60,751 ±854
Average Number of Planning Units in MARXAN Single Best Solutions	2,241 ±88	404 ±2	513 ±27	422 ±19
Selection Frequency Threshold Chosen for Best Summed Solution Parcels	40%	25%	30%	28%
Number of Parcels Meeting Selection Frequency Threshold	2,678	423	550	464
Conservation Targets Met (out of 21)	20	15	19	18
Targets Not Met	Valley Oak Woodland	Grassland in Planning Unit 5, Grassland / California Tiger Salamander, Grassland / Swainson's Hawk, Lacustrine & Riverine / California Tiger Salamander, Overwintering GGS, Valley Oak Woodland	Lacustrine & Riverine / California Tiger Salamander, Valley Oak Woodland	Grassland in Planning Unit 5, Grassland / California Tiger Salamander Valley Oak Woodland

19/21 conservation targets hit and an average of 513 parcels required. The relative patterns of both effectiveness and efficiency hold up across all four scenarios when considering both MARXAN single best solutions and MARXAN summed solutions.

Results regarding the most efficient way to maximize structural habitat connectivity in the plan are presented in Table 3.4, along with their adherence to some classic principles of reserve design posited by Diamond (1975) and Noss et al. (1997). MARXAN best summed solutions for each scenario are displayed in Figure 3.4. Actual values of both FRAGSTATS and ArcGIS Nearest Neighbor measures are less important than comparative or relative values. Scenario A with all parcels results in habitat patches that are closest together on average, but they are many and small, with the highest perimeter-area ratio and the lowest within-patch contiguity. Scenario B, with Priority 1 lands only, and Scenario D, with Priority 1 lands and corridors, both result in fewer, larger habitat patches with low perimeter-area ratio and high within-patch contiguity, but also the greatest average distance between patches. Scenario C, with Priority 1 and 2 lands, – results in habitat patches closer together than Scenarios B or C, with a moderate perimeter-area ratio and relatively high within-patch contiguity.

Results of our analysis of connectivity for selected focal species are illustrated in Figure 3.3 and presented in Table 3.5. The least cost pattern of movement for the burrowing owl had the highest conformance with Scenario D, Priority 1 parcels and corridors but the lowest average cost consistent with Scenario A, all parcels. For the California tiger salamander, the least cost network had the highest conformance and the lowest average cost with Scenario D, Priority 1 parcels and corridors. The western pond turtle network had the highest conformance with Scenario B, Priority 1 and 2 Parcels, with the same average cost across all scenarios.

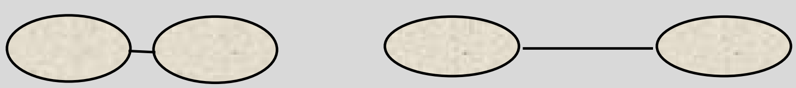
Table 3.4. Structural connectivity of four land acquisition scenarios based on the principles of reserve design. All values are interpreted relative to one another, with the most desirable values representing a design principle marked with a *

<table>
<tr><td colspan="5">A single large reserve is better than several small reserves of the same total area. Larger habitat blocks support higher populations for a species (Diamond 1975, Noss et al. 1997).
</td></tr>
<tr><td>Measure is number of contiguous habitat patches. *Lowest is best.</td><td>Scenario A -- All Parcels</td><td>Scenario B -- Priority 1 Only</td><td>Scenario C -- Priority 1 and 2</td><td>Scenario D -- Priority 1 with Corridors</td></tr>
<tr><td>Number of Contiguous Patches – Summed Solution</td><td>211</td><td>*50</td><td>85</td><td>54</td></tr>
<tr><td>Number of Contiguous Patches – Random Best Single Solution</td><td>176</td><td>50</td><td>73</td><td>*47</td></tr>
<tr><td colspan="5">A compact reserve is better than an elongated reserve. Compact shapes minimize edge effects or negative, external influences on habitat (Diamond 1975, Noss et al. 1997).
</td></tr>
<tr><td>Measure is perimeter/area ratio for each contiguous patch. *Lowest is best.</td><td>Scenario A -- All Parcels</td><td>Scenario B -- Priority 1 Only</td><td>Scenario C -- Priority 1 and 2</td><td>Scenario D -- Priority 1 with Corridors</td></tr>
<tr><td>Average Perimeter/Area Ratio – Summarized Solution</td><td>137.37 ±97.39</td><td>33.46 ±51.78</td><td>65.69 ±105.08</td><td>*33.00 ±35.50</td></tr>
<tr><td>Average Perimeter/Area Ratio – Random Best Solution</td><td>109.28 ±98.95</td><td>*33.28 ±51.69</td><td>43.53 ±68.48</td><td>36.58 ±65.21</td></tr>
</table>

Habitat in contiguous blocks is better than fragmented habitat. Fragments can become isolated and small, which lowers species richness due to decreased immigration rates and increased extinction rates (Noss et al. 1997). Contiguity in FRAGSTATS is a measure of patch shape, capturing habitat that is likely in the process of fragmenting.

Measure is within-patch contiguity. * Highest is best.	**Scenario A -- All Parcels**	**Scenario B -- Priority 1 Only**	**Scenario C -- Priority 1 and 2**	**Scenario D -- Priority 1 with Corridors**
Average Within-patch Contiguity Index Value – Summarized Solution	0.88 ±0.09	*0.97 ±0.05	0.94 ±0.09	*0.97 ±0.03
Average Within-patch Contiguity Index Value – Random Best Solution	0.90 ±0.09	*0.97 ±0.05	0.96 ±0.06	*0.97 ±0.06

Reserves that are close together are better than reserves that are far apart. Species can more easily disperse between habitat blocks that are closer together (Diamond 1975, Noss et al. 1997).



Measure is average nearest neighbor between habitat patches. * Lowest is best.	**Scenario A -- All Parcels**	**Scenario B -- Priority 1 Only**	**Scenario C -- Priority 1 and 2**	**Scenario D -- Priority 1 with Corridors**
Average Nearest Neighbor (feet, Euclidean distance)– Summed Solution	*2,769	9,652	6,742	7,743
Average Nearest Neighbor (feet, Euclidean distance)– Random Best Solution	*558	2,063	1,736	1,809

Table 3.5. Connectivity for selected focal species in four land acquisition scenarios, measured as the conformance of least cost network solutions with best summed solutions. All values are interpreted relative to one another, with the most desirable values denoted with an asterisk (*).

	Scenario A - All Parcels	Scenario B - Priority 1 Lands Only	Scenario C - Priority 1 and 2 Lands	Scenario D - Priority 1 Lands and Corridors
Burrowing Owl (*Athene cunicularia*)				
% of Least Cost Network Segments Intersecting Best Summed Solution	48%	65%	55%	67%*
Median Path Cost of Intersecting Segments	120*	145	145	145
California Tiger Salamander (*Ambystoma californiense*)				
% of Least Cost Network Segments Intersecting Best Summed Solution	94%	86%	85%	99%*
Median Path Cost of Intersecting Segments	630*	678	678	630*
Western Pond Turtle (*Emys marmorata*)				
% of Least Cost Network Segments Intersecting Best Summed Solution	60%	70%*	63%	63%
Median Path Cost of Intersecting Segments	42*	42*	42*	42*
Valley Elderberry Longhorn Beetle (*Desmocerus californicus dimorphus*)				
% of Least Cost Network Segments Intersecting Best Summed Solution	86%*	49%	53%	68%
Median Path Cost of Intersecting Segments	232	237	207*	207*

Finally, the valley elderberry longhorn beetle network had the highest conformance with Scenario A, all parcels, and the lowest average cost with Scenario C, Priority 1 and 2 parcels, and Scenario D, Priority 1 parcels and corridors.

Results of each measure were then ranked across all four scenarios, with one representing the highest rank and four the lowest rank for any given measure. We summed the ranked scores for each scenario and assigned an overall ranking based on the summed value, with the lowest summed value representing the highest overall rank (Table 3.6). Scenario D, with Priority 1 lands and corridors shows the highest overall ranking, followed by Scenario B, with Priority 1 lands only; Scenario C, with Priority 1 and 2 lands; and, Scenario A, with all parcels.

DISCUSSION

With ever-increasing landscape fragmentation due to human population expansion resulting in critical needs for conservation and limited resources with which to accomplish those actions, it is increasingly important that the potential outcomes of systematic conservation strategies be assessed for their efficacy. This case study presents several potential conservation outcomes over a 50-year build-out time period for a county that has gone through an extensive effort at systematic conservation planning with a goal of habitat connectivity for multiple species. Also, data may be limited in a multi-species systematic conservation plan, yet strategic decisions must still be made to maximize efficiency and effectiveness when assembling a connected reserve system over time. One goal here was to consider several measures that may serve as inputs to such decision making.

Table 3.6. Ranked summary results table. Tied values for any given measure are assigned equal rank. (1 = highest rank, 4 = lowest rank)

	Scenario A - All Parcels	Scenario B - Priority 1 Only	Scenario C - Priority 1 and 2	Scenario D - Priority 1 with Corridors
Lowest Average Cost				
In Acres	4	3	1	2
In Planning Units	4	1	3	2
Highest Number of Conservation Targets Met				
Highest Number of Conservation Targets Met	1	4	3	2
Highest Level of Structural Connectivity Following Reserve Design Principles				
Lowest Number of Contiguous Habitat Patches				
Summed Solution	4	1	3	2
Random Best Solution	4	2	3	1
Lowest Average Perimeter/Area Ratio of Contiguous Habitat Patches				
Summed Solution	4	2	3	1
Random Best Solution	4	1	3	2
Highest Average Within Patch Contiguity				
Summed Solution	3	1	2	1
Random Best Solution	3	1	2	1
Lowest Average Nearest Neighbor				
Summed Solution	1	4	2	3
Random Best Solution	1	4	2	3

	Scenario A - All Parcels	Scenario B - Priority 1 Only	Scenario C - Priority 1 and 2	Scenario D - Priority 1 with Corridors
Highest Level of Connectivity for Selected Focal Species				
Highest % of Least Cost Network Segments Intersecting Best Summed Solution				
Burrowing Owl (***Athene cunicularia***)	4	2	3	1
California Tiger Salamander (***Ambystoma californiense***)	2	3	4	1
Western Pond Turtle (***Emys marmorata***)	3	1	2	2
Valley Elderberry Longhorn Beetle (***Desmocerus californicus dimorphus***)	1	4	3	2
Median Path Cost of Intersecting Segments				
Burrowing Owl (***Athene cunicularia***)	1	2	2	2
California Tiger Salamander (***Ambystoma californiense***)	1	2	2	1
Western Pond Turtle (***Emys marmorata***)	1	1	1	1
Valley Elderberry Longhorn Beetle (***Desmocerus californicus dimorphus***)	2	2	1	1
Sum of Ranked Scores	48	41	45	31
Overall Ranking (representing lowest to highest summed values)	**4**	**2**	**3**	**1**

For the Yolo HCP/NCCP it would seem most effective to focus on Priority 1 lands and corridors, although additional lands must still be acquired to fully meet all conservation targets. Priority 1 and 2 lands together may not prove as effective, particularly because the advantage of Priority 2 lands lies in their adjacency to Priority 1 lands. If they are selected as an alternative to Priority 1 lands, the result may be less compactness and connectivity than Priority 1 lands would achieve alone or in conjunction with corridors. The Priority 1 lands with corridors strategy also holds up well for individual focal species, likely because many of the existing public lands are in the grassland/agriculture landscape matrix and many of the corridor lands are in both this matrix or in the riparian/wetland matrix along streams. We recommend using spatial prioritization software and employing several measures of connectivity in decision-making, and doing so either in the planning phase of a systematic conservation plan or early in the process of acquiring land for an approved plan, before reserve lands have been purchased and when an analysis of potential land acquisition strategies may have the greatest effect on land purchase decisions.

Results here may be limited in that they illustrate best-case scenarios for connectivity under specific, idealized criteria for a total conservation target commitment of 24,406 acres in Yolo County. No single strategy for parcel acquisition is likely to be exactly realized due to a policy for the plan which dictates that no parcel may be purchased without a willing seller. Thus, some parcels may be unavailable for acquisition and may preclude ever achieving a fully connected reserve system in Yolo County unless the permit term for the plan is extended well beyond 50 years. It is also worth noting that few Priority 1 lands exist on Putah Creek, an important riparian corridor that forms the southern boundary of the plan west of the county's southeastern panhandle, so many parcels here were ignored by the optimization scenarios. If land parcels along Putah Creek are acquired in the future for recreational or other purposes it could provide the basis for greater acquisitions by the Yolo HCP/NCCP plan to enhance connectivity in this riparian corridor. For these reasons, we recommend that MARXAN be re-run after each parcel is acquired in real time to re-assess connectivity opportunities, as results are highly sensitive to initial conditions.

Although NCCPs such as the Yolo HCP/NCCP are required to plan for habitat connectivity for covered species, the temporal dimension of land acquisition illustrates why maximizing connectivity for multiple focal species in a single plan is an ongoing process. Unexpected future land title or easement donations with high conservation value can alter the course of implementing the plan and create opportunities in new areas at the expense of other areas. Conversely, unexpected urban development in areas adjacent to the plan or even, in the case of the Yolo HCP/NCCP, a shift within the agricultural matrix from herbaceous and semi-permeable crops to orchards or vineyards with lower connectivity value, can alter future acquisition priorities based on a lowering of conservation value.

Additional species occurrence data and more highly refined distribution models may also become available over time. This Yolo County case study shows that the efficacy of potential outcomes of systematic conservation strategies can vary significantly depending on priorities, permit time period, sequence of acquisitions, and data availability. Conservation planners need to be cognizant of all these factors in developing and implementing future systematic conservation plans, including federal HCPs and California NCCPs for species at risk.

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Summary

This dissertation researches the explicit use of species models in the science and practice of systematic conservation planning in California. Its focus has been less about the principles and practices of constructing species conceptual models (SCMs) and species distribution models (SDMs) and more about their effective use in the context of conservation planning and management. Modelers work with the maxim, attributed to George E. P. Box, that "Essentially, all models are wrong, but some are useful." I would add that, despite their being wrong, we cannot do science without them. We especially cannot do applied conservation science, a multi-disciplinary and multi-stakeholder endeavor that requires strong communication among all actors. Where there is necessarily incomplete knowledge of any natural phenomenon, a good model provides a framework for shared learning. It documents for everyone the assumptions and key uncertainties based on the current level of knowledge at a point in time. A model used explicitly explains decisions made.

The aim here has been to improve best practices in the application of models to conservation planning and management and to help close the "research-implementation gap" identified in the literature. Recommendations are based on the importance of models as communication devices when data are incomplete. Chapter 1 recommends that management-oriented species conceptual models (SCMs) be created while a Natural Community Conservation Plan (NCCP) is still in the planning phase. SCMs are a bridge between the goals and objectives of a conservation plan and the conservation measures or management actions assumed necessary for achieving them. They serve to identify priorities for monitoring and critical uncertainties that still need research, beneficial information for scoping the long-term

cost of a plan. Chapter 2, with an emergent theory “A Collaborative Ideal: Personalities and Attitudes of Individuals Affect Outcomes and Consensus is Reported,” identifies several best practices related to inclusion of and communication among stakeholders in SCM model development, so that models have maximum utility for all. Chapter 3 acknowledges that species occurrence records are often limited and that SDMs using suitable habitat as a surrogate for species presence can be complicated to use together when designing a connected reserve network for multiple species. Yet, it points to several different tools for assessing connectivity, given what is known.

In introducing this work, I aligned NCCPs with the SCP framework for decision-making. Schwartz et al. (2018) associate several core tools with this framework that are utilized in NCCPs and demonstrated here. Chapter 1 examines the explicit use of compiled data on conservation targets in framing the goals and objectives and reserve design of a plan. Data analysis in Chapter 3 employs spatial prioritization tools such as MARXAN. However, Schwartz et al. (2012) found NCCPs (following Atkinson et al. 2004) to be lacking in comparison to SCPs when it comes to documenting assumptions behind (threat) interventions in adaptive management. The authors compared several project management frameworks such as NCCPs and SCPs to Open Standards (OS) for the Practice of Conservation (CMP 2010), a conservation management tool that requires practitioners to formalize assumptions about how a target ecosystem functions, how human actions are impacting that ecosystem, and about how ecosystems are expected to respond to intervention. They concluded that NCCPs contrast with OS when it comes to documenting assumptions behind (threat) interventions while SCPs converge with OS. Conceptual models are where such assumptions become explicit, and they are clearly a part of the adaptive management process used in NCCPs, as demonstrated in Chapter 2. I conclude, that for the authors to make this determination, conceptual models either do not figure prominently enough in NCCPs as plans, a conclusion reached in Chapter 1, or that systematic learning based on hypothesis testing could be more explicit in the adaptive management loop, something the scientists in San Diego County (Chapter 2) recognize as they consider how to revise and share conceptual models based on monitoring data. To this end, they might consider the approaches advocated by OS (CMP 2020) for documenting and sharing learning. Such explicit communication would maximize the effectiveness of NCCPs, arguably the best examples of systematic conservation plans in California and the most powerful in conserving species at risk.

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