

Climate Change Adaptation Approaches
for
Habitat Conservation Plans



January 2020

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January 2020



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Acknowledgements

This project was developed and facilitated by John Hopkins, Institute for Ecological Health, and Edmund Sullivan, Santa Clara Valley Habitat Agency, without whom it would not have taken place.

Participants in the two case studies shared significant time and expertise to inform this report:

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Insights and expertise were shared by:

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This project was funded by the Resources Legacy Fund, the National Habitat Conservation Plan Coalition, and the Santa Clara Valley Habitat Agency.

Recommended Citation

McGraw, J. M. and N. Heller. 2020. Climate Change Adaptation Approaches for Habitat Conservation Plans. Report prepared for the National Habitat Conservation Plan Coalition, Valley Habitat Agency, and Institute for Ecological Health. Prepared by Jodi McGraw Consulting. January 2020. 59 pages. Available at: <https://www.nhcpcoalition.org/documents/coalition-documents/>

Executive Summary

Project Background

Human activities are estimated to have increased global temperatures 1.0 °C (1.8 °F) above pre-industrial levels (1901-2016) and the climate is expected to increase another 1.4 °C (2.5 °F) by the middle of the century, regardless of emissions reductions (Hayhoe et al. 2018). Due to direct and indirect effects of temperature increases, which include extreme rainfall, drought, sea level rise, and altered fire regimes (Jay et al. 2018), climate change has been ranked as the third leading driver of species extinction (Box 1; IPBES 2019).

Habitat Conservation Plans (HCPs) can play an essential role in preventing species extinctions in the United States (Box 2). For HCPs to be successful, they will need to address the threats posed by climate change, which has the potential to alter the effectiveness of HCP conservation strategies and exacerbate the detrimental effects of a plan's covered activities.

Project Need

Recognizing the need for more information and guidance about how to address climate change in HCPs, members of the National HCP Coalition (NHCP) initiated this project to identify key climate adaptation approaches for HCPs based on a review of scientific literature, practitioners' guides, and other resources, including websites, and highlight methods for addressing each.

Project Approach and Products

The project included two main elements: 1) a review of the literature on climate change and conservation plans to identify climate-adapted approaches to HCPs; and, 2) exploration of how existing HCPs are addressing climate change through case studies (Tables 1 and 2) of the Balcones Canyonlands Conservation Plan (BCCP; RECON and USFWS 1996) and the Santa Clara Valley Habitat Plan (ICF 2012). The project technical advisory group comprised of individuals participating in various aspects of HCPs throughout the United States (Box 3) provided input at critical junctures. This report presents:

- Six key approaches to make HCPs more climate adapted (Table 3, Section 2.1);
- Eleven additional climate change resiliency concepts that emerged during the project, and are organized under two themes, bigger and more flexible (Section 2.2); and
- Recommendations for potential next steps to further explore how to integrate climate adaptation into HCPs (Section 3).

The climate change adaptation approaches and resiliency concepts in this report were presented to the National Habitat Conservation Plan Coalition during its annual meeting in November 2019.

Climate Adaptation Approaches

Table 3 identifies six climate adaptation approaches for HCPs (Section 2.1) that were selected because they are anticipated to be: 1) widely applicable across various HCPs; 2) impactful, in terms of facilitating meaningful conservation goals for species as well as broader communities and ecosystems; and 3)

robust to multiple climate change futures and/or able to be adapted to the context of specific HCPs by practitioners using straightforward methodologies. For each approach, Table 3 cites key literature and other resources listed in the *References*, which provide additional background as well as methods to apply the approaches.

1. Assess Climate Change Threats and the Vulnerability of Species

A crucial strategy for climate-adapted HCPs is to identify the anticipated climate changes in the plan area, assess the vulnerability of the covered species and their habitats to the anticipated changes, and develop and implement strategies to increase resiliency of the species based on the results of the analysis (Section 2.1.1). Projections should be based on the most recent, highest-resolution (downscaled) climate models available for the HCP plan area; multiple scenarios should be independently evaluated (rather than averaged) as they may predict disparate climate futures (e.g., hotter and drier vs. hotter and wetter).

Once the anticipated climate changes are known, conceptual ecological models, species distribution models, and vulnerability assessments can be used to identify their potential implications for covered species populations, distributions, and habitats. This information can inform all aspects of an HCP, including the conservation strategy as well as the covered species selection and changed circumstances analysis. In the BCCP, a local climate projection was commissioned and used to evaluate the vulnerability of the covered species to climate change; this vulnerability analysis, in turn, informed habitat protection and management activities that are being implemented as part of the conservation strategy (Box 5).

2. Conserve the Geophysical Stage

Although complex interactions between climate, ecosystems, and human systems make it difficult to predict the ultimate effects of climate change on a given species and its habitat, HCP reserve systems should protect and connect the geologic, soils, and hydrologic conditions that support a covered species; safeguarding these land facets across a range of abiotic gradients (e.g., latitude and topography) can help sustain species by providing opportunities for them to migrate to stay within their climate envelope (Section 2.1.2).

Protecting a range of geophysical conditions within the plan area can also help protect the ‘evolutionary stage’ that drives diversification (Beier and Brost 2010), thus sustaining the biodiversity that promotes ecosystem resiliency (Oliver et al. 2015). Box 6 describes how the Santa Clara Valley Habitat Plan is working to conserve and manage in its reserve system serpentine soils across a range of environmental gradients, in order to capture the variable microclimates and promote persistence of the 10 covered species that inhabit these unique communities (Box 6; ICF 2012).

3. Protect Climate Change Refugia

Habitat conservation plans can conserve covered species by identifying, protecting, restoring, and connecting areas that buffer species from climate changes; these include more persistent refugia that can sustain populations as well as more transient refuges that can reduce an individual’s exposure to climate change (Section 2.1.3). Planners and implementers of HCPs can use climate projections, conceptual models, and climate change vulnerability assessments (Section 2.1.1) to identify refugia and

refuges, which should be mapped to facilitate their conservation in the HCP conservation strategy including: 1) avoidance by covered activities, 2) inclusion in reserve systems, 3) active management, as needed to sustain their value and functions, and 4) connection within the landscape to species access to them. General refugia from a warming climate, including north-facing slopes, wet areas, and areas where species can stay within their climate envelope with relative short-distance movements (i.e., areas of low climate velocity), can be protected as refugia to promote biodiversity conservation and resiliency of ecosystems (Oliver et al. 2015). In the BCCP, plan implementers used a local climate projection and vulnerability assessment to identify mesic forests and deeper caves as covered species climate refugia, which they are protecting, restoring, and managing (Box 5).

4. Enhance Regional Connectivity

Habitat conservation plans can promote species adaptation to climate change by identifying and protecting broad landscape linkages (≥ 2 km or 1.25 miles; Beier 2019) to promote species migration in response to a changing climate (Section 2.1.4). When compared to narrow wildlife corridors, such broad landscape linkages can: 1) support more diverse habitat conditions that will be more conducive to movement of multiple species as conditions change over time; 2) enable slower-moving species including plants to 'live in' the habitat and migrate over multiple generations; and 3) better buffer species against the influence of adjacent human activities and converted habitat. As with all corridors, broad landscape linkages should be located in areas that are most conducive to animal movement and the flow of other ecological processes. A variety of techniques have been developed to facilitate integration of climate change considerations into corridor design (Keeley 2018a).

Habitat conservation plans can also facilitate species migration by facilitating wildlife movement through transportation infrastructure (i.e., road culverts, overpasses, or underpasses) or removing barriers such as fencing. Such measures to enhance permeability of the landscape were included in the Santa Clara Valley Habitat Plan, which also identifies a range of landscape linkages to be protected to promote migration in response to climate change (Box 6; ICF 2012).

5. Sustain Ecosystem Processes

Habitat conservation plans should include provisions to safeguard and restore ecosystem processes that sustain endangered species populations and promote native biodiversity, which can benefit rare species indirectly including by promoting ecosystem functions and resiliency (Hooper et al. 2005, Oliver et al. 2015; Section 2.1.5). Conceptual models can help illustrate the important ecological processes that can be driven by factors that occur away from covered species habitat. Mapping key drivers of ecosystem process in the landscape can help avoid altering them during implementation of HCP covered activities; it can also help design the reserve system to protect and restore lands that are critical to maintaining important ecosystem processes.

Active habitat management within HCP reserves may be needed to address alterations of ecosystem processes, including those resulting from climate change. For example, where increased temperature, drought, and climatic water deficit increases fire frequency and severity, such as in the BCCP, vegetation management and other strategies can be used to reduce fire risk and conserve populations of fire intolerant species including those adapted to later-successional communities (Box 5). Likewise, rare plant and animal populations can be sustained through livestock grazing to reduce competition from

exotic plants, the growth of which may be promoted by climate change; such management is being used to promote rare serpentine species in the Santa Clara Valley Habitat Plan (Box 6).

6. Employ the Climate-Smart Conservation Cycle

The long-term effectiveness of HCPs in a changing climate can be enhanced by integrating elements of the climate-smart conservation cycle—a framework for developing, implementing, monitoring, and adjusting conservation actions that is designed to enhance their effectiveness over time (Figure 1; Stein et al. 2014). Developed based on a more general adaptive management framework that has been recommended for HCPs (USFWS and NOAA Fisheries 2016), the climate-smart conservation cycle reflects important climate adaptation approaches including:

1. An assessment of climate change impacts and vulnerabilities (Section 2.1.1), to ensure conservation actions specifically address the impacts of climate change in concert with other existing threats;
2. Development of forward-looking goals and objectives that address decades to centuries; and
3. Identifying multiple adaptation options based on a range of possible future conditions to account for uncertainties in future climatic conditions as well as ecological and human responses.

Robust monitoring in HCPs is essential to identify the need for modifications to conservation strategies as well as goals and objectives, in order to achieve the intent of the HCP conservation strategy.

Resiliency Concepts

During the process of examining the climate adaptation approaches through the case studies, a number of additional concepts emerged for best practices to enhance resiliency of HCPs to climate change. They are organized under two main concepts: **bigger is better** and **flexibility and adaptation** (Section 2.2).

Bigger is Better

Reflecting the widespread and pervasive nature of climate change and its impacts, the concept ‘bigger is better’ emerged often in evaluating methods to make HCPs more effective in a changing climate (Section 2.2.1).

1. **Bigger Reserves and Reserve Systems (Section 2.2.1.1):** Conservation areas for species should be as large as possible, all else being equal, to: 1) protect climate change refugia, 2) capture a diverse range of geophysical conditions needed to sustain species and promote biodiversity, 3) buffer habitat against the impacts of adjacent land uses, and 4) sustain larger populations of covered species, which are more resilient.
2. **Bigger (Wider) Corridors (Section 2.2.1.2):** As discussed above, broad landscape linkages are better than narrow corridors as they provide ‘live in’ habitat that enable slower species (e.g., plants) to migrate over time; like larger reserves, broad linkages capture more diverse conditions and buffer habitat against adjacent land uses.
3. **Bigger Planning Area (Section 2.2.1.3):** HCPs will benefit from addressing a larger plan area, including areas that may be outside of the local land jurisdiction or land ownership. Working with willing partners in such a broader plan area will enable the conservation strategy to

accommodate species distribution changes in response to climate, promote connectivity, and help sustain ecosystem processes within a larger, more holistic landscape.

4. **Bigger (Longer) Timeframes (Section 2.2.1.4):** Longer permit terms for implementing aspects of the conservation strategy (if not the other covered activities) can promote its effectiveness by allowing more time to monitor and evaluate climate change effects on species and habitat, and to adapt the conservation strategy to address the observed changes.
5. **Bigger Scope of Habitat Restoration and Management (Section 2.2.1.5):** Climate change is anticipated to exacerbate existing threats as well as result in new threats to species, necessitating more active habitat management. Habitat restoration can increase the area of suitable habitat thus promoting species' population persistence and resiliency to climate change.
6. **Bigger (Better) Science (Section 2.2.1.6):** Scientific approaches will be needed to develop and implement robust conservation strategies in the face of climate change, including climate model projections, climate change effects analyses, and comprehensive monitoring of populations, communities, and ecosystems.
7. **Bigger Tent (Section 2.2.1.7):** Partnering with research institutions can help facilitate efforts to integrate science and scientific approaches into HCPs, which will also benefit from: 1) greater coordination with adjacent landowners, to facilitate more holistic landscape management, and 2) outreach to stakeholders and the broader community, to promote support for HCPs by communicating their benefits for multiple conservation values (e.g., water, cultural, and scenic resources) and climate change mitigation (i.e., protected habitat sequesters carbon; Ackerly et al 2017).

Flexibility and Adaptation

Another key concept that emerged repeatedly during this project is the need for HCP conservation programs to be flexible to adapt to climate change (Section 2.2.2).

1. **Identify the Uncertainties and Develop a Flexible Conservation Program (Section 2.2.2.1):** To be effective in the long-term, HCP conservation strategies should identify information gaps, which should be addressed through the adaptive management framework during implementation of the plan, including through long-term monitoring. Flexible conservation programs should include mechanisms to incorporate new scientific information, including the HCPs monitoring results, and adapt to changes.
2. **Flexible Reserve Systems (Section 2.2.2.2):** Because the suitability of land protected in HCP reserve systems for covered species can change as a result of climate change, reserve systems created through HCPs should be flexible, if possible. Rather than providing for permanent protection of pre-identified lands, HCP reserve systems can be 1) assembled over time based on criteria for suitability, and 2) allow lands to change, including by using term easements (rather than permanent easements). These or other methods of ensuring that the land protected and managed through HCPs continues to support the species it is designed to benefit could be explored in a future project (Section 3.3).
3. **Flexible Restoration and Management Techniques (Section 2.2.2.3):** HCPs should identify restoration and management techniques that are anticipated to be successful, including based on multiple potential scenarios for the changing climate (Sections 2.1.1.1 and 2.2.1.6); they

should also clearly identify (and analyze the effects of) alternative strategies that may be applied through adaptive management framework (i.e., climate-smart conservation cycle; Figure 1).

4. **Adaptive Funding (Section 2.2.2.4):** To meet the needs of an evolving conservation strategy, HCPs should feature adaptive funding including: 1) contingency funding for underestimated costs, 2) remedial funding to address issues encountered in implementing the plan and changed conditions, and 3) adaptive financial management, to adjust fees and funding over time based on actual needs. Surety/Performance Bonds and Escrow accounts may provide tools for HCPs that are not funded by participant fees and instead by landowners, who need financial assurances.
5. **Enhance the Adaptive Nature and Flexibility of HCPs (Section 2.2.2.5):** HCPs should be written to build in adaptation, by identifying the uncertainties (Section 2.2.2.1) and describing how elements of the conservation strategy can evolve as they are addressed as part of the adaptive management framework. More changes should be accommodated through adaptive management and/or the HCP amendment process should be streamlined, to avoid implementation of maladaptive plants ‘at all costs’.

Next Steps

Future projects to address climate change adaptation and resiliency in HCPs could include one more of the following (Section 3).

1. **Applying the Climate Adaptation Approaches to HCPs (Section 3.1):** A new set of case study HCPs, including plans in preparation and implementation stages, can work to deliberately apply the six climate change adaptation approaches, as well as the applicable resiliency concepts. These case studies could be evaluated to assess feasibilities and challenges related to policy, funding, expertise, or technical aspects of the plans and illuminate successful practices for future HCPs.
2. **Identifying Approaches to Addressing Common Issues Encountered in a Changing Climate (Section 3.2):** A ‘Phase 2’ Project could explore in more detail methods to address specific climate change issues that are encountered by HCP developers and implementers. These can include: 1) fire and fire management, 2) coastal systems and sea level rise, and 3) aquatic systems. The actual focal issue(s) evaluated could be determined using a poll of National HCP Coalition members to determine the areas of greatest need and thus project impact.
3. **Evaluating Issues for Enhancing the Climate Change Resiliency of HCPs (Section 3.3):** A future phase of this project could address the complex issues at the nexus of biology and policy that are presented by extending the HCP timeframe (permit term) and including more flexibility in HCP reserve systems, including through soft-line reserve systems and term easements.

1 Introduction

1.1 Project Need

1.1.1 Climate Change and Species Ranges

Human activities are estimated to have caused approximately 1.0 °C (1.8 °F) of global warming above pre-industrial levels (1901-2016). The past two decades have seen record-breaking climate extremes; 19 of the 20 warmest years have occurrence since 2001 (NASA/GISS 2020). In addition to increasing temperatures on land and in the oceans, increasing carbon dioxide and other greenhouse gas concentrations in the atmosphere are causing cascading perturbations, such as extreme rainfall and drought, sea level rise, and ocean acidification (IPCC 2018). Over the next few decades, regardless of emissions reductions, global warming is expected to increase another 1.4 °C (2.5 °F; Hayhoe et al. 2018).

These changes in climate are altering ecosystems through direct effects, as well as a host of indirect effects, such as fire, pest and disease outbreaks, and human responses to climate change, including land use changes (Jay et al. 2018). By the middle of the century, global warming is anticipated to cause overall contractions of range size in the majority of terrestrial species (IPBES 2019). As a result, climate change has been identified as the third largest driver of species extinctions (Box 1), threatening up to 1 million (13%) of the Earth's estimated 8 million animal and plant species with extinction (IPBES 2019). Land protection, restoration, management, and mitigation of climate change, among other strategies, will be needed to conserve rare and endangered species and prevent the alteration of natural communities and loss of ecosystem functions associated with the loss of native biodiversity.

**Box 1: Extinction Drivers¹
(IPBES 2019)**

1. Changes in land and sea use (i.e., habitat modification)
2. Direct exploitation of organisms
3. Climate change
4. Pollution
5. Invasive alien species

¹ In descending order of impacts

1.1.2 Habitat Conservation Plans

Habitat Conservation Plans (HCPs) can play an essential role in preventing the extinction of threatened and endangered species in the United States (Box 2). In particular, regional HCPs, which cover large geographic areas, multiple species, and a broad range of covered activities, can help ensure that species protection and mitigation is implemented in conjunction with regional land use; in doing so, these plans can provide for the recovery of listed species, while preventing other rare species from being listed. Though records of HCPs are not readily available, HCPs permitted since 1982, when the Endangered Species Act was amended to enable their preparation and issuance of incidental take permits, have contributed to the conservation of hundreds of species through protection of hundreds of thousands of acres of habitat across the United States.

For HCPs to be effective tools for preventing extinction and promoting listed species recovery, they will need to confront the threats posed by climate change. Climate change should be considered during development of all aspects of an HCP, from the species covered by the permits (covered species), to the activities covered by the permits (covered activities), to the conservation strategy, including long-term monitoring and adaptive management elements; climate change must also be addressed throughout

Box 2: Habitat Conservation Plans

- Plans to help conserve federally listed threatened or endangered species and comply with the Endangered Species Act; can also address other federal and state regulations
- Prepared to receive an incidental take permit issued by the US Fish and Wildlife Service or National Marine Fisheries Service, to cover the impacts (take) of specific activities on federally listed species
- Describe how the take/impacts to covered species will be avoided, minimized, and mitigated to the maximum extent practicable
- Regional HCPs can cover large geographic areas, many species, and a broad suite of covered activities including general land use

HCP implementation, which can take place over several decades, with land protection and management often occurring in perpetuity (Bernazzani et al. 2012, USFWS and NOAA 2016, USFWS 2019).

As with other long-term conservation plans, there are many challenges, perceived and real, to adequately addressing climate change in HCPs. Those developing HCPs, known as applicants, may view the process of engaging scientists and other experts to implement a robust planning process to address climate change as adding to the costs and timeline for developing and permitting their plan, thus holding up and increasing the costs of the project(s) they are working to permit. Integrating climate change adaptation into HCPs may also raise concern about additional costs for the plan's conservation strategy, and thus the funding required for plan implementation.

Nonetheless, the long-term effectiveness of an HCP may hinge on it adequately addressing climate change. Plans that fail to do so may incur greater costs to devise and carry out amendments and other adjustments to the

conservation strategy that prove to be necessary to achieve the HCP's biological goals and objectives. Making modifications to the conservation strategy during implementation, as required as a condition of most incidental take permits (USFWS and NOAA Fisheries 2016), will likely prove to be more costly than addressing climate change considerations during planning. Moreover, plans that fail to use the best available science for climate change projections and to account for climate change impacts to listed species may fail to meet the permit issuance criteria, thus delaying plan approval and permitting; they could also face legal challenges. As a result, addressing climate change from the outset can save time as well as reduce costs.

Applicants who recognize the need to integrate climate change considerations into their HCPs may encounter challenges including: 1) uncertainty about climate change projections and the anticipated implications of climate change for the covered species; 2) limited technical information or guidance for how to address climate change in HCPs; and 3) a lack of confidence in the anticipated changes due to the complexity of climate and its interactions with other biotic and abiotic changes in ecosystems.

1.2 Project Background, Goals, and Objectives

Recognizing the need for more information and guidance about how to address climate change in HCPs, members of the National HCP Coalition (NHCP) initiated this project to show how to build adaptation, management, and resiliency approaches for HCPs. Grants from the Resources Legacy Foundation and NHCP, as well as funding from the Santa Clara Valley Habitat Agency, enabled preparation of this report, which was prepared to identify climate change adaptation approaches that can be integrated into existing or new HCPs. The specific objectives of the project were to:

1. Identify a set of key climate adaptation approaches for HCPs based on a review of scientific literature, practitioners' guides, and other resources, including websites, and highlight methods for addressing each;
2. Evaluate opportunities and constraints to addressing the key climate adaptation strategies through two case studies of HCPs in the planning and implementation phases; and
3. Recommend approaches to increasing climate change resiliency in HCPs in a report and accompanying presentation for the National Habitat Conservation Plan Coalition, which was provided on November 13, 2019.

1.3 Project Methods

The project included two main elements: 1) a review of the literature on climate change and conservation plans to identify climate-adapted approaches to HCPs; and, 2) implementation of two case studies to explore how existing HCPs are addressing climate change. Input on the project was provided by the technical advisory group, which was comprised of individuals participating in various aspects of HCP development, implementation, and permitting throughout the United States (Box 3).

1.3.1 Literature Review

There is an extensive and growing body of climate change adaptation resources to inform the development and implementation of climate-adapted conservation plans for species, communities, and ecosystems. This includes:

1. Existing scientific studies for managing natural ecosystems and species (e.g., Lawler et al. 2015, Root et al. 2015);
2. Synthesis reports and recommendations (e.g., Heller and Zavaleta 2009 Cross et al. 2012, Keeley et al. 2018a, b);
3. Practitioners' guides for conservation in the face of climate change (e.g. Stein et al. 2014);
4. Online resources with guidance, analytic tools, and case studies including [Climate Adaptation Knowledge Exchange](#), [Climate Commons](#), [TBC3.org](#), the California Department of Fish and Wildlife's [guidance](#) for addressing climate change in Natural Community Conservation Plans, and the [Climate Informed HCPs website](#) (USFWS 2019); and
5. Literature specifically addressing integration of climate change into HCPs (Bernazzani et al. 2012).

Box 3: Technical Advisory Group Members

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Integrating all of the information from these existing resources was beyond the scope of this project, which instead focused on identifying a set of key climate adaptation approaches that should be addressed in HCPs; specifically, approaches that are not overly deterministic and instead are likely to be robust in the face of alternative climate futures and applicable to a variety of ecological systems. The resources listed above and in the *References* provide additional resources beyond this report to develop and implement climate-adapted HCPs.

1.3.2 Case Studies

After identifying the six climate adaptation approaches, this project conducted two case studies to explore how the approaches as well as other climate change considerations are being integrated into HCPs. The objectives of the case studies were to vet and refine the six selected climate adaptation approaches, and to identify opportunities and constraints to integrating them into HCP planning and implementation.

Table 1 lists the general attributes of the two HCPs that were used as case studies: the Balcones Canyonlands Conservation Plan (RECON and USFWS 1996) and the Santa Clara Valley Habitat Plan (ICF 2012).

Table 1: The Case Study HCPs

Characteristic	Santa Clara Valley Habitat Plan	Balcones Canyonlands Conservation Plan
Term	50 years (2013 - 2063)	30 years: 1996 - 2026
Plan Area	510,000 acres in southern Santa Clara County, central coastal California	561,000 acres (Travis County, TX except a National Wildlife Refuge and non-participating cities)
Reserve/ Preserve System Area	~46,900 acres	32,603 acres
Implementing Entity	Valley Habitat Agency, a Joint Powers Authority (JPA) of County of Santa Clara, three cities therein, and two local agencies	City of Austin Travis County
Type	HCP and Natural Community Conservation Plan (Federal and State)	HCP
Covered Species	18 species, 9 plants and 9 animals: <ul style="list-style-type: none"> • 1 invertebrate • 4 herps • 3 birds • 1 mammal 	8 endangered animals <ul style="list-style-type: none"> • 2 birds • 6 invertebrates 27 additional species of concern will benefit from the preserve
Type	HCP and Natural Community Conservation Plan (Federal and State)	HCP

These plans feature many commonalities including they both: 1) are regional plans that include more than half of a million acres in their plan area; 2) involve multiple local jurisdictions (cities and counties); and 3) cover multiple species including federally listed threatened and endangered species, as well as unlisted rare species in the region. The plans differ in two interrelated respects (Table 1):

1. **Development Period:** The Balcones Canyonlands Conservation Plan (BCCP) was developed in the late 1980s and early 1990s, when climate change science was in its relative infancy, while the Santa Clara Valley Habitat Plan (SCVHP) was developed in the 2000s when relatively greater information about climate change was available; and
2. **Permit Period:** The SCVHCP is entering its seventh year of implementation in 2020, with the 50-year permit set to expire in 44 years (2063), whereas the 30-year permit issued based on the BCCP permit ends in six years (2026).

The case studies were implemented through four main steps which are outlined in Table 2.

Table 2: Case Study Approach

Phase	Description	Objectives
1: Document Review	Review HCP and related documents, such as recent annual report.	Obtain background information about the HCP that will be used to characterize it in the project report, and facilitate an informed discussion during the interview.
2: Questionnaire	Distribute a questionnaire (Appendix A) to be completed in advance of the interview by HCP personnel, which will include the implementing entities and HCP planners.	Supplement understanding of the HCP gained through document review, with insights from those involved in the HCP.
3: Interview	Hold semi-structured interviews with HCP staff via teleconference.	<ul style="list-style-type: none"> • Discuss the climate change adaptation approaches (Table 3). • Discuss climate adaptation tools to obtain input about their utility.
4: Follow-Up Research	Follow-up on aspects of the HCPs obtained through interviews and the questionnaire.	Resolve any questions or obtain more information from topics identified in the questionnaire and interview.

1.3.3 Report Overview

This report describes presents the following:

- Six key approaches to make HCPs more climate adapted (Section 2.1);
- Additional climate change resiliency concepts that emerged during the project (Section 2.2); and
- Recommendations for next steps to integrate climate adaptation into HCPs, such as through piloting their application in HCPs in development or implementation phase, and conducting more focused analyses of specific issues encountered by planners and practitioners when trying to integrate climate change with HPC policies and best practices (Section 3).

2 Climate Change Approaches and Resiliency Concepts

2.1 Climate Change Adaptation Approaches

Table 3 identifies six climate adaptation approaches recommended for HCPs. While there are numerous strategies to help attain conservation goals in a changing climate, these approaches were selected as they were deemed:

1. widely applicable across various HCPs;
2. impactful, in terms of facilitating meaningful conservation goals for species as well as broader communities and ecosystems; and
3. most likely to be robust to multiple climate change futures and/or able to be adapted to the context of specific HCPs by practitioners using straightforward methodologies.

The strategies were adapted from those proposed by Groves et al. (2012) for systematic conservation planning. They were augmented to include approaches related to assessing climate change threat and species vulnerability, and developing and implementing plans using the climate-smart conservation framework (Stein et al. 2014). In 2019, the climate-adapted approaches were reviewed by the technical advisory group and were deemed appropriate for exploration in the project.

Table 3 summarizes the climate-adapted approaches and their applications for HCPs, cites key literature and other resources listed in the *References*, which provide additional background as well as methods to apply the approaches.

The following sections describe the climate adaptation approaches and evaluate opportunities and constraints to applying them, as well as methods to address key constraints related to resource availability (e.g., funding and staff capacity), data gaps, uncertainties, and/or lack of alignment with the HCP policies. Boxes 5 and 6 highlight ways in which the two case studies have addressed these approaches during planning and implementation.

2.1.1 Assess Climate Change Threats and the Vulnerability of Species

A crucial strategy for climate-adapted HCPs is to identify the anticipated climate changes in the region, assess the vulnerability of the covered species and their habitats to the anticipated changes, and develop and implement strategies to increase resiliency of the species based on the results of the analysis. Table 3 outlines the approaches and lists some key literature, including 'how to' guides and other tools to implement climate vulnerability assessments.

2.1.1.1 Obtaining Local Climate Change Projections

Climate-adapted HCPs should be developed based on the most recent, highest-resolution (downscaled) climate models available for the HCP plan area, as climate responses are mediated by local factors including topography and pollution (Flint and Flint 2012, Girvetz et al. 2013). Anticipated changes should be explored across a range of scenarios, derived from multiple greenhouse gas emission scenarios and models. The consequences of the various scenarios should be independently evaluated (rather than averaged) as they may predict disparate climate futures (e.g., hotter and drier vs. hotter and wetter)

Table 3: Summary of the six key climate adaptation approaches for HCPs. Details are provided in the text.

Approach	Description	Recommendations for Climate-Adapted HCPs	Key Literature and Resources
1. Assess Climate Change Threats and Species Vulnerability	<ul style="list-style-type: none"> • While climate change is a global phenomenon, the impacts are locally unique. • Multiple projections can be available for a region, based on different scenarios for future greenhouse gas emissions and/or different models • Climate change can affect species through a variety of mechanisms, including alterations of biological systems and responses of human systems, which make it difficult to predict the net effects of climate change for species' distributions, populations, and persistence • Criteria and tools have been developed to assess climate change threats, gauge a species' vulnerability to extinction, and guide development of conservation strategies. 	<ul style="list-style-type: none"> • Use the most locally relevant (i.e., downscaled) climate change projection(s) for the plan area; if none are available, have one developed. • When faced with multiple projections, particularly disparate ones (e.g., increase vs. decrease in rainfall), develop strategies for the alternative scenarios, rather than the average conditions, to develop a plan that is robust. • Conduct vulnerability assessments to assess the exposure, sensitivity, and adaptive capacity of the species and/or their habitats to the anticipated change(s). • Conceptual models that illustrate the direct and indirect effects of climate on species can help unravel the uncertainty about the implications for climate change. • Species distribution models can help identify where species will occur in a future climate. • Use the results to design elements of the HCP, including: <ul style="list-style-type: none"> ○ Covered species: species that might not otherwise be impacted may need to be covered under the plan once climate change impacts are considered; ○ Conservation strategy: the HCP goals and objectives as well as avoidance, minimization, and mitigation measures, should address various aspects of the outcome of the vulnerability analysis, and incorporate elements to promote resiliency to climate change; ○ Changed Circumstances: the changed circumstances should address all climate futures for the region, thoroughly analyze their implications for the covered species, and identify the plan's responses to each; ○ Adaptive Management Program: Monitoring should evaluate changes in species and their habitats including those due to climate change, and identify novel management responses to changes that will limit the ability of the plan to achieve the goals and objectives. 	<p>Bagne et al. 2011 Glick et al. 2011 Foden et al. 2018 Klausmeyer et al. 2011 Stein et al. 2014 Thomas et al. 2011 Williams et al. 2008 USFWS 2018 USFWS 2019</p>

Table 3: Summary of the six key climate adaptation approaches for HCPs. Details are provided in the text.

Approach	Description	Recommendations for Climate-Adapted HCPs	Key Literature and Resources
2. Conserve the Geophysical (Abiotic) Stage	<ul style="list-style-type: none"> • Topography, soil mineralogy, and hydrology, among other factors, create the abiotic conditions that structure ecological communities and create habitat for plants and animals. • These geophysical conditions are relatively persistent in the landscape and will continue to set the evolutionary stage in a changing climate. • Areas featuring diverse abiotic conditions currently will likely provide the diverse environments to support future biodiversity, in spite of climate change. 	<ul style="list-style-type: none"> • Use species models tied to the geophysical aspects (i.e., land facets) of their habitats (e.g., certain community types) and climate projections to identify diverse areas that will support them in a future climate. • Protect and restore, where needed, areas featuring a range of abiotic conditions, including geologic, topographic, and hydrologic gradients, to: <ul style="list-style-type: none"> ○ conserve a range of habitat conditions for covered species, and thus their genetic diversity; and ○ protect biodiversity which can benefit covered species indirectly including by enhancing ecosystem resiliency (Oliver et al. 2015). • Capture a range of geophysical conditions in reserves and landscape linkages to protect genetic diversity and facilitate adaptive capacity and dispersal along these gradients in response to a changing climate. 	<p>Harris et al. 2006 Anderson and Ferree 2010 Anderson et al. 2012 Anderson et al. 2016 Ackerly et al. 2010 Dobrowski 2011 Beier and Brost 2010 Comer et al 2015 Lawler et al. 2015</p>
3. Protect Climatic Refugia	<ul style="list-style-type: none"> • Certain areas in the environment (e.g., wet areas, poleward-facing slopes, steep canyons or valleys, areas of canopy cover) may moderate changes in climate and thus buffer species from rapid change in temperature, sea level rise, or other conditions. • Areas of low climate velocity (the speed at which a population would have to move to keep up with the changing climate; Loarie et al. 2009) may be considered a type of refugia 	<ul style="list-style-type: none"> • Define, map, conserve, connect, manage, monitor and restore (where necessary), climate refugia that are large enough to sustain persisting populations of covered species. • Map climate velocity and conserve low-velocity areas for the focal species (e.g., areas with steep topographical gradients). 	<p>Morelli et al. 2016 Loarie et al. 2009 Klausmeyer et al. 2011</p>

Table 3: Summary of the six key climate adaptation approaches for HCPs. Details are provided in the text.

Approach	Description	Recommendations for Climate-Adapted HCPs	Key Literature and Resources
4. Enhance Regional Connectivity	<ul style="list-style-type: none"> • Species must migrate to stay within their climate envelope (i.e., temperature precipitation regimes to which they are adapted). • Broad landscape linkages (as opposed to narrow corridors) will enable species that disperse slowly, including over generations, to migrate. • Human-created corridors including hedgerows and stepping stone features, such as wetlands, can also be essential for some species • Assisted migration may be needed for species that cannot migrate due to barriers, insufficient time, etc.; however, this should be a last resort 	<ul style="list-style-type: none"> • Linkages between protected areas will be essential to promoting migration in response to climate change and therefore should be protected, managed, and where necessary, restored. • Linkage models that address climate conditions in evaluating suitability (or resistance) can help identify the most suitable locations for migration in response to climate. • Abiotic gradients (e.g., temperature and precipitation gradients, or also soil hydrology, texture, and chemistry gradients), which can be important linkages as they facilitate migration and <i>in-situ</i> adaptation, should also be protected, managed, and restored, where necessary. • Areas of low climate velocity (Loarie et al. 2009) may provide effective corridors, particularly for slow-moving species whose migration could be outpaced by climate change. • Assisted migration, which should be a last resort, should follow best practices to enhance effectiveness and minimize risks 	<p>Keeley et al. 2018a, b</p> <p>McLachlan et al. 2007</p> <p>Hewitt et al. 2011</p> <p>Costanza and Terando 2019</p>

Table 3: Summary of the six key climate adaptation approaches for HCPs. Details are provided in the text.

Approach	Description	Recommendations for Climate-Adapted HCPs	Key Literature and Resources
5. Sustain Ecosystem Processes	<ul style="list-style-type: none"> • Ecosystem processes that structure communities, and therefore species habitat, are essential to long-term persistence. • Landscapes-scale conservation actions that can sustain ecosystem processes can be climate smart, by preventing activities associated with development or other land use from indirectly impacting conditions within conservation lands. • Because climate change may influence the effects of ecosystem processes on species, conservation and restoration should focusing on ecosystem functions rather than species composition. • Because biodiversity influences ecosystem function, conservation should focus on maintaining and restoring biodiversity at the landscape scale. 	<ul style="list-style-type: none"> • Conservation strategies should be based on an understanding of, and focused on, sustaining and restoring, where needed, at a landscape scale, the ecosystem processes that structure communities and support species and their habitat. • Climate vulnerability analyses for species must assess the effects of climate on ecosystem processes, such as disturbance regimes, hydrologic processes, and nutrient cycling. • Although HCPs are inherently species based, safeguarding and restoring ecosystem processes is essential to maintaining habitat and promoting gene flow to support species. 	Lawler 2009 Hooper et al. 2005

Table 3: Summary of the six key climate adaptation approaches for HCPs. Details are provided in the text.

Approach	Description	Recommendations for Climate-Adapted HCPs	Key Literature and Resources
6. Employ The Climate Smart Conservation Cycle	<ul style="list-style-type: none"> • Climate change causes cascading effects that make it difficult to predict the long-term suitability of a site or conservation action (e.g. habitat management technique) for a species or community. • Because of this, historical patterns including species distributions and community composition, and ecology including species interactions and ecosystem processes, may not provide a solid basis for future conservation actions. • Uncertainty in future conditions necessitates that conservation strategies be nimble and adaptive, rather than rigid and set in stone. 	<ul style="list-style-type: none"> • Develop and implement conservation plans through the ‘climate-smart conservation cycle’ (Figure 1; Stein et al. 2014). • Conservation strategies should avoid establishing hard-line reserve networks during the planning phase and instead, identify goals for protecting, restoring, and managing ecosystems processes, communities, and species’ populations in a landscape and allow implementers to protect the most suitable including climate resilient lands. • Management and restoration plans should focus on outcomes (e.g., population sizes, species diversity) and identify potentially effective strategies to achieve them, but allow for adaptation over time. • Monitoring will be essential to evaluating effectiveness and determining adjustments to promote goals. • Plans and their implementors should have the flexibility to identify and adjust maladaptive elements, such as goals, sites, and management strategies, and not be held to implementing them at all cost. 	<p>Stein et al. 2014</p> <p>Safford et al. 2012</p>

that can have different consequences for species and their habitats, necessitating alternative conservation actions.

Obtaining local, high-resolution data may be regarded as a challenge to HCP planners and implementers. Box 4 identifies some existing sources of downscaled climate data that can be evaluated for use. Local experts are most suited to advise about the best models and scenarios, including future time frame, with which to work in any particular geography. Accordingly, HCP prepares and implementers are recommended to engage climatologist and related experts as part of the broader team to help ensure that climate considerations are being developed based on the best available scientific information and approaches. Local experts at regional USGS climate adaptation centers, landscape conservation cooperatives, university extension centers, university research labs, and other organizations that specialize in climate science can be consulted to identify anticipated climate changes for relevant climate and hydrological variables.

**Box 4: Downscaled Climate Projection Data
Available for the United States**

Climate and Hydrology Projections

https://gdo-dcp.ucllnl.org/downscaled_cmip_projections/dcpinterface.html#About

PRISM Climate Data

<http://www.prism.oregonstate.edu/>

US Climate Projections and Scenarios

<https://www.data.gov/climate/portals/>

USGS Regional and Global Climate

<http://regclim.coas.oregonstate.edu/visualization/rccv/states-counties/>

Planners and implementers of HCPs may want to commission development of local climate change projections for their specific planning area. In addition to being necessary if local data are not already available, working with scientists directly can help ensure that projections are targeted in terms of the model suitability as well as geographic area. In 2014, the BCCP implementers integrated the findings from a climate change analysis for their plan area in 2014 that was commissioned by the City of Austin (Box 5; Hayhoe 2014). That climate change analysis has helped the team identify species vulnerable to climate change and develop strategies to address its impacts (Box 5).

2.1.1.2 Assessing Climate Change Impacts

Once the climate change projection is developed for the HCP area, conceptual ecological models, species distribution models, and climate change vulnerability analyses, among other tools, can help identify potential implications of the changes for species' populations, distributions, and habitats, as well as their important biotic interactions, such as host plants, pollinators, and predators.

- **Conceptual models** can be used to illustrate how climate changes may interact with other stressors to influence species directly and indirectly. Presented as diagrams or verbal descriptions, conceptual models illustrate processes, interactions, and feedback loops that are important for a species. These models can be used to evaluate how projected changes in climate will influence species and help inform decision making about how to address climate change in all aspects of HCPs, including the extent to which it is addressed and how (Hoffman 2017).
- **Species distribution models** can predict where a species will most likely occur in the anticipated future climate. Such models can help inform various aspects of the HCP conservation program including reserve design and habitat restoration and management priorities. Species distribution models can also help identify the HCP covered activities by determining where a species

Box 5: Balcones Canyonlands Conservation Plan



Developed in the late 1980s and early 1990s when climate change science was in its infancy, the Balcones Canyonlands Conservation Plan (BCCP) does not address (or even mention) climate change (RECON and USFWS 2016). However, biologists, planners, and others implementing the HCP, including experts originally involved in its planning/permitting are integrating climate change adaptation into plan implementation including through updates to the BCCP Land Management Plan (BCCP LMP)—a ‘living plan’ that addresses how the BCCP’s ~32,000-acre reserve system is managed.

The following highlight some of the climate-adapted approaches that are being implemented as part of the BCCP.

CLIMATE ADAPTIVE APPROACHES

Local Climate Change Projection: In response to observed changes in the local climate and observed and anticipated impacts to the covered species and conservation strategy, BCCP implementers integrated into their management of the Preserve the results of a climate change projection commissioned by the City of Austin, which projected the following for the BCCP region: 1) increases in annual and seasonal average temperatures, 2) more frequent high temperature extremes, 3) little change in annual average precipitation, 4) more frequent extreme precipitation, 5) a slight increase in the number of dry days per year, and 6) more frequent drought conditions in summer due to hotter weather (Hayhoe 2014).



Vulnerability Assessments: BCCP implementers used the climate change projection to assess the threats posed by climate change to the covered species in the BCCP LMP updates. Key vulnerabilities identified through the analysis include:

- Threats to the 31 invertebrate species endemic to the karst caves, which are adapted to narrow temperature and humidity regimes;
- Direct and indirect effects to Golden-Cheeked Warbler (*Setophaga chrysoparia*), as described below; and
- Challenges for fire management, due to increased incidence of fire resulting from drought and increased temperatures, which cause die off of vegetation.



Climate Change Refugia: The analysis of species vulnerability to climate change helped identify potential refugia for the covered species in the future hotter climate.



Golden-Cheeked Warbler: This neotropical migrant breeds only in the central Texas region, where it nests exclusively in mature Ashe juniper-oak woodlands. Heat waves in spring threaten nestlings directly, while increased temperatures and drought threaten to convert forests to shrublands by increasing tree mortality due to desiccation stress and pathogens, and promoting fire. Dense forests suitable for nesting may persist in more mesic areas including deep canyons, and cooler north- and east-facing slopes; conversely, forest in more xeric sites may transition to shrublands that are unsuitable but may be suitable for Black-Capped Vireo (*Vireo atricapilla*), thus increasing habitat in the for this covered species while that for Golden-Cheeked Warbler below the permit requirements.

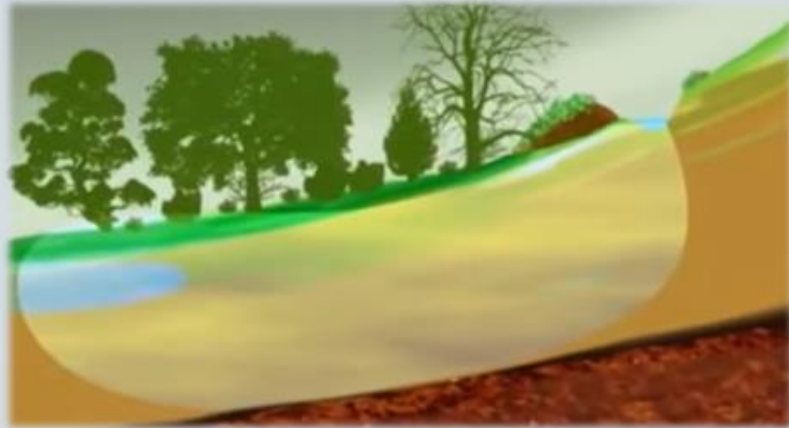
Box 5: Balcones Canyonlands Conservation Plan (cont.)

Climate Smart Conservation Cycle:

BCCP managers are using results from their local climate projection, vulnerability assessment, and climate refugia analysis to develop and implement conservation, restoration, and management strategies to enhance resiliency of the preserve to climate change (BCCP 2019).

Managers are employing a range of treatments to restore degraded landscapes. They have used berms and swales (upper right) to try to capture, sink, and spread water into the landscape. They are also applying organic mulch and actively revegetating degraded areas (lower right) to capture more water into the landscape.

Preserve managers have also been cutting down invasive trees and inoculating the cut logs with a native turkey tail fungus (bottom left). During decomposition, these logs, which are left on site, function as 'sponges' that promote water retention and native tree seedling establishment (bottom right) to revegetate forests, as well as assist with erosion control (O'Donnell et al. 2019).



Monitoring the effectiveness of these and other strategies to address climate change can inform updates the BCCP LMP which will continue to be implemented including as part of the upcoming permit extension.



might occur with respect to planned projects, and conduct the take/impact assessments by quantifying the area of habitat that could be affected by the covered activities. The USFWS Climate Informed HCPs quick guide provides additional information about the various types of models and assesses their utility for HCPs (Hoffman 2016).

- **Vulnerability assessments** can examine the susceptibility of a species to negative impacts of climate change based on an analysis of pressures, impacts, and mechanisms underlying them. A wide range of approaches have been used to generally evaluate the following three factors which determine climate change vulnerability of a given species (Foden et al. 2018):
 - **Exposure:** the nature, magnitude, and rate of climate and associated environmental changes;
 - **Sensitivity:** the degree to which the species will be adversely or perhaps beneficially affected by the climate change; and
 - **Adaptive capacity:** the potential ability of a species to adjust to climate change to moderate potential damage, take advantage of opportunities, or respond to the consequences.

Vulnerability assessments are oftentimes used to rate a group of species based on their relative vulnerability to climate change and thus prioritize conservation actions across species. Such a comparative analysis can help select the species that will be covered by an HCP, by evaluating how species might be indirectly affected by covered activities in a changing climate. Moreover, the mechanistic analysis of a single covered species' vulnerability can also inform many aspects of an HCP conservation strategy, including:

- Habitat protection priorities, by identifying areas most important for species persistence;
- Management actions, by identifying the pressures that are acting on a species directly and are perhaps exacerbated by climate change and should be the focus of habitat management; and
- Monitoring to detect changes and evaluate species responses to conservation actions.

Climate vulnerability analyses may already be available for an HCP's covered species, such as those evaluated as part of a State Wildlife Action Plan; existing vulnerability analyses should be reviewed and refined as part of HCPs, to ensure they address local conditions. Climate Adaptation Science Centers, which are headed up by the United States Geological Survey and comprised of multi-institution consortia, including university and non-university partners, develop data and tools that address the informational needs of natural resource managers in eight geographic regions of the US, which are provided on their website (USGS 2019).

An understanding of climate change and its potential impacts on ecosystems and species will be fundamental to developing all aspects of the HCP. Specific information about anticipated climate change should be included in the changed circumstances section of the HCP, which should address all climate futures for the region, analyze their implications for the covered species, and identify the plan's responses to each.

In the BCCP, the local climate projection was used to evaluate the vulnerability of the covered species to climate change; this vulnerability analysis, in turn, informed their habitat protection and management activities implemented as part of the conservation strategy (Box 5).

2.1.2 Conserve the Geophysical Stage

The complex interactions between climate, ecosystems, and human systems make it difficult to predict the ultimate effects of climate change on a given species and its habitat. In developing HCPs, planners can use species models that incorporate geophysical aspects, also referred to as land facets, of their habitats, such as certain community types. Protecting these land facets across a range of other abiotic conditions that influence climate, such as topography, can capture the range of conditions that promote biodiversity in a region (Anderson et al. 2012 and 2016).

For individual species that are tied to specific geophysical conditions, including geology, soils, and hydrology, HCPs can conserve such abiotic conditions across a range of topographic conditions; in doing so, they can protect a diversity of microclimates within close proximity, including microclimates that are decoupled from regional climate (Dobrowski 2011). As a result, topographic complexity can promote climate change resilience for species (Loarie et al 2009).

Ensuring that protected habitat areas feature the range of abiotic conditions that are created by variable topography, geology, and hydrology can help create opportunities for species to persist and adapt as climate changes. It can also help safeguard native biodiversity, which adds to ecosystem resiliency (Oliver et al. 2015). Variable abiotic conditions give rise to unique species assemblages and ecological communities (Lawler et al. 2015).

Protecting these diverse land features in HCP reserves can promote ecological processes, evolutionary interaction, and range shift (Beier and Brost 2010). Areas featuring a diversity of current abiotic conditions will likely provide the diversity of environments needed to support future biodiversity, even if the climatic conditions and species in those areas change (Ackerly et al. 2010, Anderson and Ferree 2010, Beier and Brost 2010, Lawler et al 2015). In this way, patterns of geophysical diversity can be used as a proxy for conserving the ecological and evolutionary stage for species in a region in both current and future conditions (Comer et al. 2015, Lawler et al. 2015). Much diversity occurs at microscales (<10 meters; Ackerly et al. 2010); so depending on target species, the scale of the analysis must be fine enough to capture the relevant microsite diversity.

Gap analyses can be used to evaluate how well geodiversity is already represented and protected in current conservation areas supporting the covered species and determine where to prioritize land protection to address any gaps. For example, if a covered species occurs on two primary soil types, it might then be important for the HCP to set goals to conserve occurrences on both soil types, to cover the range of abiotic conditions as well as perhaps genetic diversity represented. Protecting the soil types across a range of landscape positions can further increase species resiliency by protecting a range of current and likely future microclimates.

Box 6 describes how the Santa Clara Valley Habitat Plan is working to conserve and manage in its reserve system serpentine soils across a range of environmental gradients to capture the variable microclimates and promote persistence of serpentine endemic species covered by the HCP as the climate warms (Box 6; ICF 2012).

2.1.3 Protect Climate Change Refugia

Habitat conservation plans can help contribute to conservation of covered species in the face of climate change by identifying, protecting, restoring, and connecting areas that buffer a species from climate changes, such as increased temperature or sea level rise. These occur at two spatial scales (Morelli et al. 2016):

1. **Refugia:** areas buffered from climate change over time and are large enough to sustain a manageable unit of that species, such as a population or subpopulation of a metapopulation; and
2. **Refuges:** smaller, transient microenvironmental areas where species can reduce their exposure to climate change.

The physical conditions that create refugia and refuges from warming temperatures can include: 1) various aspects of topography, such as poleward (i.e., north-facing) aspects and valley bottoms; 2) areas featuring water, including snow, water bodies, and groundwater; and 3) biological aspects of communities that moderate temperature such as areas with tree canopy cover (Morelli et al. 2016).

Refugia are important for any climate-sensitive species, which can include: 1) species that are highly sensitive to temperature or moisture changes, 2) populations already near their southern range limit, and 3) relic species that were more widespread in the past, but now only persist in isolated areas (refugia). Many of these relict species are naturally rare and are often threatened or endangered or meet the criteria for such listing under ESA. Refuges can provide species with access to resources (e.g., food) or temporary refuge during drought or extreme heat events and flooding events, and may be critical as these events increase in frequency.

Planners and implementers of HCPs can use climate projections, conceptual models, and climate change vulnerability assessments (Section 2.1.1) to identify refugia and refuges for each covered species. These areas should be mapped to facilitate their conservation including: 1) avoidance by covered activities, 2) inclusion in reserve systems, 3) active management, as needed to sustain their value and functions, and 4) connection within the landscape to species access to them. General refugia from a warming climate, such as identified by Morelli et al. 2016 (e.g., north-facing slopes and wet areas), can also be identified and mapped so they can be considered in conservation strategies that address the protection of biodiversity more broadly, which can promote resiliency of ecosystems (Oliver et al. 2015).

As with all mapping, finding sufficiently resolved information about the landscape to reveal refugia may be challenging, as some refugia and refuges will occur at fine spatial scales. However, high-resolution current climate data can be used to identify present-day refugia, based on the assumption that most such places will continue to behave as refugia in the future. Biodiversity patterns and the occurrence of relic populations may also be indicators of refugia that should be protected and managed through the plan. In the BCCP case study, plan implementers used local climate projections and vulnerability assessments to identify two types of climate refugia for the covered species, mesic forests and deeper caves; BCCP managers are using novel management treatments to try to maintain the suitability of habitat in these areas (Box 5).

Areas of relatively low climate velocity may also be considered a type of refugia in a warming climate. Climate velocity describes the rate and direction that an organism would need to migrate to maintain an isocline of a given climate variable including temperature (Loarie et al. 2009) or climatic water

Box 6: Santa Clara Valley Habitat Plan

Developed beginning in the mid-2000s and permitted in 2013, the Santa Clara Valley Habitat Plan (ICF 2012) used a climate change projection for California to assess potential impacts on the covered species and natural communities in the plan, which is also a Natural Communities Conservation Plan (NOCP) under California Endangered Species Act. The HCP/NOCP integrates aspects of the analysis into its conservation strategy, which uses a landscape-level approach to encompass ecological processes, environmental gradients, biological diversity, and regional connectivity; climate change is also addressed in the changed circumstances analysis and adaptive management framework (ICF 2012). The following highlight some of the climate-adapted approaches reflected in the plan and its implementation over the past six years.

CLIMATE ADAPTIVE APPROACHES

Conserving the Geophysical Stage: The Valley Habitat Plan reserve system is designed to protect habitat types across environmental gradients to provide topographic diversity that can enable natural communities and species to adapt *in situ* to changes in temperature and precipitation. Capturing the range of conditions will be essential to prevent the extinction of Bay checkerspot butterfly (*Euphydryas editha bayensis*), which is covered along with nine plant species that are endemic to, or preferentially occur on, serpentine soils: low-nutrient, high-metal soils that support unique assemblages of plants and animals. The reserve system is being assembled to protect a serpentine communities that feature variable abiotic conditions (e.g., slope aspects, hydrology, etc.) to facilitate migration of Bay checkerspot butterfly, its host plants, and the covered plants to areas of suitable serpentine habitat that is within their climate envelope.



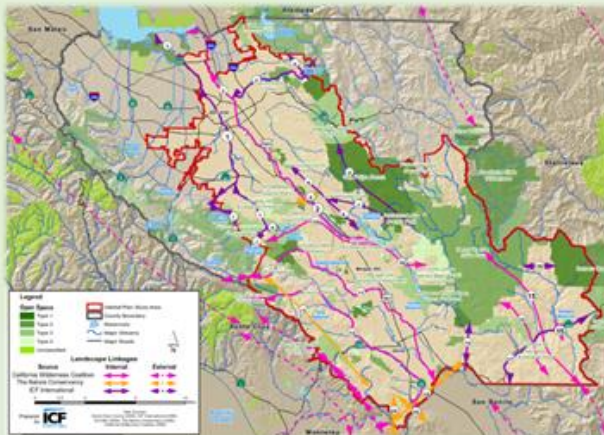
The Valley Habitat Plan also includes a nitrogen deposition fee that is paid by plan participants and that will be used to offset the indirect effects of covered activities that increase in atmospheric nitrogen deposition—an airborne pollutant that fertilizes serpentine soils and promotes growth of exotic plants, which outcompete the covered plants and degrade habitat for Bay checkerspot butterfly by reducing populations of its host plants. The fee will help fund the additional costs to actively manage serpentine and other communities sensitive to nitrogen deposition, including using cattle grazing to control exotic grasses, to promote Bay checkerspot butterfly host plants as well as populations of the nine covered plants that occur within the serpentine communities.

Box 6: Santa Clara Valley Habitat Plan (cont.)

Climate Change Vulnerability and Refugia: The Valley Habitat Agency developed hydrological modelling methods to assess climate change vulnerability of ponds, which provide breeding habitat for four of its covered species (California red-legged frog, California tiger salamander, western pond turtle, and Tricolored Blackbird; Balance Hydrologics 2018). The analysis will be used to prioritize ponds that are more likely to persist in the future climate (i.e., refugia) for land protected in the reserve system; the pond prioritization models will also be used to inform pond restoration and management.



Enhance Regional Connectivity: To promote adaptation to climate change, the Valley Habitat Plan emphasizes protection and enhancement of regional landscape connectivity. As illustrated below, the plan mapped linkages: 1) within the plan area, to help species migrate to cooler areas (refugia) in the mountains as temperatures increase on the valley floor; 2) through the plan area, to facilitate migration along latitudinal gradients (i.e., northward); and, 3) across Coyote Valley, where intensifying land uses threatens to sever connectivity between two mountain ranges (the Santa Cruz and Diablo ranges). The plan also calls for transportation infrastructure improvements to facilitate wildlife movement through highways, and removing fences and other barriers to wildlife movement; these additional measures are designed to promote permeability of the landscape. The Valley Habitat Agency has partnered with other conservation agencies and organizations on a series of projects to promote habitat connectivity including: 1) supporting research to track wildlife movement in the region to inform linkage designs and prioritize connectivity projects (Serieys et al. 2019), 2) working to develop transportation infrastructure improvements to reduce road kill, and 3) advising on the design of new major transportation infrastructure in the region (i.e., California High-Speed Rail) to minimize the impacts on connectivity.



The plan mapped linkages: 1) within the plan area, to help species migrate to cooler areas (refugia) in the mountains as temperatures increase on the valley floor; 2) through the plan area, to facilitate migration along latitudinal gradients (i.e., northward); and, 3) across Coyote Valley, where intensifying land uses threatens to sever connectivity between two mountain ranges (the Santa Cruz and Diablo ranges). The plan also calls for transportation infrastructure improvements to facilitate wildlife movement through highways, and removing fences and other barriers to wildlife movement; these additional measures are designed to promote permeability of the landscape. The Valley Habitat Agency has partnered with other conservation agencies and organizations on a series of projects to promote habitat connectivity including: 1) supporting research to track wildlife movement in the region to inform linkage designs and prioritize connectivity projects (Serieys et al. 2019), 2) working to develop transportation infrastructure improvements to reduce road kill, and 3) advising on the design of new major transportation infrastructure in the region (i.e., California High-Speed Rail) to minimize the impacts on connectivity.

Climate Smart Conservation Cycle: The Valley Habitat Agency determined that areas originally identified in the plan for Western Burrowing Owl conservation are unoccupied by the species and are vulnerable to sea-level rise. Areas occupied by the covered species and that appear more suitable for long-term are located just outside of the plan area. Thus, the Valley Habitat Agency would like to conduct activities designed to increase the nesting population in the area just south of the Plan Area. However, an HCP amendment will be required for the implementing entity to conduct elements of the conservation strategy in this preferred and more climate-adapted area.



balance¹ (Dobrowski et al. 2013). For species that migrate more slowly, areas of low climate velocity, such as areas with steep elevational gradients for increasing temperature, can be important to protect to facilitate their adaptation to climate change.

2.1.4 Enhance Regional Connectivity

Protecting and enhancing landscape connectivity is the most often recommended strategy to adapt to climate change (Heller and Zavaleta 2009). There is widespread recognition that corridors connecting reserves should be wide, to enhance their effectiveness at facilitating species movements including in response to a changing climate. Broad landscape linkages that are at least 2 km (1.25 mi) wide, as opposed to narrow corridors, should be protected and maintained between reserves, wherever possible (Beier 2019). Such broad landscape linkages will be more effective than narrow corridors for several reasons including:

1. **More Diverse Habitat:** Landscape linkages can incorporate more diverse habitat conditions that support more species' movements, or use by a single species as conditions change over time;
2. **Live-In Habitat:** Rather than just providing habitat that species can move through, broad landscape linkages that are wide enough for species to live in can enable slow-moving species, such as plants and invertebrates, to migrate in response to climate change over multiple generations; and
3. **Buffered Habitat:** Broad linkages will be more buffered from impacts of adjacent land uses (e.g., development and agriculture), enabling animals that are wary of humans or intolerant of edge effects to use the linkage, whereas they might be deterred from using narrow corridors.

As with all corridors, broad landscape linkages should be located in areas that are conducive to animal movement and the flow of other ecological processes.

Although broad landscape linkages are more effective, narrower corridors may nonetheless be essential components of climate-adapted conservation strategies in areas where: 1) habitat has already been largely converted and cannot be feasibly restored, 2) animals need to move across transportation infrastructure (e.g., roads and highways); and/or 3) opportunities to protect broader linkages are otherwise constrained. Connectivity plans can also include habitat enhancements to facilitate movement of species confined to specific habitats; for example, creating steppingstone features such as ponds and wetlands, or hedgerows of native trees that provide shade, fruit, or other resources, may help promote animal movement through fragmented landscapes (Davies and Pullin 2007).

Habitat conservation plans can also facilitate species migration in response to climate change by enhancing the permeability of the landscape. The specific steps can depend on the species and the characteristics of the landscape, but can include removing fencing or other barriers, or adding specific food plants along roadways or fence lines. Such measures were included in the Santa Clara Valley Habitat Plan, which includes provisions to promote habitat permeability as well protect a range of landscape linkages (Box 6; ICF 2012).

The design of effective landscape linkages and other connectivity elements for HCPs should consider be integrated with planning to conserve geophysical diversity (Section 2.1.2), climate change refugia

¹ The climatic water balance is defined as the difference between precipitation depth and the depth of potential evapotranspiration at a given site during a certain time period.

(Section 2.1.3) and also sustain ecosystem processes (Section 2.1.5). Gradients of abiotic diversity are often highly suitable landscape linkages, as they can facilitate migration and *in-situ* adaptation. Likewise, areas of low climate velocity (Section 2.1.3), where species need migrate shorter distances to stay within their climate envelope (climate conditions to which they are adapted) will function more effectively as corridors than areas of high climate velocity, where slow-moving species may be outpaced by climate change.

Keeley et al. 2018a provides an overview of climate change connectivity modelling methods that could be used to develop the connectivity elements of HCPs. The implementation of corridors to support species migration are most successful when based in a common vision, inclusive of multiple benefits, developed with diverse stakeholders, including public support (Keely et al. 2018b).

Development of connectivity elements of HCPs may also need to consider assisted migration (translocation) for species that will not be able to migrate fast enough on their own in response to climate change. Assisted migration is under fierce debate, as it can impact source populations and have unintended consequences for other species, including cause species extirpations (Olden et al. 2011). As a result, it should be a last resort for HCPs. Importantly, assisted migration should not be used to mitigate loss of connectivity as a result of covered activities; instead, safeguarding and restoring connectivity should be a priority of HCPs.

Nonetheless, assisted migration may be necessary for HCPs where connectivity is constrained prior to the plan development and implementation of the HCP's covered activities, and where landscape connectivity cannot be restored through the plan's conservation strategy; in such circumstances, assisted migration may be essential not only to facilitate migration in response to climate change, but also metapopulation dynamics and gene exchange. In addition, HCPs may also involve translocations of individuals that would otherwise be impacted by a covered activity to a new area as part of the conservation strategies minimization measures (USFWS and NOAA Fisheries 2016). In such cases, planners and implementers of HCPs should develop translocation strategies based on a review of literature that explores the best practices for translocations and assisted migration to maximize the benefits and minimize its risks to resident species and communities.

2.1.5 Sustain Ecosystem Processes

Ecosystem processes related to water and nutrient cycling, energy fluxes, and community dynamics (e.g., disturbance) can be essential to sustaining endangered species populations as they maintain suitable habitat meet species' life history requirements (e.g., fires that promote seed germination); these processes can also sustain native biodiversity, which can benefit rare species indirectly including by promoting ecosystem functions and resiliency (Hooper et al. 2005, Oliver et al. 2015).

Climate change can alter these ecosystem processes, including fire regimes and hydrology, by increasing temperatures and changing precipitation regimes. These alterations can have consequences for rare species, which should be assessed as part of climate change vulnerability analyses conducted for HCPs (Section 2.1.1.2). Conceptual models can help illustrate the important ecological processes that can be driven by factors that occur away from covered species habitat; for example, the hydrologic functions and structure of a wetland can be influenced by hydrologic processes elsewhere in the watershed, including water diversions that diminish groundwater recharge. Mapping key drivers of ecosystem process in the landscape can help avoid altering them during implementation of HCP covered activities;

it can also help design the reserve system to protect and restore lands that are critical to maintaining important ecosystem processes.

Like many aspects of climate-smart conservation, sustaining and restoring ecosystem processes will require consideration of a broader geographic scale, as ecosystem processes function at landscape scales to influence conditions in a given site. Effective HCP conservation strategies may need to include actions outside of reserves or perhaps outside of the plan area, or the plan area may need to be expanded to encompass areas important for sustaining species populations (Section 2.2.1.3).

Maintaining landscape connectivity, including through the protection of broad landscape linkages (Section 2.1.4) can help sustain ecosystem processes, including propagation of disturbances (e.g., stream flows and fires), as well as including dispersal and gene flow.

Restoration of hydrology (or connecting hydrology in novel ways) can be evaluated as a method to sustain ecosystem processes and adapt to climate change. Surface waterways are critical to dispersal and migration of many species. Surface and subsurface water flows provide habitat and can create microrefugia that may provide vital refuge to populations (Section 2.1.3; Morelli et al. 2016). Restoring natural hydrology can also help conserve geophysical diversity (Section 2.1.2).

Active habitat management with HCP reserves may be needed to address alterations of ecosystem processes, including those resulting from climate change. For example, where increased temperature, drought, and climatic water deficit increases fire frequency, such as in the BCCP, vegetation management and other strategies can be used to reduce the risk of fire and conserve populations of fire intolerant species including species adapted to later-successional communities (Box 5). Likewise, rare plant and animal populations can be sustained through livestock grazing to reduce competition from exotic plants, the growth of which may be promoted by climate change; such management is being used to promote rare serpentine species in the Santa Clara Valley Habitat Plan (Box 6). Management could also be used to simulate the effects of periodic flooding or other hydrological processes in aquatic ecosystems to promote species that depend on scour or other conditions that it creates. Some habitat management techniques can be expensive, pointing to the importance of working to sustain natural ecosystem processes to avoid the need for ongoing intervention, which may nonetheless be necessary for species that are vulnerable to declines.

Though HCPs are oftentimes regarded as plans for species rather than ecosystems, Congress recognized when enacting ESA that individual species must be viewed in terms of their relationship to the ecosystem of which they are a constituent element (Box 7; Taylor and Doremus 2015). Recovering listed species will require addressing ecosystem processes and functions.

Box 7: Endangered Species Act and Ecosystems

In enacting the Endangered Species Act, Congress recognized that individual species should not be viewed in isolation, but must be viewed in terms of their relationship to the ecosystem of which they form a constituent [sic] element. Although the regulatory mechanisms of the Act focus on species that are formally listed as endangered or threatened, the purposes and policies of the Act are far broader than simply providing for the conservation of individual species or individual members of listed species.

**-H.R. Conf. Rep. No. 97-835, at 30 (1982),
reprinted in 1982 U.S.C.C.A.N. 2860, 2871**

2.1.6 Employ The Climate-Smart Conservation Cycle

The long-term effectiveness of HCPs in a changing climate can be enhanced by integrating elements of the climate-smart conservation cycle into their design and implementation. *Climate-Smart Conservation: Putting Adaptation Principles into Practice* (Stein et al. 2014) describes in detail a suite of climate-adapted approaches to conservation and management, and outlines a stepwise process for developing climate-smart conservation plans of all types; as such, it is an excellent resource for the development and implementation of climate-adapted HCPs.

A key recommendation in the report is to implement the climate-smart conservation cycle—a framework for developing, implementing, monitoring, and adjusting conservation actions that is designed to enhance their effectiveness over time (Figure 1; Stein et al. 2014). Developed based on a more general adaptive management framework that has been recommended for HCPs (USFWS and NOAA Fisheries 2016), the climate-smart conservation cycle reflects important climate adaptation approaches including:

1. An assessment of climate change impacts and vulnerabilities (Section 2.1.1), to ensure conservation actions specifically address the impacts of climate change in concert with other existing threats;
2. Development of forward-looking goals and objectives that address decades to centuries; and
3. Identifying multiple adaptation options based on a range of possible future conditions to account for uncertainties in future climatic conditions as well as ecological and human responses.

Robust monitoring is essential to implementing the climate adaptation approaches as part of HCPs, many of which are implemented over the course of decades and thus provide opportunities to track longer-term responses to climate. Monitoring in HCPs should help address the uncertainty introduced by climate change as well as that inherent in all conservation strategies, and can include:

1. Tracking changes in climate, in terms not only of mean and annual temperature and precipitation, but also trends and events including the duration and frequency of extreme events (e.g., floods and droughts) or cycles (e.g., so-called ‘whiplashes’ between droughts and floods);
2. Evaluation of ecosystem, community, and population changes over time to both understand responses to climate change and revise the conservation strategy to prioritize areas that are (or will become) most important; and
3. Examination of changes across climate and hydrological gradients to assess how geophysical variation may affect species persistence, vulnerability, and resilience, including whether areas are acting as refugia.

The climate-smart conservation cycle calls for goals and objectives to be revised, as needed, to promote the effectiveness of the plan. The adaptive management framework outlined in the HCP handbook (USFWS and NOAA Fisheries 2016) allows adjustments to conservation actions, as well as the objectives if such changes are built into the plan; however, changes to the biological goals require an amendment to the HCP, which is a time and resource consumptive process. Streamlining the amendment process, and/or expanding types of changes that can be made without an amendment to include biological goals, can help promote effectiveness of HCPs in a changing climate (Section 2.2.2.5).

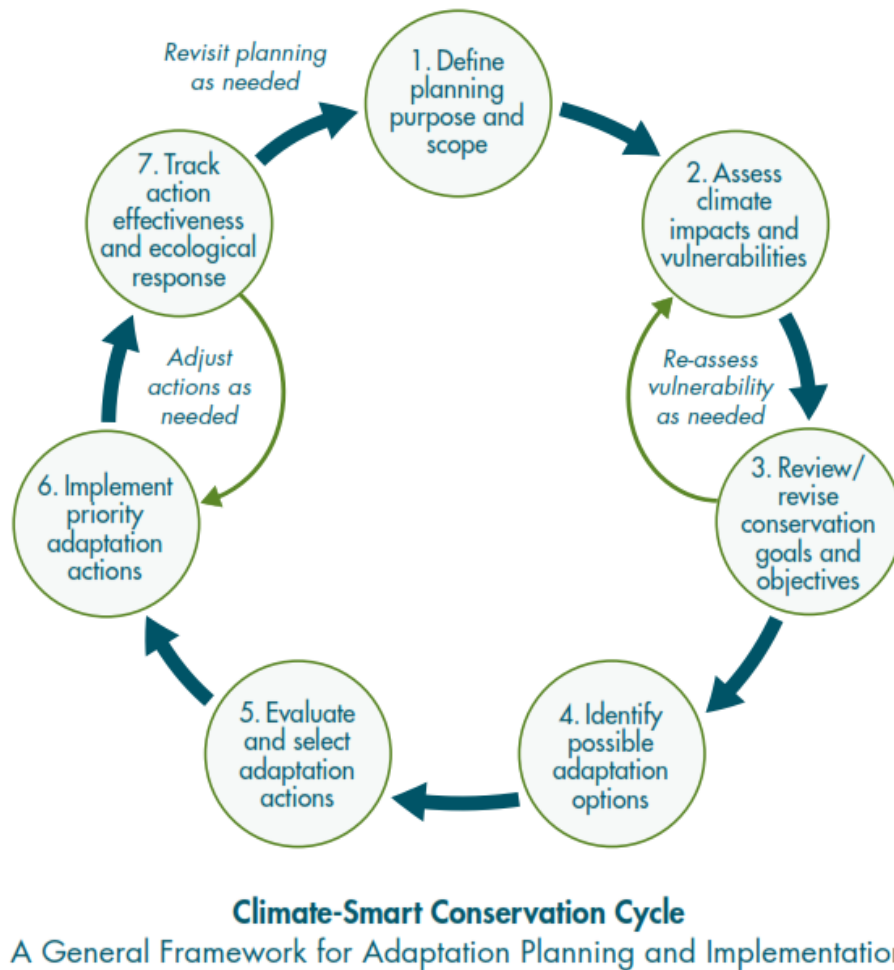


Figure 1: Climate-Smart Conservation Cycle (from Stein et al. 2014)

2.2 Resiliency Concepts

During the process of examining the climate adaptation approaches through the case studies, a number of concepts emerged for best practices to enhance resiliency of HCPs to climate change. They are outlined briefly below in terms of two main concepts: **bigger is better** and **flexibility and adaptation**. These concepts are aimed to increase resilience of HCPs so that they are robust to uncertainties introduced by climate change.

2.2.1 Bigger is Better

Reflecting the widespread and pervasive nature of climate change and its impacts, the concept ‘bigger is better’ emerged often in evaluating methods to make HCPs more effective in a changing climate.

2.2.1.1 Bigger Reserves and Reserve Systems

Though small reserves can play critical roles in conservation (Schwartz 1999), larger reserves have long been recognized as superior to smaller ones, all else being equal. The nature and magnitude of climate change effects on species will make it even more important that areas set aside for maintaining populations of covered species be as large as possible, as larger areas are more likely to feature the following:

1. **Climate change refugia** and refuges where species can migrate to stay within their adapted climate envelopes;
2. **Diverse** geophysical conditions that will increase biodiversity and thus feature assemblages of co-occurring species upon which the covered species may rely for habitat, food (host plants or prey) and other aspects of their life history and ecology (e.g., mycorrhizae, pollinators, etc.);
3. **Buffered habitat** owing to their larger area-to-perimeter ratios, which will insulate habitat from edge effects, including those that can be exacerbated by climate change, such as increased wildfire risk; and
4. **Larger Populations** of covered species, which will be more persistent in the face of other pressures and stressors caused by climate change.

Those planning HCPs should design reserves to achieve these benefits, by siting them in high quality habitat that supports large populations, incorporating climate change refugia (Section 2.1.3) and diverse geophysical conditions (Section 2.1.2), and minimizing future edge effects including reducing perimeter-to-area ratios and evaluating adjacent land uses (current and likely future) and their impacts. Those implementing existing HCPs can use these and other considerations to evaluate the climate-adaptive nature of existing (or planned) reserves, and where possible and necessary, expand the area protected to further achieve these benefits of large reserves.

Overall, climate change will render traditional approaches to conserving and managing a network of reserves in a matrix of unprotected private lands less effective for two reasons: 1) species will need to migrate in response to climate change, and 2) adjacent lands may have a greater influence on the biotic composition and functions of reserves in a changing climate. Conservation strategies should take a more holistic landscape approach which will benefit from coordination with adjacent landowners (Section 2.2.1.7).

2.2.1.2 Bigger (Wider) Corridors

As described in greater detail in Section 2.1.4, there is widespread agreement that corridors connecting reserves should be wider (≥ 2 km or 1.25 miles) to promote species movements in response to a changing climate (Beier 2019). When compared to narrow wildlife corridors, such broad landscape linkages can: 1) support more diverse habitat conditions that will be more conducive to movement of multiple species as conditions change over time; 2) enable slower-moving species including plants to 'live in' the habitat and migrate over multiple generations; and 3) better buffer species against the influence of adjacent human activities and converted habitat (Section 2.1.4). As with all corridors, broad landscape linkages should be located in areas that are most conducive to animal movement and the flow of other ecological processes (Section 2.1.4).

2.2.1.3 Bigger Planning Area

In the face of climate change, HCPs will benefit from addressing a larger plan area and permit area (i.e., area within which the incidental take permit applies). Regional HCPs based on county boundaries or other jurisdictional areas, as well as HCPs based on large land ownerships, may need to buffer their planning area beyond their jurisdiction/landholdings to address biotic changes due to climate change. While these HCP applicants may not be able to affect land use or impose other terms in areas outside of their jurisdiction, expanding the plan and permit area will enable implementation of voluntary conservation actions (e.g., land acquisition from willing sellers) in a broader geographic area, which can help the plan in the following ways:

1. **Accommodate Species Distribution Changes:** Expanding the HCP plan and permit areas will be necessary to account for species migrations along climate gradients during the course of the plan. Examining a broader geographic area during planning can account for:
 - a. Listed species that may migrate into the permit area, and thus will need to be covered by the plan and permit to avoid permitting issues; and
 - b. Species currently in the region may migrate out of the plan area, necessitating that reserve systems include modeled/predicted future habitat, to promote their long-term effectiveness.
2. **Incorporate a Broader, More Interdependent Landscape:** Planning across a larger region will enable consideration of the other factors in the landscape that influence the effectiveness of a conservation strategy. A changing climate will alter land use activities and patterns, as humans adapt to climate changes and alter ecosystem processes (e.g., hydrologic regimes, fire regimes) in ways that can affect the structure and composition of communities (i.e., habitat conditions). Anticipating and monitoring human land-use change and how it interacts with HCP reserve design and management will be essential to the design and implementation of a robust conservation strategy.

Traditionally, a priority has been placed on mitigating the impacts of covered activities within or near the site where they occur, so that the mitigation offsets the effects of the activity on the ecologically equivalent resources (genes and populations). Climate change adaptation may necessitate that optimal mitigation occur farther away from the covered activity than it would otherwise. Like other landscape factors that influence long-term site suitability, climate change should be evaluated in siting reserves and restoration projects, to ensure they will have long-term conservation value based on the best available science to promote their effectiveness.

2.2.1.4 Bigger (Longer) Timeframes

Consideration should be given to extending the timeframe for implementation of HCP conservation strategies. Longer timeframes can promote effectiveness by allowing more time to monitor and evaluate climate change effects on species and habitat, and to adapt the conservation strategy to best address the observed changes.

Permit terms in HCPs oftentimes include the timeframe for implementation of the compensatory mitigation, including habitat protection and restoration, as well as the covered activities for which the permit is originally sought (e.g., development or resource extraction). Most large-scale HCPs including

regional HCPs include in perpetuity habitat protection (i.e., establishment of reserves) to mitigate for permanent impacts of the covered activities, as well as a non-wasting endowment to fund long-term management and monitoring beyond the end of the permit period. It may be necessary to adapt management and monitoring strategies after the covered activities are completed to ensure the durability of the conservation goals and objectives; as a result, HCP permit terms should be lengthened or other steps taken to accommodate the ongoing implementation of the conservation strategy post permit.

Longer permit terms can increase the amount of uncertainty about aspects of the plan that influence its effectiveness, including whether the benefits of the conservation program will outweigh the impacts of the taking; as a result, robust adaptive management programs and funding assurances are needed for longer permits while shorter permit requests are noted to expedite permitting (USFWS and NOAA 2016). However, implementation of robust monitoring and adaptive management plans provides an opportunity to address the uncertainty about the impacts of climate change on covered species and thus adjust elements of the conservation program, including the reserve design and restoration and management strategies, during the course of implementing the plan. If that timeframe is shorter, there will be less time for climate change impacts to accrue and for long-term monitoring and other evaluation to detect them, thus potentially reducing the likelihood that the conservation strategy will be effective in the long term. Having separate permit terms for implementation of aspects of the conservation program that can cause take (e.g., monitoring or restoration) and the covered activities for which the permit is originally sought (e.g., development or resource extraction) can reduce the uncertainty associated with issuing longer-term take permits for covered species while still allowing ample time to implement an effective conservation strategy.

The argument for longer permit terms outlined above assumes that climate change impacts and understanding of them will accrue over time in a continuous fashion; however, episodic impacts such as extreme climate years or catastrophic wildfires could cause abrupt changes, including population extirpations, at any time during plan implementation. Likewise, new scientific information that points to the maladaptive nature of the conservation strategy could emerge at any time. These potentialities point to the importance of a robust analysis of changed circumstances around climate change, and a clear plan for adapting the HCP to address climate change, irrespective of the permit term.

Given the tradeoffs between certainty and adaptability that are inherent in determining the permit term for HCPs, this topic is recommended for potential further analysis (Section 3.3).

2.2.1.5 Bigger Scope of Habitat Restoration and Management

Climate change increases the importance of habitat restoration and active habitat management to maintaining covered species populations. Climate change is anticipated to exacerbate existing threats as well as result in new threats to species, such as exotic species competition, pests and pathogens, and altered disturbance regimes (Heller and Zavaleta 2009). These stressors, which can reduce populations and threaten persistence, will likely necessitate active management of reserves to promote populations of covered species.

Habitat restoration can similarly play an important role in increasing the resiliency of the landscape to climate change by increasing the area of suitable habitat thus promoting their population persistence. Habitat restoration and management can also reduce the other stresses impacting species populations,

thus promoting their resiliency to climate change. The review by Heller and Zavaleta (2009) identifies a suite of management and restoration responses as well as conservation actions to address climate change which can be evaluated for their applicability in developing each climate-adapted HCP.

2.2.1.6 Bigger (Better) Science

In general, the additional stress and complication of climate change requires that HCP planners and implementers add data to their toolbox and consider more complex and dynamic interactions among the variables monitored. Uncertainty about how exactly climate change will manifest and impact natural systems, which are highly stochastic, presents challenges to developing and implementing conservation programs designed to achieve set goals and quantitative objectives for species. Steeped in uncertainty, the field of conservation biology has developed many tools for decision makers and managers to implement robust conservation actions despite the unpredictable nature of complex natural systems.

Scientific approaches will be needed to develop and implement robust conservation strategies in the face of climate change. More and better data are needed for:

- 1. Climate Model Projections:** HCPs should be developed based on the most recent, finer-resolution (downscaled) climate models available for the region, which should be identified in coordination with local climate scientists, climate extension specialist, and climate adaptation centers (Section 2.1.1.1). In addition, the land facet approach (Section 2.1.2) requires fine-grained hydrological and geological data, to stratify conservation strategies across a diversity of geophysical types.
- 2. Climate Change Effects:** HCP planners and implementers will need to assess potential climate change impacts on species, and understand how sensitive species are to potential climate changes based upon multiple climate model projections. These assessments can be implemented with the aid of vulnerability assessments and conceptual models (Section 2.1.1.2). Where different climate futures are projected, a robust plan should identify a consensus reserve network across the different model scenarios. Where data are missing, such as when a species sensitive to climate thresholds is unknown, vulnerability analysis can help identify knowledge needs that can drive partnerships with research labs to fill data gaps.
- 3. Population/Community/Ecosystem Monitoring:** Monitoring of covered species populations, the structure and species composition of the communities they inhabit (i.e., their habitats), and the ecosystem processes that are essential to their persistence, will be necessary to assess the effectiveness of the conservation strategy amidst climate change, which has introduced additional uncertainty into conservation and management (Section 2.1.6). Monitoring data should be curated in databases that enable integrated analyses across the hierarchical levels, such as by relating population trends to changes in community composition, and community composition to ecosystem processes.

Partnering with research institutions can help facilitate efforts to integrate science and scientific approaches into HCPs (Section 2.2.1.7). The data and analyses generated through HCP monitoring programs should be shared with scientists and practitioners working on the covered species or systems in the region to leverage the benefits of the HCP's conservation investments and aid in interpretation and adaptive management.

2.2.1.7 Bigger Tent

Given the uncertainty of species conservation and its dependence on factors in the broader landscape, HCPs will benefit from being implemented in coordination with a diverse range of participants including scientists, private landowners, and the broader community.

Partnerships with research institutions including universities, government agencies (e.g., USGS, climate adaptation centers), and private organizations (e.g., scientific museums) can facilitate efforts to integrate the necessary scientific data and current adaptation approaches, such as robust conceptual models and adaptive monitoring programs, into HCPs.

Greater coordination with owners of land in the plan area can facilitate landscape-scale conservation and management that climate change necessitates. Such coordination will be essential to increase the likelihood that species can disperse successfully across private lands, and to manage threats, such as non-native species and pollutants. This coordination will be particularly important for land adjacent to reserves, and for lands which are interconnected through ecosystem processes, such as land in the watersheds of important streams.

Finally, outreach to stakeholders and the broader community can promote their support for the HCP and its success during planning/permitting as well as implementation. Increased support can be achieved by emphasizing the multibenefited nature of HCP conservation programs; specifically, how habitat protection, restoration, and management will also: 1) promote protection of water, cultural, and scenic resources, 2) provide opportunities for compatible recreation, in some cases, and 3) help mitigate the effects of climate change, as protected and restored land can help sequester carbon.

2.2.2 Flexibility and Adaptation

Another key concept that emerged repeatedly during this project is the need for HCP conservation programs to be flexible to adapt to climate change. The following are some specific climate change resiliency approaches that relate to flexibility.

2.2.2.1 Identify Uncertainties and Develop a Flexible Conservation Program

To be effective in the long-term, HCP conservation strategies should identify and address uncertainties, including those resulting from climate change. During the planning process, information gaps should be identified and filled where possible; where significant questions cannot be answered, they should be addressed through the adaptive management framework during implementation of the plan, including through long-term monitoring of species, communities, and ecosystems (Section 2.2.1.6).

Given inevitable uncertainties, conservation programs should be flexible so that they can adapt to changes in conditions and new scientific information, including the HCPs monitoring results. Though this sounds sensible, there is a tension between flexibility and certainty/assurances in HCPs. The agencies involved in issuing take permits (USFWS and NOAA Fisheries) and providing other permits and authorizations based on HCPs (e.g., state wildlife agencies, the Army Corps of Engineers) need assurances that benefits will be realized from conservation programs in order to issue permits; accordingly, most HCPs outline their conservation actions with specificity and analyze their anticipated benefits in the plan to meet those assurances. For example, HCPs can identify specific properties or

acres of lands in a specific region for inclusion in the reserve system, or acres of habitat to be restored in a given area. However, what if one or more covered species for which these actions are being implemented are no longer supported by the lands targeted? Climate-adapted HCPs should ideally be designed with the flexibility to evaluate the potential for these and other climate-induced changes to influence the actions in the conservation program, and clearly describe in the conservation program and changed circumstances analysis how adjustments will be made to the conservation actions in order to achieve the HCP biological goals, thus meeting the No Surprises Assurances².

2.2.2.2 Flexible Reserve Systems

The suitability of land included in HCP reserves can change as a result of climate change. The following are two approaches to adding flexibility to the reserve systems created through HCPs.

1. **Soft-Line Reserve Systems:** Rather than specifying specific properties or acreages to be protected in designated geographic areas (so-called 'hard-line reserve systems'), HCPs can identify the criteria that will be used to assemble the reserve system over time, based on the long-term conservation value of habitat for the covered species. Such an approach can provide implementers the flexibility to meet biological objectives by ensuring that future reserves support the species when the land protection project takes place, which can occur several decades after the HCP is planned or even permitted in the case of HCPs with long permit durations (≥ 50 years). Soft-line reserves can also provide flexibility to address issues of willing sellers, and reduce the escalation of land costs that can result when hard-line reserves are identified in HCPs.
2. **Shifting Reserve Systems:** Rather than permanently protecting and managing a set reserve system, in which one or more reserves may cease to provide suitable habitat for covered species as a result of climate change (or other factors), term easements (i.e., conservation easements with a finite term) could be used to protect the conservation values of lands while they support species. To provide assurances for long-term persistence of the species and its habitat, HCPs would need to provide funding, such as through non-wasting endowments, to replace the term easements, which would presumably cost less than permanent easements. Safe harbor agreements could be used to promote establishment and growth of populations of covered species on specified lands, which will be managed to benefit the species for a set time.

Though these approaches may have advantages for addressing uncertainty regarding the long-term conservation value of lands protected as part of HCPs, HCP applicants and permitting agencies have identified the following advantages of permanent reserves established in hard-line reserve networks:

- **Durability:** Permanent reserves meet the expectation for permanent habitat protection in the HCP handbook, which states "If habitat will be permanently lost, alternative habitat must be protected in perpetuity to offset the loss and the appropriate habitat conditions at the mitigation site must be maintained in perpetuity" (page 9-14, USFWS and NOAA 2016). This requirement likely assumes that the alternative habitat protected and maintained in perpetuity

² Federal No Surprises Assurances (codified at 50 CFR 17.3, 17.22(b)(5), 17.32(b)(5); 50 CFR 222.307(g)) provides assurances to Section 10 permit holders that, as long as the permittee is properly implementing the HCP and the ITP, no additional commitment of land, water, or financial compensation will be required with respect to covered species beyond those specified in the HCP without the consent of the permittee. To receive assurances, the adaptive management strategy should identify the range of possible operating conservation program adjustments that could be implemented as new information or data is obtained (USFWS and NOAA 2016).

will provide suitable habitat and support the covered species in perpetuity—an assumption that may not be valid in many cases, but that is made less certain as a result of climate change. Nonetheless, HCPs proposing a shifting reserve system may find it more challenging to meet the durability requirement for permit issuance.

- **Certainty:** Identifying reserves in the HCPs provides the agencies, as well as the applicants and other project proponents, certainty as to which properties will satisfy the mitigation needs or alternatively, will be able to be covered by permits authorizing take and impacts to covered species. Deferring reserve system assembly to HCP implementation could present challenges associated with negotiations among the parties involved.

Given complex biological as well as policy issues confronted by this topic, further analysis is recommended to identify approaches to safeguarding habitat for covered species in HCPs amidst the shifting landscape resulting from changing climate (Section 3.3).

2.2.2.3 Flexible Restoration and Management Techniques

As with reserve design, flexibility in the design and implementation of habitat restoration and management will be essential to long-term effectiveness of the conservation program in an HCP. During planning, HCPs should identify restoration and management techniques that are anticipated to be successful, including based on multiple potential scenarios for the changing climate (Sections 2.1.1.1 and 2.2.1.6). The adaptive management framework of the HCP should also clearly identify additional or alternative strategies that may be used, and the plan should analyze their impacts, so that they can be included in the implementer's toolkit.

2.2.2.4 Adaptive Funding

In order to meet the needs of an evolving conservation strategy, HCPs should feature adaptive funding elements including, but not limited to, the following:

1. **Contingency Funding:** After estimating the costs to implement conservation actions, including land protection, restoration, habitat management, and monitoring tasks, contingency funding should be applied to fund unanticipated costs or overages. The amount of the contingency funding should reflect the uncertainty regarding actual costs; contingencies of 15-25% of actual estimated costs are commonly applied.
2. **Remedial Funding:** HCPs should provide funds to remedy issues encountered during implementation of the conservation strategy, such as erosion in a reserve or a catastrophic wildfire; HCPs should also include remedial funding to address changed circumstances. Remedial funds can be estimated based on the costs to implement actual remedies based on prototypical projects and the likelihood (or frequency) of occurrence during the period of the plan.
3. **Surety/Performance Bonds and Escrow Accounts:** These additional financial tools can be explored as mechanisms to provide additional funding for conservation strategy should the contingency and remedial funding be outstripped by actual costs, including as a result of climate change.
4. **Adaptive Financial Management:** The funding strategy for HCPs should be reviewed and revised periodically during plan implementation to ensure funding is adequate for the conservation program. For regional HCPs funded by local jurisdictions that use fees collected from plan

participants to fund the conservation strategy, financial reanalysis should be used to recalculate the fees to ensure they are sufficient to meet the needs of the plan.

2.2.2.5 Enhance the Adaptive Nature and Flexibility of HCPs

Overall, there is broad recognition that, as long-term planning documents, HCPs must be able to be readily adapted during the course of their implementation to enhance their effectiveness in a changing climate. Even the most skilled and insightful scientists and planners working with agency partners to apply the best scientific approaches and information to an HCP will not be able to foresee all of the circumstances that will be encountered by the practitioners who will ultimately be tasked with implementing the plan over multiple decades. The following are recommendations that will avoid the need to implement maladaptive elements of plans.

1. **Build in Adaptation:** The HCP should identify the uncertainties and how they will be addressed during plan implementation, so that those doing so have the latitude to make the adjustments necessary to promote effectiveness of the strategy including in response to climate change.
2. **Allow Updates:** The HCP should outline how the plan's conservation program will be updated periodically, to reflect changes that will alter the ability of the current program from being successful, including:
 - New climate change projections based on new data, scenarios, or models;
 - New scientific information including monitoring results for covered species populations or the conditions of their habitat, including as a result of climate change; and
 - New information about the effectiveness of elements of the conservation strategy, including experimental restoration and management techniques.

Given the time and resources that are typically required to amend an HCP, changes designed to enhance the effectiveness of the conservation strategy should ideally be conducted as part of the adaptive management process and not require a plan amendment. Efforts should be made during planning to integrate adaptation processes to facilitate this. Recognizing there may be limitations from a regulatory standpoint on the types of adjustments that can be made to the conservation strategy to address climate change without amending an HCP, the HCP amendment process should ideally be streamlined to facilitate the necessary adjustments to the plan and avoid the need to implement maladaptive elements of the program, 'at all costs'.

3 Next Steps

This report outlines six key climate-adapted approaches to developing HCPs; it also identifies a series of additional resiliency concepts under two main themes, bigger and more flexible, that emerged during the process of evaluating the applicability of the approaches, including through the case studies. Next steps in the broader effort to enhance the climate-adapted nature of HCPs could include the following non-mutually exclusive elements.

3.1 Applying the Climate Adaptation Approaches to HCPs

In the next phase of this effort, a new set of case study HCPs, which could include HCPs in the preparation stage as well as implementation stage, can work to deliberately apply the six climate change adaptation approaches, as well as the applicable resiliency concepts. The goal of the case studies would be to evaluate feasibilities and challenges related to policy, funding, expertise, or technical aspects of the plans and illuminate successful practices for future HCPs.

The project could involve experts in aspects of climate change adaptation science related to the chosen HCPs, as well as the technical advisory group (as assembled in this project), including representatives from the USFWS and NOAA Fisheries, to ensure that a broad range of experience is integrated into the project. Optionally, the project could entail representatives from one or more HCPs that have effectively integrated climate change into their plans mentoring HCPs in development or implementation as part of the National HCP Coalition mentor program (NHCP 2020). A 'Phase 2' report could identify specific tools, policy changes, and other recommendations to enhance the effectiveness of HCPs at addressing climate change in robust ways.

3.2 Identifying Approaches to Addressing Common Issues Encountered in a Changing Climate

A more detailed analysis could be conducted to explore methods of addressing specific climate change issues that are encountered by HCP developers and implementers, which were beyond the scope of this more general overview of climate-adapted approaches to HCPs. The specific issues that would be addressed could be identified through a poll circulated to members of the National HCP Coalition, to determine where the greatest needs, and thus benefits, of future analysis. The following are some topics/issues that could be explored in greater detail:

- **Fire:** Climate change can alter fire disturbance regimes including by increasing drought, and promoting pests and pathogens, which increase vegetation die off and thus the frequency, size, and intensity of fires. These changes in fire regimes can have direct consequences for even fire-adapted systems; they can also impact natural systems indirectly as a result of human responses (e.g., through vegetation modification). Such challenges with fire management are being faced in both case studies evaluated for this project.

A future, focused analysis of fire could address topics relevant to HCP planners and implementers including:

- Approaches to predicting the consequence of climate change for fire regimes, which can depend on the regional climate, the changes in climate, and the vegetation, among other factors;

- Methods of assessing impacts of altered fire regimes on species including assessments of direct and indirect impacts; and/or
- Management actions to mitigate the climate change impacts on fire regimes, including methods of reducing the incidence and intensity of fire.
- **Coastal Systems:** Global change can cause unique issues for coastal ecosystems including beaches, dunes, wetlands, and estuaries, which support many federal and state-listed species. A focused analysis could be conducted to develop climate-adapted approaches to addressing species conservation in the face of sea-level rise and its direct and indirect effects, including complications from human migration (i.e., relocation of human communities).
- **Aquatic Systems:** Freshwater systems including streams, ponds, vernal pools, wetlands, and lakes will also face changes due to altered hydrology and temperature regimes, which can have implications for plant and animal distributions and thus food webs. An analysis of these systems could explore these changes and their implications for listed species, as well as types of conservation actions that can be used to address them, which can differ from those often used to protect, restore, and manage terrestrial systems.

These or other priority issues for the HCP community could be explored through literature review, expert outreach, and case studies of HCPs and other conservation and management plans focused on rare species and biodiversity protection. The results of these analyses could be written up in reports that could be used to guide their application to HCPs. These more detailed techniques could then be applied to HCPs in development or implementation, so that they can be refined and opportunities and constraints to their applications can be explored either part of the project or a subsequent 'Phase 2' project as outlined in Section 3.1.

3.3 Evaluating Issues for Enhancing the Climate Change Resiliency of HCPs

Finally, a future phase of this project could explore more thoroughly the complex issues raised by expanding the timeframe for the permit (Section 2.2.1.4) and/or allowing for a more flexible approach to HCP reserves (Section 2.2.2.2). Such a project could use case studies of existing HCPs as well as outreach to HCP planners and implementers, conservation and climate scientists, and representatives from the Services involved in review and permitting of HCPs, and influencing and implementing policies related to HCPs. The goal of the project would be to develop practical solutions to meeting the permit issuance criteria for HCPs while increasing the flexibility of the plans to adapt to a changing climate.

Climate Change Adaptation Approaches for Habitat Conservation Plans

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Appendix A Case Study Questionnaire

This appendices contains the questionnaire that was used to obtain information from planners and implementers of the two HCPs regarding how they are addressing climate change. Written responses to the questions, which were compiled by multiple respondents for each HCP, were reviewed by the project staff who then discussed them with the respondents to obtain additional information that was integrated into the report.

Purpose

This questionnaire is provided to representatives of two regional habitat conservation plans that will be case studies for the *Integrating Climate Change Adaptation Strategies into Habitat Conservation Plans*.

Background

The National HCP Coalition (NHCCPC) is implementing a project to build adaptation, management, and resiliency principles for climate change into habitat conservation plans (HCPs) through the development of implementation strategies and practical tools. The project will develop policies and methodologies for selected approaches to climate change adaptation that can be integrated into existing or new HCPs. The objectives of the project are to:

- Facilitate adoption/integration of approaches to climate change adaptation by other HCPs, into the USFWS HCP Handbook, and state wildlife agencies charged with endangered species conservation;
- Facilitate habitat restoration and/or creation projects as part of HCPs that factor in climate change; and
- Build resiliency and redundancy into the landscape and protect habitat refugia to promote species recovery and prevent the loss of species to climate change.

One element of the project is to conduct two case studies to explore how climate change adaptation can be integrated into HCPs. The objectives of the case studies are to vet and refine the draft climate adaptation strategies, which are outlined in Table 1 at the end of this document, and to identify opportunities and constraints to integrating climate change considerations into HCP planning and implementation. The two HCPs chosen are the Santa Clara Valley Habitat Plan, and the Balcones Canyonlands Conservation Plan.

This document contains the questionnaire for representatives of each of the case studies to describe how climate change was addressed during planning and is being addressed during implementation, as well as provide feedback on the proposed adaptation strategies.

Questionnaire

The questionnaire is designed to provide the project team with information to describe how climate change is currently addressed in HCPs, and identify ways to increase the effectiveness of HCPs at addressing climate change. The questions are organized in three main sections:

1. **Section 1 - Respondent Information:** These questions help us understand the respondent's backgrounds and experience with the HCP, which will provide important context for their responses.
2. **Section 2 - Addressing Climate Change During Plan Preparation:** These questions inquire about how climate change and climate adaptation were address during development of the plan and the factors that influenced that.
3. **Section 3 - Addressing Climate Change During Plan Implementation:** These questions address how climate change is being observed and how climate change and climate adaptation are being address during implementation of the HCP and its conservation strategy.
4. **Section 4 -Feedback on Targeted Climate Change Adaptation Strategies:** These questions evaluate the strategies that the team proposes to address in the project, which are outlined in Table 1.

The questionnaire can be completed by multiple representatives from each HCP, if different people have different histories/experiences with the plan (e.g., planners versus implementors) and/or different educational backgrounds or experiences that could influence perspectives (e.g., planners versus scientists, etc.). The team recognizes that the questionnaire could require several hours to complete thoroughly, including by providing references to documents for more information. The project team appreciates the time spent and assistance provided to the project.

The following are some guidance and tips for completing the questionnaire:

- Write directly in the document in the space below each question in a font color other than black. Multiple respondents for the same HCP/case study who are completing the same questionnaire should use different colored font, so the team can follow up with people individually, if appropriate. Alternatively, different respondents can utilize different copies of the questionnaire, if preferred.
- Please address the questions as thoroughly, specifically, and candidly as possible. Provide references to other documents such as the HCP, any follow-on plans (e.g., preserve system management plans), and annual reports, where it would help the team further understand the response; when doing so, please list specific page numbers and sections to help guide the team to the specific content.
- If one or more questions are not applicable for some reason, please briefly describe why.
- If any questions are unclear, please email Jodi McGraw (jodi@jodimcgrawconsulting.com) for clarification.

Section 1: Respondent Information

1. Please fill out the table below to provide information about the respondents. Add rows, as needed.

Name	Title	Organization

Please have each respondent answer all questions that follow.

2. What is the nature and duration of your involvement (e.g., planner, implementor, etc.) with the habitat conservation (HCP)?
3. Please describe your background, in terms of education and professional experience, related to HCPs in particular, conservation and land use planning in general.
4. Please describe your background in terms of education and professional experience with climate science.

Section 2: Addressing Climate Change During Plan Development

5. In what ways does your HCP address (describe, analyze, strategize around, etc.) the direct and indirect effects of climate change?
 - A. Does your HCP analyze the anticipated climate changes and the threats they pose to covered species and their habitat (e.g., sea level rise, increased frequency of fire, etc.)? If so:
 - i. Which factors were explored and over what future time period?
 - a. Temperature? Annual or seasonal?
 - b. Precipitation? Annual or seasonal?
 - c. Changes in variability or extreme weather?
 - d. Other?
 - ii. Which climate data sets were used?
 - B. Does the HCP address climate change as a changed circumstance and if so, how did it characterize the anticipated change?
 - C. Does the HCP integrate climate change adaptation strategies into the plan's conservation strategy? If so,

- i. What aspects of the conservation strategy (e.g., reserve design, restoration and management strategies, etc.) addressed climate change adaptation strategies?
 - ii. Which climate change factors were addressed in adaptation strategies and how was each addressed?
 - a. Temperature? Annual or seasonal?
 - b. Precipitation ? Annual or seasonal?
 - c. Extreme weather or variability?
 - d. Other?
 - D. Does the HCP incorporate climate change adaptation approaches including species and community response/adaptations to climate change into the monitoring program?
 - E. Does the HCP allow implementers to adapt the plan's conservation strategy based on monitoring data related to climate change? If so, can changes be made to:
 - i. The land protection strategies (e.g., reserve design)?
 - ii. Land restoration and management strategies?
 - iii. Monitoring approaches?
 - iv. Plan goals and objectives?
 - F. In what other ways not already discussed above does the HCP address climate change?
- 6. What factors may have limited the extent to which climate change was addressed in development and permitting of the HCP? Please describe how the factors below, as well as any additional factors, may have limited how climate change was addressed.**
 - A. Was scientific information about climate change projections (i.e., unavailable or uncertain predictions) limiting? If so, please describe.
 - B. Was scientific information about climate change impacts (direct and indirect effects) on the covered species and their vulnerability to climate factors limiting? If so, please describe.
 - C. Was limited knowledge of conservation planning strategies to adapt to climate change, or other tools or information for how to develop and apply climate adaptation strategies a factor? If so, why and how? If so, please describe.
 - D. Did limited resources during plan preparation phase limit the ability to develop robust climate adaptation strategies? If so, please describe.
 - E. Did jurisdictional issues, such as control over lands or waters identified as important, limit the ability to integrate climate adaptation strategies into the plan? If so, please describe.
 - F. Did organizational mandates or directives limit the ability to integrate climate change adaptation in HCP during planning? If so, please describe.

- G. Did real or perceived concerns that robustly addressing climate change would increase the permitting timeline play a role in limiting how climate change adaptation was addressed in the plan? If so, describe.
- H. What other factors reduced the extent to which climate change was addressed in the HCP?

Section 3: Addressing Climate Change during Plan Implementation

- 7. Have climate changes been observed in the plan area? If so:**
 - A. What are they changes to climate?
 - B. What are the changes to species or their habitats?
 - C. How were the changes detected?
 - D. Over what time period have they been detected?

- 8. Has climate change potentially had, or is it having, any impacts on the ability to implement the conservation strategy and/or attain the plan's biological goals and objectives? If so, describe how.**

- 9. Have aspects of the plan, such as the conservation strategy, monitoring program, etc., been modified to address climate change? If so,**
 - A. What observations or information prompted the modifications?
 - B. What changes were made?

- 10. What process was followed to make them (e.g., adaptive management, plan amendment, etc.)?**

- 11. Have climate change adaptation strategies incorporated in the plan either at the outset or through modifications and adaptation management been effective at mitigating the impacts of climate change on the covered species? If so, in what ways?**

- 12. What factors are currently limiting, or might limit in the future, the plan's ability to address climate change during implementation. Factors that might be addressed include but are not limited to:**
 - A. Accurate/reliable, local data from the system to identify climate change effects;
 - B. Sufficient understanding of covered species' vulnerability to climate change;
 - C. Scientific projections for climate change and/or its effects on covered species (direct or indirect) at scales appropriate for projecting impacts;

- D. Plan implementation factors, such as staff expertise, funding, plan structure, or other requirements.
- E. Other?

Section 4 Feedback on Targeted Climate Change Adaptation Strategies

The following questions address the six climate change planning and adaptation strategies that the team is anticipating addressing in this project, which are outlined in Table 3.

13. How appropriate/relevant are each of the strategies?

- A. Assessing Climate Change Threats and Species Vulnerability
- B. Conserving the Geophysical (Abiotic) Stage
- C. Protecting Climatic Refugia
- D. Enhancing Regional Connectivity
- E. Sustaining Ecosystem Processes
- F. Using the Climate Smart Conservation Cycle to Promote Effectiveness Over Time

14. How has your plan, or will your plan, address each? Are there ones your plan will not address? If so, why?

- A. Assessing Climate Change Threats and Species Vulnerability
- B. Conserving the Geophysical (Abiotic) Stage
- C. Protecting Climatic Refugia
- D. Enhancing Regional Connectivity
- E. Sustaining Ecosystem Processes
- F. Using the Climate Smart Conservation Cycle to Promote Effectiveness Over Time

15. What opportunities and constraints might the HCP planning or implementation organization encounter in addressing each? Opportunities and constraints could address available data, species knowledge, planning tools, expertise, funding, politics/local directives, jurisdiction over land and resources, HCP permitting process, coordination etc.

- A. Assessing Climate Change Threats and Species Vulnerability
- B. Conserving the Geophysical (Abiotic) Stage
- C. Protecting Climatic Refugia
- D. Enhancing Regional Connectivity
- E. Sustaining Ecosystem Processes

- F. Using the Climate Smart Conservation Cycle to Promote Effectiveness Over Time
- 16. What methods has the HCP planning or implementation organization used to address the strategies including to overcome any constraints to addressing them?**
- 17. Do you have any other feedback or questions about the strategies identified in Table 3?**
- 18. What other climate change adaptation strategies do you recommend for HCPs and why? What opportunities and constraints might planners and implementers encounter in addressing those strategies?**
- 19. Are there any model HCPs or other case studies that are particularly valuable for future guiding development of future HCPs with respect to climate change?**