Jason Kreitler, Research Geographer
Western Geographic Science Center, U.S. Geologic Survey
345 Middlefield Rd, MS-531, Menlo Park, CA 94025
jkreitler@usgs.gov, 650.329.4248

Title: Incorporating the geography of climate change into conservation planning for the California Landscape Conservation Cooperative

Project summary/goals: This project will analyze downscaled climate model data to assess the geography of climate change in California at scales relevant to actual conservation actions. There is broad consensus that climate change can already be observed (Parmesan, 2006; Moritz *et al.*, 2008), yet little is known about the fine scale variation in the vulnerability of the California landscape to that change. For conservation decisions to be most effective for the long term success of the LCC they would incorporate the potential affects of climate change. Climate model data is therefore invaluable for conservation planning to ensure that: 1) common species remain common, 2) protected areas (PAs) continue to serve their purpose, and 3) conservation acquisitions and actions put in place now will continue to be effective as climate conditions change. As an immediate application, this project will analyze the California Essential Habitat Connectivity (CEHC) products to determine which protected lands are most vulnerable, and which of the proposed corridors would partially mitigate climate change threats. Additionally, future research efforts with relevance to the CA LCC would be made possible through the data generated from this project.

Partners/Collaborators: Alan Flint, Lorrie Flint, and the Bay Area Climate Change and Conservation workgroup

How the project will advance LCC goals: This project will address many of the LCC goals for 2010, including: (text in bold are stated LCC goals)

1. ***Areas of Emphasis***: this project will incorporate **climate information** through **data sharing** to assess **habitat connectivity**, among other topics of conservation concern.
2. ***Project Considerations***: this project will address many LCC needs, while providing a portable set of tools and analyses that could be used in **other LCCs**. This work will **leverage other efforts and personnel** at the USGS, to give their work a complementary audience and increased utility, while potential **NCCWSC funds** would further leverage this project. Initial products (see methods/products) will be an **immediate result** (FY10), while the ultimate goal of this work is to ensure conservation investments will **set up the LCC for long-term success**. Due to the large geographic extent of this project, **multiple LCC partners** stand to benefit.
3. ***Desired Accomplishments***: this project is a **biological planning and conservation design project developed in response to climate change** that will assess the **risk and vulnerability** of protected areas to climate change.

Methods: As climates shift and habitats respond, the effectiveness of PAs in representing biodiversity will change (Hannah *et al.* 2002a,b; Araujo *et al.* 2004). Yet what is the expected change in climate conditions across the network of PAs, and what measures of climate are most ecologically relevant? Which areas will experience the greatest magnitude and rate of change from their historical norm, and hence, most vulnerable? Where is connectivity between PAs restricted, potentially limiting dispersal to preferred conditions? How could the network of PAs be adjusted to minimize the impacts of expected climate change? These questions will guide the development of a set of tools to assess the heterogeneity of climate change to determine

both the vulnerability of PAs (and by extension the species they protect) and to inform conservation decisions that attempt to mitigate climate change threats.

The scientific activities of this project will include an analysis of statistically downscaled climate data, the vulnerability of PAs to climate change, and the development of novel methods to prioritize corridors and new acquisitions to maximize the climatic resilience contained within the California LCC. These efforts will use two new geodatabases: 1) statistically downscaled GCMs from the USGS (Flint and Flint, unp. manuscript) to address the fine scale heterogeneity in local topoclimatic diversity, and 2) connectivity data from the state-wide California Essential Habitat Connectivity project. The climate model data is available for two models and two scenarios, at 90m and 270m resolution. The CEHC data will provide the location and resistance of individual corridors and agglomerations of protected lands. With these datasets, the products of spatial conservation prioritization methods using 'off the shelf' software (Marxan: Ball and Possingham 2000, and Zonation: Moilanen 2007) will be compared to results from a custom genetic algorithm designed to prioritize corridors to mitigate the threat of climate change. This analysis will answer the questions raised above and provide valuable information and decision analysis techniques to a wide variety of land managers.

Climate analysis: Climate conditions are a fundamental control on species' distributions and ecosystem function. Protected areas contain a range of climate conditions within their boundaries, yet those conditions may change at rates varying across the landscape (Loarie *et al.* 2009). In this research we will determine the direction, rate, and magnitude of expected future climate change to assess the vulnerability of protected areas with methods similar to Loarie *et al.* (2009) and Ackerly *et al.* (2010). Our study will differ from previous work by focusing on the CA LCC, use a much finer resolution, and will determine whether these methods of climate analysis could be operationalized for other regions.

If a PA has a large rate of change, or an entirely different set of climate conditions, this may render the protected area unsuitable for previous inhabitants. We will consider the "effective area" of protected lands the mathematical intersection of area (acres) within a reserve that contains the same climate conditions in both the present and future (see figure 1). This exercise will illuminate which areas, and by extension which habitats may undergo the greatest potential loss of *protected* range given no conservation intervention. That information could assist managers to adaptively manage protected areas, or be used in subsequent analyses as a way to weight the importance of individual protected areas.

Climate will be calculated using a suite of ecologically meaningful derivative products through BIOCLIM (Busby, 1991), in addition to mean winter and summer temperatures, and mean precipitation, as in Hayhoe *et al.* (2004) and Williams *et al.* (2007). One derivative product of particular interest is climatic water deficit, which has recently shown fine scale habitat refugia that are unobservable with coarser resolution data (L. Flint, personal communication).

Corridor and protected area prioritization: This section the research will address the objective of maximizing the climate resilience of California's protected areas by determining where reserves could be connected through corridors. We will use climate conditions within protected areas and connectivity data from the California Essential Habitat Connectivity project (CEHC) (figure 3) to determine which corridors could connect existing protected areas to minimize the vulnerability of protected climate space, and schedule these connections based on their priority to mitigate change.

We will create climate vulnerability indices, potentially similar to Ackerly *et al.* (2010), to maximize the climate resilience in the reserve network. Using a genetic algorithm (the custom case) or Marxan/Zonation, the evaluation of corridors will proceed by minimizing the network's vulnerability by systematically connecting PAs through the corridors identified by the CEHC

(figure 3), subject to both a monetary constraint and a resistance constraint. By connecting PAs, we assume resilience is increased and movement facilitated. Monetary values will be estimated from county averaged land values, while resistance values indicate the level of general dispersal difficulty in traversing a corridor, and are included in the CEHC. The inclusion of these constraints makes this analysis more applicable to on the ground conservation efforts, where resources are limited.

Though the top recommendation in Heller and Zavaleta (2009) is to increase the connectivity of reserves through corridors and the removal of dispersal barriers, few studies have specifically proposed corridor designs between protected areas based on projected impacts of climate change (Williams *et al.* 2005; Philips *et al.* 2008). This research described in this proposal is novel both in its attempts to map the vulnerability of protected areas to climate change at a broad extent and fine scale, but also addresses a neglected climate change adaptation technique highlighted in the climate change literature. These facts, combined with the relevance to management need should make this research a priority for the California LCC.

Furthermore, the data created in this project will undoubtedly be used in future analyses relating to LCC priorities. These products could be used in studies of potential changes in species' distributions, interactions between climate change and wildfire, hydrologic processes, and changes to ecosystem services. Thus the proposed products have the potential to be highly leveraged in other scientific efforts over the coming years. This should not be understated; most, if not all of climate change investigations analyzing physical, ecological, and social processes will require downscaled climate models and associated data to determine potential future effects.

Products/tasks: also see figure 2

1. Acquire downscaled data and historical products to establish baseline conditions
2. Generate ecologically relevant climate-related data (more than temp & precip)
3. Generate scripts to analyze climate data and compute rates of change
4. Assess climate conditions and vulnerability of PAs within as subset of the CA LCC
5. Prepare report (OFR) on the methodology and results of PA subset, send out for review, incorporate comments into methodology
6. Assess climate conditions and vulnerability for entire CA LCC
7. Priority analysis of corridors within the CEHC, report, journal paper
8. Design of future research projects capitalizing on this data

Project on-going: this work was proposed to the NCCWSC RFP in 2009. The program has not yet invited full proposals for 2010. The PI is involved in this research through the Bay Area Climate Change and Conservation working group, but not financially supported by the USGS or other funding source.

Timetable: products 1- 3 (first box in diagram) will be completed by the end of FY2010, meeting the needs of FWS to achieve certain accomplishments by the end of the fiscal year. The remaining tasks will be performed in FY2011, with the final report/paper(s) potentially spilling over into FY2012.

Data sharing: the products and tools generated by this project will be made publicly available for management and research purposes, and will be distributed through a project specific website.

Performance metrics:

End of FY2010

- Completed according to schedule
- Computationally tractable for desktop computing

End of FY2011

- Time required for analysis (e.g. efficiency – could this be an operationalized set of tools/analyses for other LCCs?)
- Amount of input from potential end users
- Methods accepted by peer review

Beyond FY2011

- Interest in products/methodologies as indicated by inquiries, talks, downloads
- # and variety of groups using the data products
- # of managers interested in the tools, and ways they are used for decision analysis
- Incorporation into CA LCC/CEHC regional planning processes
- Future funding, breadth of future projects using this climate data
- Times report downloaded, times paper cited

Conservation outcomes: This project would be a success if the lessons learned or the methods tested are applied to future efforts to establish habitat connectivity through the LCC or CEHC programs. Additionally, it would be a tremendous conservation outcome if the vulnerability results assisted ecosystem based management by quantifying the spatial heterogeneity of climate change threats. Many other conservation outcomes could arise from additional physical, ecological, or social research projects involving climate change.

Matching funds: Potential funds from the NCCWSC would be used as matching funds in this project, though full proposals for FY2010 have not yet been invited.

Letters of support: Letters of support from Rebecca Shaw, California TNC, and Nadine Hitchcock, California Coastal Conservancy, are included with this proposal. Others will arrive separately.

Budget:

DETAILED BUDGET				FY 2010	FY 2011
				9/1/2010	10/1/2010
SALARIES		months	% Time	9/30/2010	9/30/2011
1. Investigator - Jason Kreitler					
FY2010	$79,781	1	100%	$ 6,648	
FY2011	$82,174	4	100%		$ 27,391
FRINGE BENEFITS					

1.	Investigator - Jason Kreitler							
	1st yr.	@	25.00%		$	1,662		
	2nd yr.	@	25.00%				$	6,848
SUPPLIES								
1.	Computer hardware and storage to handle TBs of data				$	3,000		
TRAVEL								
1.	Travel to Sacramento and San Francisco to meet with collaborators and end users (multiple trips)					500		1,500
2.	Travel to national conference to present results							1,000
SUBAWARD								
1.	Award to Alan and Lorrie Flint, USGS, for downscaled data and processing					10,000		
				Total Direct Costs	**$**	**21,811**	**$**	**36,739**
INDIRECT COSTS								
Estimated Indirect rate for Cost Center								
	1st yr.	@	15.00%		$	3,272		
	2nd yr.	@	15.00%				$	5,511
				TOTAL COSTS	**$**	**25,082**	**$**	**42,250**
				TOTAL COSTS TWO YEARS	**$**			**67,332**

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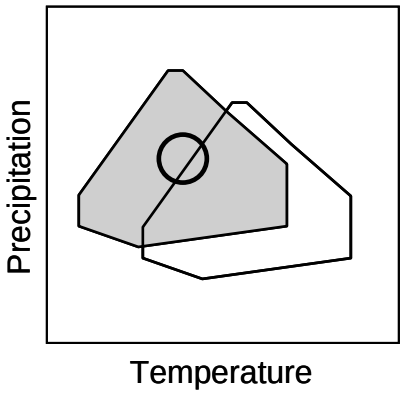

Figure 1: diagram illustrating the effective area of a hypothetical reserve (bold circle) within California climate space in present (grey) and future (outline only) climates. The effective area in the future climate is ~ 1/3 of the original, as climate conditions have shifted down and to the right in the figure, largely outside the borders of the reserve.

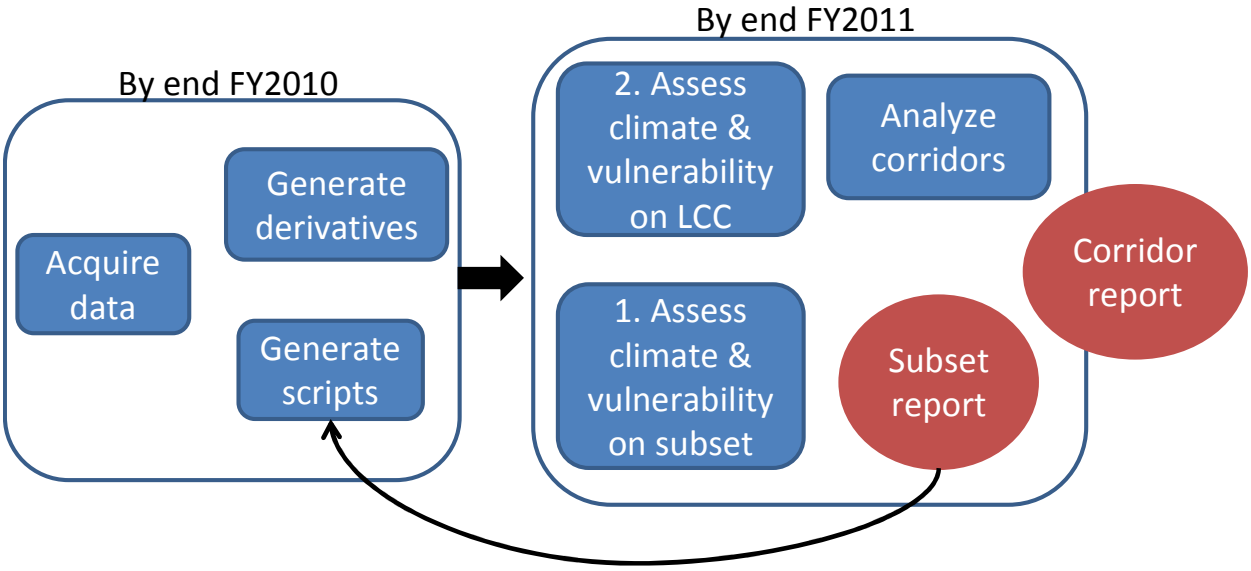

Figure 2: project diagram

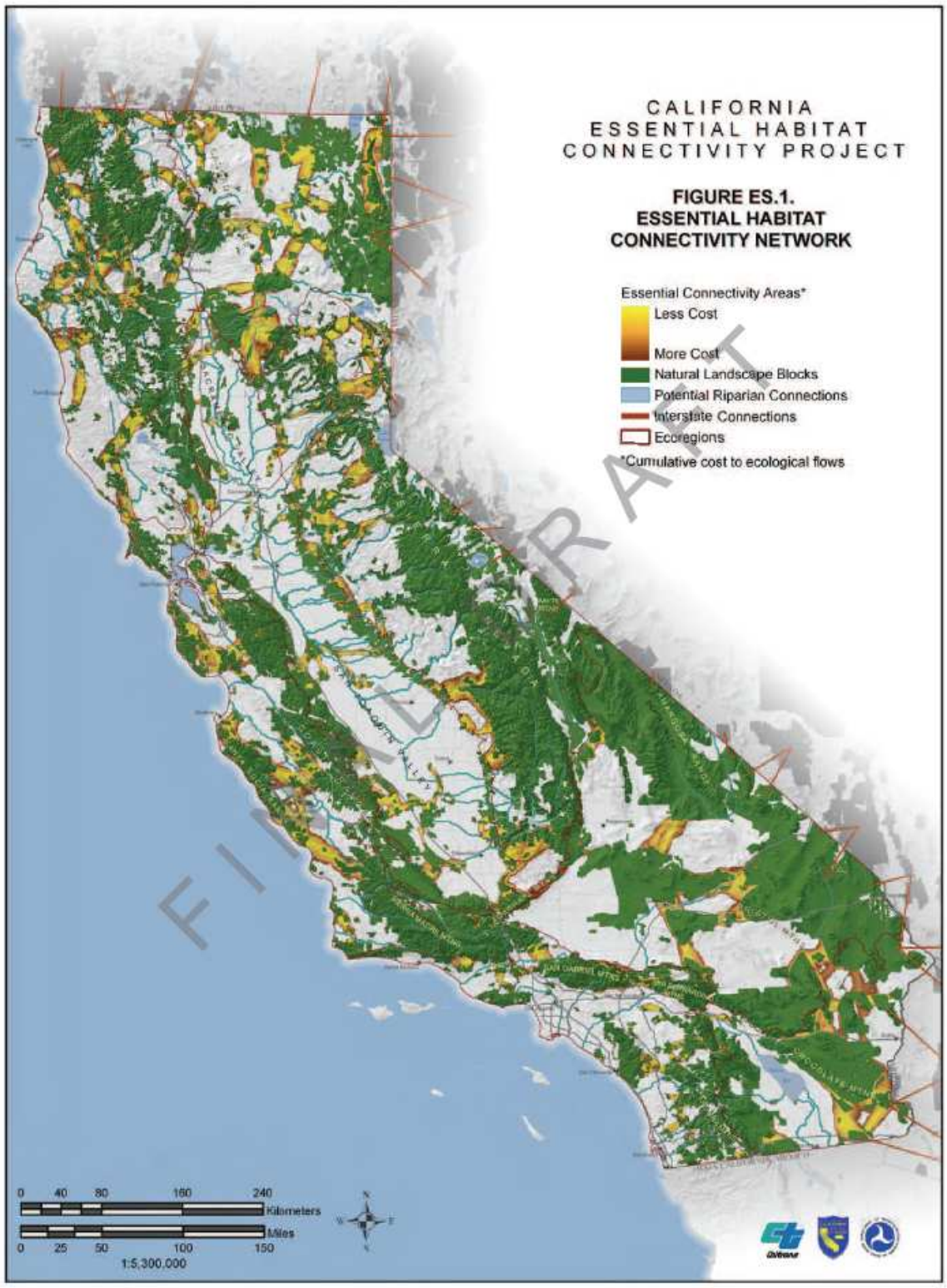

Figure 1: Essential habitat connectivity from the CEHC project. Natural landscape blocks are conglomerations of the protected areas proposed in this research. The color range in the essential connectivity areas represent the resistance to dispersal**.**

Coastal Conservancy

National Climate Change and Wildlife Science Center
U.S. Geological Survey
Office of the Interim Director

Feb 18, 2010

Attn: Dr. Douglas Beard

RE: Support for proposal titled "California Protected Area Networks and the Geography of Climate Change"

Dear Dr. Beard:

I am writing to express the California Coastal Conservancy's strong support for the proposal titled "California Protected Area Networks and the Geography of Climate Change".

The Coastal Conservancy is a non-regulatory state resource agency that acts with others to preserve, protect, and restore the resources of the California coast and watersheds, the ocean, and the nine-county SF Bay area. In recent years, the Conservancy has expended over one hundred million dollars to help acquire and restore upland habitats. Concerned about the impacts of climate change on the biodiversity supported by these habitats, our board recently adopted a climate change policy and project selection criteria that requires consideration of climate change impacts in all future expenditures related to habitat acquisition and restoration. To this end, we are collaborating with scientists to support research that can be used to assess climate change impacts, and to develop adaptation strategies that protect existing and future habitat for species impacted by climate change. We are also developing a guidance paper to assist prospective grantees in prioritizing future acquisitions, and in developing effective monitoring and adaptive management plans.

The work proposed by Jason Kreitler will support implementation of the *2009 California Climate Adaptation Strategy,* the State of California's blueprint for responding to the impacts of climate change. A key strategy to conserve California's biodiversity is to create a large scale, well connected, sustainable network of protected areas across the State. The proposed research will help us understand how existing networks of protected areas are vulnerable to climate change impacts, to identify additional lands that need protection to maximize climatic diversity, and to design optimal connection corridors to maximize organisms' ability to disburse to more suitable habitats under climate change.

I trust you will strongly consider the potential for immediate application of this important project to advance the conservation and management of California's unique and diverse ecosystems.

Sincerely,

Nadine P. Hitchcock

Nadine P. Hitchcock, Deputy Executive Officer
California Coastal Conservancy

1330 Broadway, 13th Floor
Oakland, California 94612-2512
510·286·1015 Fax: 510·286·0470

The Nature Conservancy
Protecting nature. Preserving life.™

California Regional Office
201 Mission Street, 4th Floor
San Francisco, CA 94105

Phone: 415-777 0487
Fax: 415-777-0244
Fax: 415-777-0772

To Whom It May Concern,

I enthusiastically support the proposal "California Protected Area Networks and Corridor Design: Incorporating Climate Change" submitted by Jason Kreitler of the Pacific Geographic Science Team of the U.S. Geological Survey.

This proposal outlines a research program of work that addresses critical gaps in the knowledge for effectively implementing climate change adaptation strategies to protect California's unique biodiversity. The Nature Conservancy is perfect partner for the research, development and implementation of the resulting data and tools due to our deep scientific and practical understanding of the conservation of biodiversity, our broad geographic reach, and our history of successful transfer of methodologies and scientific tools to other local partners for conservation outcomes. Indeed, The Nature Conservancy is currently working on developing conservation strategies to facilitate the adaptation of species and natural systems to climate change locally, regionally, and internationally through its broad and extensive network of partners in government, industry and non-governmental organizations. This research will help to accelerate that work.

In addition, I believe I am a natural collaborator for this research project due to my career in research on the impacts of climate change on biodiversity and ecosystem function, my work on developing practical strategies for the adaptation of natural systems to the impending climate change, and my role in developing scientifically-credible tools for implementation by conservation organizations for significant and measureable conservation outcomes.

This specific research project and The Conservancy's engagement in it is critically important to our conservation efforts as it addresses the entire state of California and a broad array of threats that will challenge the effectiveness of our conservation work in the future by

- developing a methodology for planning for climate change by assessing the vulnerability of protected areas to a change in climate conditions,
- assessing the limitations of dispersal of native species between protected areas by systematically quantifying connectivity through fragmented matrix lands, and
- prioritizing corridors between reserves to enhance adaptation and resilience of native biodiversity in the face of a changing climate.

As a result of the close collaboration, the final products and tools from this work will be readily disseminated for implementation within The Nature Conservancy and its network of partners. The data, tools and model output will be configured into a familiar and user-friendly toolbox that will be easily portable for application to regions outside of California.

Again, I heartily support this research know that the development and application of the resulting tools is critical for the success of conservation in the future.

Sincerely,

Rebecca Shaw

Rebecca Shaw, PhD
Director of Conservation
The Nature Conservancy
201 Mission Street, 4th Floor
San Francisco, California 94105 USA
+1 415.281.0480 office
+1 415.793.5921 cell
rshaw@tnc.org