Project Title:

Confronting uncertainty in species distribution projections: Increasing the applicability of an essential tool in climate change adaptation planning

Proposal by:

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Scope & Budget:

Location: Across LCCs
Duration in months: 12
Requested Funding: $100,000
Leveraged Funding: $233,400

Briefly summarize the goals of the project, what products will result, and how the products support decision-making and conservation delivery for natural resource management within the CA LCC.

CAS & PRBO propose a comprehensive analysis of uncertainty in modeling species future distributions, to increase the meaningful contribution of these ecological forecasts to climate change adaptation planning. Range-shift modeling results can help characterize organismal response to change, reveal the rate, magnitude, spatial and temporal nature of projected change, identify hotspots of stability and flux, and guide actions for species- and place-based adaptation planning. But current forecasts of species response to future climate change are considered too uncertain to deliver on this much needed decision-support information. We propose a systematic analysis of uncertainty in modeling the future distributions of ~50 California endemic plant species and ~50 California land birds, explicitly partitioning among 5 alternative sources of variation and testing for their respective contributions to overall variation among modeled outcomes. We will map the uncertainty from identified sources, which can guide decisions about monitoring, restoration, acquisition, infrastructure, etc, in relation to climate change. This project will: 1) investigate the effect of 5 different sources of uncertainty when characterizing plant and bird response to projected climate change; 2) develop metrics of the degree of projected change for 100 plant and bird species 3) quantitatively assess the statistical significance of the different sources of uncertainty; 4) produce maps of the proportion of variation in predictions from each of the sources of uncertainty, and 5) disseminate project results to the LCC environmental change network and beyond. While our focus here is on CA endemic plants and land birds, the methods we develop are applicable to most taxa, including many threatened and endangered species. We will increase the applicability of an essential tool in impacts analysis, improving the understanding of and confidence in range shift modeling for climate adaptation planning.

For continuing 2010 CA LCC projects, describe the accomplishments and outcomes to date, why additional funds are needed, and what this proposal will add to the project.

NEW PROJECT

Identify which National LCC Performance Measure(s), if any, your project addresses.

1. A risk and vulnerability assessment developed or refined for priority species and habitats. 3. A population and habitat assessment developed or refined to predict changes in species populations and habitats.

List Partners

PRBO Conservation Science. PRBO will contribute avian occurrence data, will participate substantially in all modeling and analyses, and will contribute to dissemination effort.

Briefly describe how the project team (main PIs) provides the range of experience, expertise, and organizational capacity needed to accomplish the project. List recent and current projects (names, time-periods, PI time commitments, and total budgets). Also attach 1 page CVs for the principle investigator and/or project leaders per below under additional information.

Healy Hamilton, Ph.D., is the founding director of an applied biodiversity research center at the Cal Academy that is focused on ecological forecasting for conservation planning. She and her team of programmers, distribution modelers, GIS and science visualization technicians are actively developing and applying downscaled climate surfaces for climate impacts analysis in collaboration with colleagues at UC Berkeley and Climate Central. Research in the Hamilton lab is focused on delivering both species and ecosystem based climate change impacts analyses directly to managers and conservation organizations. Current projects include ecological forecasts to update Colorado's State Wildlife Action Plan (Center for Native Ecosystems, Colorado Dept. Wildlife, & CAS; $150,739, 1 month), Climate change effects modeling for 3 Bureau of Land Management Rapid Ecological Assessments, as a collaborator with Natureserve ($210,000 to CAS, 2 months), Modeling bioclimatic range shifts in coast redwood and mountain sequoia (for Save The Redwoods League, $50,000, 1 month), and a NOAA Environmental Literacy grant that uses these research results to generate innovative scientific visualization products for global change education ($1.25M, 1 month/yr through 2013). With major equipment donations from NetApp and in collaboration with the Academy's Center for Comparative Genomics, the Hamilton lab has built the computational capacity to support rigorous ensemble modeling of climate impacts to ecological systems. Sam Veloz, Ph.D., is a spatial ecologist with PRBO conservation science. His research has been focused on using spatial modeling to test ecological theory and inform resource management decisions. Veloz , with support from the informatics and climate change group at PRBO, has been exploring alternative methods for modeling the effects of climate change on ecosystems and species and developing methods to better communicate results to decision makers and the public. These projects include: Models of plant and bird species distributions across 20 future climate scenarios in the San Francisco Bay Estuary Sept, 2010-March 2011. 5 months, $100,241.00, and modeling the impacts of climate change on birds and vegetation on military lands, 2.5 months $148,563.00. Veloz is also principally involved with the development of the maps currently available on the LCC's Environmental Change Network (ECN). His involvement with the ECN will allow results from the proposed project to be easily integrated into the site and into the development of a LCC monitoring network. The experience Veloz has acquired working with large volumes of future climate data and modeling species distributions coupled with PRBO's recent investments in the development of decision support systems for climate change adaptation planning demonstrates that he and his team have the capacity to effectively deliver the proposed products and make them accessible to a wide audience.

CALIFORNIA ACADEMY OF SCIENCES

prbo

Confronting uncertainty in species distribution projections: Increasing the applicability of an essential tool in climate change adaptation planning

Project Description

Actions to adapt existing conservation and management strategies to the reality of climate change require our best science-based understanding of potential impacts to species and ecosystems. Because conservation and management actions are largely place-based, projections of geographic range shifts induced by future climates have been central to ecological impacts assessments (e.g. Thomas *et al*., 2004, Stralberg *et al*. 2009). Range shift modeling can provide forecasts of the rate, magnitude, spatial and temporal nature of climate impacts that can help assess species relative vulnerability, highlight current habitat either most resilient or most susceptible to change, inform land acquisition strategies and connectivity design, support placement and prioritization of monitoring efforts, and guide restoration and management objectives (Hannah *et al*. 2007; Heller & Zavaleta 2009; Krosby *et al*. 2010; Mastrandrea *et al*. 2010).

Such forecasts are generally produced by applying downscaled future climate surfaces derived from general circulation model outputs to bioclimatic modeling algorithms (e.g. Loarie *et al.* 2008, Iverson & Prasad 2008; Lawler *et al.* 2010). Although hundreds of academic papers have published maps of the potential future distribution of conservation targets, the translation of models into management action has been compromised by the very large uncertainties associated with range shift modeling efforts (Pearson *et al*. 2006; Heikkinen *et al*. 2006; Dormann 2007). At every step, choices must be made about source and quality of locality data, species distribution modeling (SDM) approach, selection of environmental variables, which general circulation model outputs to use, parameterized by which greenhouse gas emissions scenarios, and downscaled to how fine a spatial resolution. Virtually every study chooses a different combination among these methodological alternatives. Estimates of uncertainty are rarely provided and almost never attributed to a particular source. Managers are understandably hesitant to use scarce time and resources for largely irreversible decisions to develop and implement adaptation plans, based on ecological forecasts with so much inherent uncertainty (Wiens *et al*. 2009; Mbogga *et al*. 2010; Huettmann & Gottschalk 2011).

CAS & PRBO propose to directly address this critical gap between modeling results and management action. We have designed a comprehensive analysis of uncertainty in modeling species future distributions that can increase their meaningful contribution to climate change adaptation planning. Using a representative sample of both California breeding birds and endemic plants, we will explicitly partition among five alternative sources of variation in SDM projections of future distributions, and test for the significance of their contribution to overall model variation. The research outputs will 1) describe the range and degree of agreement among future bioclimatic scenarios for a representative sampling of CA endemic plants and land birds; 2) develop metrics of the degree of projected change across the bioclimatic requirements for 100 plant and bird species, and quantify the uncertainty in those projections; 3) identify the highest-certainty hotspots of climate refugia and climate flux for the target plant and bird species; 4) produce maps of priority areas for monitoring of projected climate impacts, and 5) disseminate all project results to the LCC Environmental Change Network, and summary data products among a range of relevant outlets. The broader results from our project will guide managers in their ability to rely on SDM results relevant to their management targets, will help users of SDM techniques understand the inputs required to build less uncertain models, and will increase confidence in the appropriate use of range shift modeling for climate adaptation planning.

CA LCC Priorities addressed

Our project delivers both research results and methodological improvements that will support biological resource managers in decision-making for many LCC priorities. Direct research outcomes include models of both bird and plant species potential response to climate change, and the quantification of the degree of uncertainty in modeled responses. Synthesis maps will enhance existing maps (http://data.prbo.org/apps/ecn/) of the locations of stability in species richness, areas of large projected species turnover, and areas of future species richness (future hotspots), by quantifying the degree of certainty in these biogeographic outcomes and making these projections for a much larger range of future climate projections. This information in turn can inform the design and location of monitoring efforts (Bartel & Sexton *et al*. 2009), for example, monitoring population abundances in areas projecting high species turnover with low uncertainty. If feedback from monitoring efforts can ultimately be incorporated back into SDM methods, our ability to adaptively manage will be significantly improved. Where there is relative certainty of stability, these regions become anchors for connectivity planning. All of our research products, including individual species range shifts, synthesis maps of species turnover, and derived data surfaces of uncertainty, will be distributed via the LCC Environmental Change Network. Summary products will be widely disseminated via additional websites serving a range of academic, conservation, and management audiences, such as Databasin and CalAdapt. While these examples are derived from our actual modeling outcomes for 100 CA bird and plant species, the methodological advance in partitioning among sources of uncertainty in future SDM projections is transferable to other species across California and across LCC's.

CA LCC Criteria addressed

Conservation and adaptation decisions must be made today, in spite of the uncertainty in the rate and magnitude of future change (Hodgson *et al*. 2009; Conroy *et al*. 2011). The need for improved understanding of species response to climate change is already widely recognized (Willis & Bhagwat 2009; Lavergne *et al*. 2010), and will only increase as climate impacts progress. Our integrative approach will use 2304 future climate surfaces varying across spatial scales, GCMs, and emissions scenarios subjected to four alternative types of locality datasets analyzed with four major classes of SDM algorithms. Both individual species range shift forecasts and synthesis maps of turnover in plant and bird species richness, and their respective degrees of uncertainty, will be made accessible via multiple outlets on the web. We aim to disseminate the methodological insights provided by our proposed sensitivity analysis as a publication in an open-access, peer-reviewed journal. While the species upon which our sensitivity analysis is performed are restricted to 50 representative CA bird species and 50 endemic plant species, the improved understanding of uncertainty in range shift projections will contribute to ecological forecasting efforts across taxa and ecoregions. The collaboration between the Cal Academy and PRBO Conservation Science brings together two strong applied natural history research programs with diverse alliances. Together we have a broad network of established partnerships and extensive outreach capabilities that ensure the products of this work will be received by audiences ranging from academics to managers to citizens.

Approach and Scope of Work

We have designed an experiment in which the variation in modeled species distributions is partitioned and attributed to five different sources of model uncertainty. We will test whether these sources contribute significantly to variation and provide maps of the proportion of variation attributable to each source. We have chosen two economically and ecologically important taxonomic groups, CA breeding birds and CA endemic plants, which have very different life histories, including dispersal capabilities, and thus different potential responses to climate impacts. We are intentionally building on previous ecological forecasting that used a limited range of climate simulations for birds (Stralberg *et al.* 2009) and plants (Loarie *et al.* 2008), so that a comparative context exists for our range shift results. Sources we will test for their contribution to uncertainty in future species distribution modeling include:

1a) Source of occurrence data for birds. Precise, range-wide knowledge of species occurrences is almost nonexistent, and modelers must often use un-standardized locality data, such as museum specimens or citizen science observations to augment survey data for species with low numbers of observations. For birds, PRBO has both standardized observations (point counts) and citizen science avian observation data from across California and into Northern Baja (citizen science data only). We will individually run models with data from both sources for 50 of the 60 bird species modeled in Stralberg *et al.* (2009). These 60 bird species have already been selected as representative of a range of CA ecosystems. We hypothesize that the variation from these two sources of locality data will be small relative to other factors, indicating that citizen science data could be a valuable resource for managers.

1b) Source of occurrence data for plants. We will use a 50 species subset of the 591 endemic plants modeled in Loarie *et al.* (2008). These localities are derived from georeferenced museum specimen records from the Consortium of California Herbaria. Species will be filtered based on 1) availability of polygon distribution maps (see below), 2) locality error estimates of 1km or less, 3) dispersion of localities across known geographic range, and 4) percent occupancy on CA public lands, where management opportunities are focused. A second locality dataset for plants, analogous to the citizen science data for birds, is point localities randomly sampled from historical distribution polygons (Peterson *et al* 2006). We will use digital distribution polygons from the Jepson manual of CA plants for the 50 species identified by the criteria listed above. These polygons will be gridded to the spatial resolution of the climate surfaces, and converted to point localities for resampling. We will individually run models with data from both sources. Again we hypothesize that variation from these alternative sources of occurrence data will be minor relative to variation in other factors, indicating the potential value of un-standardized locality data.

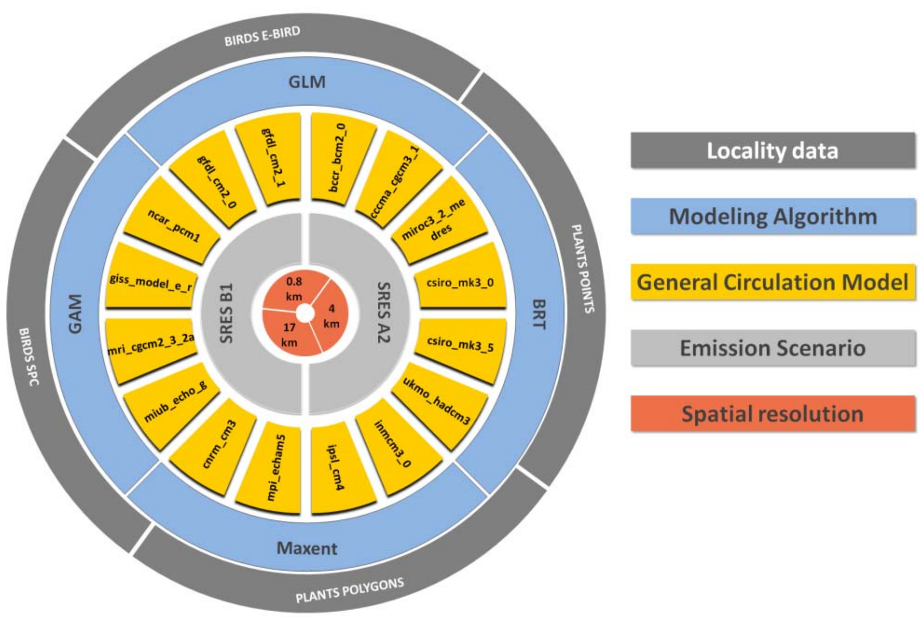
2) SDM methods. Prior model comparison efforts have found significant variation in current SDM forecasts according to choice of modeling algorithm (Elith *et al*. 2006; Elith & Graham 2009). We will test four alternative classes of distribution modeling algorithms that are currently in wide use and have consistently produced the most accurate results in model comparison tests: a maximum entropy method (Maxent; Phillips *et al* 2006), a Generalized Linear Model (GLM; McCullagh and Nelder, 1989), a Generalized Additive Model (GAM; Hastie *et al*. 2001), and Boosted Regression Trees, a machine learning algorithm (BRT; Elith *et al.* 2008). By only including top performing algorithms, we expect that overall variation due to SDM method will be less than has been found in previous studies (Diniz-Filho *et al*. 2009). However, if we find variation due to SDM method is relatively high compared to other sources of uncertainty, it would suggest that modelers should embrace the ensemble SDM approach, and that mangers should seek ensemble predictions for decision making. If variation due to method is comparatively low, then mangers can utilize the method/s most easily implemented or most appropriate for the system being investigated.

3) General circulation models (GCM). The majority of climate impacts studies utilize a very limited subset of GCMs vetted for the IPCCs most recent assessment report (Morin & Thuiller 2009; Wiens *et al*. 2009; Carroll 2010). We have assembled a dataset of 16 GCMs all run under the same two emissions scenarios and all statistically downscaled to 3 spatial resolutions (see below). By including a large sample of climate models in the SDM process, we can effectively calculate uncertainty due to different future climate projections. We expect that GCMs will account for a significant portion of the total variation in future model projections. If this hypothesis is supported by our results, then clear steps can be taken to deliver ensemble

averages and standard deviations for future modeling efforts, and managers can have more confidence in ecological forecasts derived from a large number of GCMs.

4) Future greenhouse gas emission scenarios. We will use two versions of each of the 16 GCMs based on IPCC scenarios of future greenhouse gas emissions (IPCC 2007), a high greenhouse gas emission scenario (A2) and a low emission scenario (B1). Results will indicate the contribution of variation due to alternative emission scenarios as compared to other sources.

5) The spatial resolution of the GCM. It is usually assumed that finely downscaled projections of future climate are necessary to inform management decisions. However, this assumption has never been formally tested in conjunction with other sources of uncertainty for its unique contribution to overall variation in future projections (Seo *et al*. 2009). Downscaling GCMs is a technically daunting and time consuming endeavor with little guidance on the appropriate scale to which downscaling should be attempted. We have assembled 16 GCMs that have each been downscaled at three different spatial resolutions: ~17km (Tabor and Williams 2010), ~4 km (Hamilton, Fernandez & Duffy, unpublished), and ~1km (Duffy, Loarie, and Thrasher, unpublished). Testing the difference in coarse to very fine spatial resolution across the same large set of GCMs allows us to partition the unique contribution of variation due to spatial resolution. These results could provide guidance on the most appropriate scale for forecasting species distributions. Moreover, with the next round of IPCC climate models to be released soon, managers will require guidance as to what spatial resolution they should invest in future downscaling efforts.



For each of 50 bird species and 50 endemic California plants, we will generate SDMs using each combination of the above factors. All models will use a consistent set of bioclimatic variables derived from monthly temperature and precipitation outputs from the 16 GCMs. All models will use a 1971-2000 baseline and compare to a 30 year mid-century time slice (2041-2070). The variation in future projections for all models will be partitioned to each source of uncertainty using an analysis of variance (ANOVA), including all 2-way interactions that are hypothesized to contribute to variability in predicted future species distributions. Using methods developed by Diniz-Filho *et al*. (2009), we will produce maps which show the proportion of variation accounted for by each source of uncertainty at the pixel level. These uncertainty maps can be included in the LCC's Environmental Change Network and can be used to identify areas with high priority for monitoring the effects of climate change.

Our team has the technical capacity and the computational resources to carry out this ambitious factorial experiment to quantify alternative sources of variation in modeling future species distributions. In addition to the programming and spatial analysis skills resident at both CAS and PRBO, CAS has a 280-core Apple Xserve High Performance Computing Cluster with 232GB of RAM connected to a high performance NetApp file storage system with over 20TB of space that will be remotely accessible to PRBO project collaborators. This scale of computational capacity is essential to this project and we consider it to be a significant in-kind contribution to the project resources required.

Products/Data Sharing

1. Distribution maps of ensemble averages and standard deviations for each specie's modeled future bioclimatic envelope.
2. Maps of community turnover, changes in species richness, and the uncertainty underlying these synthetic analyses.
3. Spatial data layers demonstrating the proportion of variation explained by each source of uncertainty tested.
4. Prepare methodological manuscript for peer-reviewed publication
5. Format, upload, and disseminate species maps and/or synthesis products to the ECN, Databasin, CalAdapt, and other relevant information portals

Timetable for Completion

Project Deliverable	Oct 2011	Dec 2011	Feb 2012	April 2012	July 2012	Sept 2012
Filter plant species and prepare locality and climate data for modeling input	X					
Model plant and bird distributions		X				
Run factorial experiment for 100 species			X			
Conduct ANOVA on model outputs				X		
Produce distribution maps of ensemble averages per species and synthesis products of species richness and uncertainty summaries					X	
Prepare methodological manuscript						X
Format and disseminate results to a variety of venues						X

Measuring Results

We will produce and disseminate maps highlighting: 1) Ensembles of and variation in future projections of plant and bird species distributions and 2) the proportion of variation attributable to significant sources of model uncertainty, via the LCC's Environmental Change Network. We will also distribute summary maps products to other portals, such as Databasin and CalAdapt, to insure our results reach a wide user audience. The success of our products can be measured by how frequently data/maps are downloaded and how often our work influences management action. We expect our results to offer important guidance to both the scientific community and resource managers for how to most efficiently invest time and money for downscaling the next round of IPCC future climate models, due to be released within the next year. For example, our results will show whether the costs of additional data storage and computational time are worth the added benefit of generating fine scale future climate surfaces. Thus, our success can also be quantified by the number of times our manuscript is cited in peer-reviewed journals.

CAS & PRBO CA LCC
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California Landscape Conservation Cooperative 2011 Proposal Budgets

Healy Hamilton/Uncertainty in species distributions projections

Budget Categories	CA LCC Request	Partner(s) Contribution(s) (monetary)	Partner(s) Contribution(s) (non-monetary value/in-kind)	**Total**
Salaries (CAS)	$49,884			
Salaries (PRBO)	$32,471	$40,000		
Supplies		$0	$0	$0
Overhead (CAS)	$5,432			
Overhead (PRBO)	$11,213	$13,400	$0	$24,613
Climate surface development (CAS)			$50,000	$50,000
Code Development, preliminary results (PRBO)			$100,000	$100,000
Equipment (Computing Infrastructure PRBO)		$0	$30,000	$30,000
Conference Fees and Travel (PRBO)	$1,000	$0		$1,000
Total	$100,000	$53,400	$180,000	$333,400

United States Department of the Interior

NATIONAL PARK SERVICE
1849 C Street, N.W.
Washington, D.C. 20240

9 April 2011

Dear California Landscape Conservation Cooperative
Proposal Review Committee,

I am writing this letter to express my enthusiastic support for the proposal "Confronting Uncertainty in Species Distributions Projections: Increasing the Applicability of an Essential Tool in Climate Change Adaptation Planning" submitted by Dr. Healy Hamilton and colleagues. I have reviewed the 2011 California LCC priorities and criteria, as well as a near-final draft of Dr. Hamilton's proposal. I have not reviewed the proposed project budget. I am not directly or indirectly involved in the proposed project.

There are several reasons why I believe this proposal to be of excellent quality and value.
First, the proposed project serves many of the core functions and objectives of the Landscape Conservation Cooperatives. This includes improvement of range shift forecasting and quantification of alternative sources of uncertainty. Second, the project's development of future species distribution projections, combined with quantified uncertainty levels, would result in very valuable tools for prioritizing inventory and monitoring needs, alerting managers to potential species invasions, forecasting stability and resilience patterns (as well as patterns of rapid transition), and designing networks of connected landscapes. Third, the project's emphasis on advancing our understanding and measurement of uncertainty in specific climate change consequences is very much the kind of science-driven advance that resource managers require in order to make effective decisions, and fits extremely well within the goals and objectives of Landscape Conservation Cooperatives.

The potential for this project to deliver "usable knowledge" to resource managers is very high, and reflect the need for science-based tools and well-supported methods. The proposed products (especially the map series) will be of high value and interest, and can help stimulate new routes of inquiry, visualization, and technology transfer within the Landscape Conservation Cooperative community.

Dr. Hamilton has prepared an intriguing proposal—creative yet specific, theoretically grounded yet practical, and useful to both the climate change scientific community and resource managers. I believe support of this proposal will result in a significant contribution to our understanding of conservation landscapes.

Sincerely,

Dr. Gary Machlis
Science Advisor to the Director
National Park Service

(916) 653-6725

April 12, 2011

Ms. Rebecca Fris
Science Coordinator
California Landscape Conservation Cooperative
3020 State University Drive East, Suite 2007
Sacramento, CA 95819

Dear Ms. Fris:

I am writing to express California State Parks' support for the "Confronting uncertainty in species distribution projections" project proposed by the California Academy of Sciences and PRBO Conservation Science. As proposed, this project will address a key barrier between models and field level resource management planning for climate adaptation.

California State Parks and other land management agencies rely in part on the results of modeling efforts to inform management decisions. But uncertainties have hindered translation of model results into adaptation management strategies. This project's focus to rigorously identify uncertainty in species distribution projections under climate change scenarios can help managers understand how those projections function and their utility to natural resource management.

Another major need of public land managers is identifying the species and locations of greatest threat from climate change and using that information to prioritize management actions. The proposed project will offer some insight into this question based on 100 bird and plant species, and may help identify important public lands that offer the most bioclimatic stability, while identifying continuing to refine forecasting methods.

I have been directly communicating with Dr. Hamilton about the species choices for the proposed CAS-PRBO species distribution modeling effort. Among other elements incorporated into the proposed project, the endemic plants chosen for modeling will be filtered by their known distributions and the percent occupancy on public lands. While the 50 final endemic plants to be modeled represent only a small percentage of California's plant diversity, both the modeling results and the insights gained through the process could have direct benefits to State Parks' adaptation planning efforts.

Natural resource management in State Parks requires constant translation of relevant science into on the ground planning efforts that can be implemented by field staff. The proposed project will be a valuable contribution towards that end and State Parks encourages the Landscape Conservation Cooperative to fund it for implementation.

Thank you for your consideration.

Sincerely,

Jay Chamberlin
Chief, Natural Resources Division

United States Department of the Interior

U.S. GEOLOGICAL SURVEY
Western Ecological Research Center
Modoc Hall, Suite 3006
3020 State University Drive East
Sacramento, CA 95819

April 8, 2011

California Landscape Conservation Cooperative Program
3020 State University Drive East, Suite 2007
Sacramento, California 95819

To whom it may concern,

The purpose of this LCC funding opportunity is to provide support for projects that improve the ability to make science-based adaptation planning decisions that translate into management action within the California Landscape Conservation Cooperative. As a federal agency charged with providing scientific information to support adaptation actions, USGS recognizes the challenges presented by the complex uncertainties facing resource managers.

For this reason, I am writing in support of the proposal from the California Academy of Sciences and PRBO Conservation Science entitled "Confronting uncertainty in species distribution projections: Increasing the applicability of an essential tool in climate change adaptation planning". The analysis will provide a much-needed quantification of alternative sources of uncertainty when creating forecasts of species response to climate change. These forecasts are a tool in understanding potential ecological impacts of climate change, but so far their results have not been embraced by managers, who recognize the large uncertainties involved. Those using species distribution projections must make choices about which species occurrence datasets to submit to which statistical algorithm, to be run with which and how many global climate simulations, run under which alternative emissions scenario, and downscaled to what appropriate spatial scale. To a manager trying to consider the implications of range shift projections for their species or ecosystem, this uncertainty can be paralyzing. Each of these factors contributes uncertainty to future projections, and managers have little guidance as to how much uncertainty is attributable to any one factor.

The need to improve the translation of range shift forecasting results into management actions is urgent and clear. This is one of the few tools we have for investigating the range of possible ecological responses to future climates. Where uncertainty can be quantified and is found to be low, the results of these ecological forecasts can form the scientific basis for vulnerability assessments, investments in land acquisition, for planning connected networks of protected areas, for prioritization of where and what to monitor, or for understanding potential future distributions of invasive species. In addition, results of species distribution models can feed into models of fire regime shifts or vegetation transitions. Where uncertainty is high, specific direction can be provided for obtaining additional information. Increasing our understanding of the behavior of uncertainty in projecting future distributions will serve not only the CA LCC, but will advice the scientific basis for adaptation planning.

Credible ecological forecasts will be essential to supporting adaptation of both human and natural systems to the one certainty we do face – that our world is rapidly changing. I strongly support the proposed CAS-PRBO effort to improve our limited tool set for adapting to these changes.

Sincerely,

Steven Schwarzbach, Director
Western Ecological Research Center

Curriculum Vitae

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RESEARCH INTERESTS: Biodiversity conservation and education

Conservation biogeography; Ecological forecasting; Systematics, phylogeography, and conservation of seahorses & pipefish

EMPLOYMENT

2002 -- Director, Center for Applied Biodiversity Informatics, California Academy of Sciences

APPOINTMENTS

2004--present Adjunct Assistant Professor, Dept. of Geography & Human Environmental Sciences, SFSU

2001--2005 Research Associate, Dept. of Environmental Science, Policy & Management, UC Berkeley

EDUCATION

2001 **Ph.D.** Integrative Biology, University of California, Berkeley

1992 **M.Sc.** Environmental Studies, Yale University, School of Forestry & Environmental Studies

1987 **B.A.** Ecology, Behavior & Evolution, University of California, San Diego

MOST RELEVANT PUBLICATIONS

Ackerly, D.D., Loarie, S.R., Cornwell, W.K., Weiss, S.B., **Hamilton, H.**, Branciforte, R., and N.B.Kraft. 2010. The geography of climate change: Implications for conservation biogeography. ***Diversity & Distributions*** 16:476-487

Loarie, S.R., Duffy, P.B., **Hamilton, H,** Asner, G.P., Field, C.B. & D.D. Ackerly. 2009. The velocity of climate change. ***Nature*** 462:1052-1055

Fernandez, M.A., Blum, S.B., Reichle, S., Guo, Q., Holzman, B.A., & **H. Hamilton**. 2009. Locality uncertainty and the differential performance of four common niche-based modeling techniques. ***Biodiversity Informatics*** 6:36-62

OTHER RECENT PUBLICATIONS

Huffard, C., Saarman, N., **Hamilton, H.** & W.B. Simison. 2010. The evolution of conspicuous facultative mimicry in octopuses: an example of secondary adaptation? ***Biological Journal of the Linnean Society*** **101**:68-77

Saarman, N, K.D. Louie, & **H. Hamilton.** 2010. Genetic differentiation across eastern Pacific oceanographic barriers in the threatened seahorse *Hippocampus ingens.* ***Conservation Genetics*** **11**:1989-2000

McDonald, M. & **H. Hamilton.** 2010. Phylogeography of the Angolan Black and White Colobus monkey, *Colobus palliatus angolensis,* in Kenya and Tanzania. ***American Journal of Primatology*** **71**:1-10

RELEVANT RECENT GRANTS

2010 The Worldviews Network: Ecological Literacy Programming for Digital Planetariums, $1,243,493 (With Denver Museum of Nature and Science and WGBH). NOAA Environmental Literacy Grant Program.

2009 Integrating Climate Change and Wildlife Corridors Conservation, $150,739 (With Center for Native Ecosystems). Wildlife Conservation Society.

2009 Forecasting Climate Induced Range Shifts for western conservation targets in support of connectivity conservation, $40,000. The Wilburforce Foundation.

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EDUCATION

Ph.D. Ecology, University of California Davis, September 2002-July 2008
Advisor: Deborah Elliott-Fisk
B.A. Environmental Studies, Minor in Latin American Studies,
University of California, Santa Cruz, June 1997.

RESEARCH EXPERIENCE

PRBO Conservation Science, Spatial Ecologist current
Bryson Interdisciplinary Climate People and the Environment postdoctoral fellow,
Department of Geography, Center of Climatic Research, University of Wisconsin Madison. 8/2009-7/2010.
Advisor: Jack Williams
Postdoctoral Researcher, Department of Environmental Science and Policy, UC Davis,7/08-8/09
Advisor: Susan Harrison.
Doctoral Research, UC Davis, 9/02- 9/08
Environmental Services Intern, Calif. State Parks, Monterey District. (10/98 – 8/02)

PEER REVIEWED PUBLICATIONS

Veloz, S.D. (2009) Spatially autocorrelated sampling falsely inflates measures of accuracy for presence-only niche models. *Journal of Biogeography*. 36: 2290-2299.

Veloz, S.D. , Williams J, Vavrus, S. Vimont, D. Lorenz, D. Identifying climatic analogs for Wisconsin under 21st-century climate-change scenarios. *Climatic Change (*In review)

Veloz, S. D., Anacker, B. Safford, H. Identifying factors that may limit the transferability of species distribution models for future climate change. *Ecograpy. (*In review)

Williams, J. Kharouba, H., **Veloz, S.D**. McLachlan,J., Vellend, M., Liu, Z., Otto-Bliesner, B., He, F. The Ice Age Ecologist: Testing Methods for Reserve Prioritization During the Last Global Warming. *Global Ecology and Biogeography*, Special issue (In review)

PUBLICATIONS IN PREPARATION

Nogues-Bravo, D.*, **Veloz, S.D.***, Brewer, S., Arrajo, P., Haywood, A., Rahbek, C., Rodriguez, J., Valdes, P., Williams, J. Reevaluating future extinction risk with a combination of contemporary and paleoecological data. Target journal: *Proceedings of the National Academy of Science.* *Co-first authors

Veloz, S.D., John Williams, Feng He, Zhengyu Liu, Bette Otto-Bliesner. No-Analogue Climates and Shifting Realized Niches During the Late Quaternary: Implications for Species Distribution Models. Target journal: Ecology

Grossenbacher, D.L., **Veloz, S.D**., Sexton, J. and Whittall, J.B. Niche evolution is related to speciation: A test within the genus *Mimulus*. Target journal: *Evolution*.

REFEREE ACTIVITIES

Journal of Biogeography, Marine Ecology Progress Series