

**Project Title:**

Effects of climate change on inland fishes of California:tools for adaptation

**Proposal by:**

Peter Moyle, Professor  
University of California, Davis  
Dept of Wildlife, Fish, and Cons Biology, 1 Shields Ave  
Davis, CA 95616

530-752-6355  
pbmoyle@ucdavis.edu

**Scope & Budget:**

Location: CA LCC-Wide  
Duration in months: 24  
Requested Funding: \$92,564.08  
Leveraged Funding: \$300,000.00

---

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.

California's 129 native fishes are mostly (80%) endemic to California, with no place to go as streams become warmer and unfavorably altered in flows as the result of climate change. Many of the 51 alien fishes, however, are likely to increase in abundance. The goal of this project is to synthesize information we have been systematically gathering since the release of the book *Inland Fishes of California* in 2002, on behalf of different agencies. The information includes status (75% of endemic fishes in decline, 25% in danger of extinction), population and distribution trends, life history traits, and impacts of climate change. The quantitative information will be synthesized and posted on an accessible website, and backed up by written summaries for each native species and many alien species. Analyses of status and trends of species with different vulnerabilities to climate change will be produced using the most recent models of climate change effects. Adaptation strategies for the major aquatic zoogeographic regions of California will be developed, through identification of key refuge streams for fish assemblages, including streams that could benefit from improved regulation by dams. This information will enable agencies to determine which species will be most strongly affected by climate change, positively or negatively, and to develop state and regional conservation strategies for these species.

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. 2. Inventory and monitoring protocols developed or refined to capture data on fish and wildlife populations and their habitats to detect changes resulting from climate change. 3. A population and habitat assessment developed or refined to predict changes in species populations and habitats. 4. A biological planning and conservation design project developed in response to climate

change.

List Partners

US Forest Service, California Department of Fish and Game, California Energy Commission, Trout Unlimited, California Trout, Resource Renewal Institute, Center for Watershed Sciences(UCD)

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.

The basic team consists of Dr. Peter Moyle (PI, see CV), Dr. Cathryn Lawrence, and two exceptionally experienced graduate students, Jacob Katz and Rebecca Quinones. Dr. Lawrence is a fisheries ecologist and assistant director of the Center for Watershed Sciences. She will advise all parts of project operation. Both students had wide experience before coming to UCD for graduate work, working with diverse agencies. They have worked with the PI on the studies that his project is designed to synthesize. Together team members have dozens of contacts in California agencies with whom we are working to collect the desired information. The PI is recognized as perhaps the foremost expert on the inland fish fauna of California, having written *Inland fishes of California* (2002, UC Press, Berkeley) which summarizes what was known about this unique fish fauna up to 2002. Most recently (2011) he is a co-author of the book *Managing California water: from conflict to reconciliation* (Public Policy Institute of California, San Francisco). He has been studying the California fish fauna since 1969 and has published widely on status and trends of native and introduced species, as well as on conservation strategies for the inland waters of California (see CV). This proposed study is designed to bring together information from four recent and ongoing projects: (1) a study of the status of California salmonids (California Trout, report in 2008); (2) production of a report California fish species of special concern (California Department of Fish and Game, \$110,000, ends 2011); (3) production of a GIS-based report on distribution and status of sensitive species on USFS land (\$93,000, ends 2011), and (4) a report predicting the likely effects of climate change on the inland fishes of California, especially the Bay Area (California Energy Commission, \$77,000, ends 2011). Much of the PI's research time (30+%) is devoted to these projects, and this project if it gets funded. The PI also is in charge of projects monitoring Suisun Marsh fishes (since 1980, funded by DWR, at about \$70,000/yr present contract), Putah Creek (funded by Solano Water Agency, since 1996, \$20,000/yr) and two Sierra Nevada streams (currently not funded, since 1979). These studies contribute to PI's understanding of climate change and other issues.

**Project Title: Effects of climate change on inland fishes of California: tools for adaptation**

**Project Leader/ Contact Information: Peter B.Moyle, Center for Watershed Sciences, University of California, Davis, Davis CA 95616. 530-756-8475; pbmoyle@ucdavis.edu**

**Project Description:** The goal of this project is to synthesize information the PI and his students have been systematically gathering since the release of the book *Inland Fishes of California* in 2002, to allow agencies to better predict the impacts of climate change on specific waterways and regions, as well as to develop management and adaptation strategies to keep native fishes from extinction.

Objectives include (1) final development of a user friendly data base and protocol that enables managers to determine current status of the 129 native inland fishes of California, (2) final development of a user friendly data base and protocol that enables managers to predict the effects of climate change on the 129 native inland fishes of California, and 51 alien species, (3) development of standard narratives and GIS-based maps for declining native species. All three objectives will be posted on a website and be available for easy downloading and updating. These ambitious objectives can be accomplished because much of the work has been accomplished or is underway, from other funding. An additional objective is to recommend climate-change adaptation strategies for the major aquatic zoogeographic regions of California, through identification of key refuge streams for fish assemblages, including streams that could benefit from improved regulation by dams.

CA LCC funding will fund a graduate student who will help the PI and others integrate the three objectives, get the information posted on a website, complete narratives and assessments not accomplished under existing projects, and assist in write-ups of results for the final report and, ultimately, publication in peer-reviewed journals

**CA LCC Priorities addressed:** This project addresses both of the 2011 CA LCC priorities. For the “Ecosystem Response...” priority, it provides basic information on the biology, status, and likely responses to climate change for all California fishes. This information includes protocols for calculating changes in status as well as for responses to climate change, which can be used by agencies to set priorities for management. It will also identify biodiversity hotspots for conservation and connectivity needs (watershed approaches). The information can be readily ‘plugged in’ to management plans (e.g. flow releases from dams to regulate temperatures) or models.

For the “Decision Support...” priority, the project should provide information useful for scenario planning, identifying ecosystem impacts of land use change (fish as indicators), and setting priorities for conservation. Important

in our information are development of standardized methods of assessing changes in status of multiple species, as well as likely responses to climate change.

**CA LCC Criteria addressed:**

**1. Applicability to Conservation and Adaptation Decisions-** the project is designed to help decision-makers set priorities for aquatic conservation.

**2. Ecological or Ecosystem Response to System/Climate Change –** A key project component is assessment of responses of both native and non-native species to climate change. Assessments of multiple species can help determine how fish faunas are likely to shift.

**3. Breadth of Understanding-** The project is integrative across all fish taxa in California, including providing information on responses to physical and chemical changes to their environment.

**4. Accessibility –** A key component of this project is user-friendly data bases and reports available from a readily accessible website.

**5. Scope/Transferability –** The project is California-wide in scope and the assessment methodologies developed should be widely transferable to any aquatic region.

**6. Partnerships/Leveraging –** The project builds on on-going collaborations with state and federal agencies, as well as NGOs. Much of the funding comes from outside sources; LCC funding will provide for integration and better presentation of the information. New partnerships are likely to result as our work become more widely available.

**7. Timeliness and Urgency –** The project is both timely and urgent, given that the fish fauna of California is in serious trouble (75% of endemic fishes in decline, 25% in danger of extinction), with about one species/year being listed under the ESA.

**Approach and Scope of Work:**

Our approach is to basically bring together four lines of research and present them in a way that will allow anyone who is interested, from agencies to NGOs to individuals, to evaluate the state of fish faunas at any scale from local to statewide, including predicting the likely effects of climate change. The information should also help policy makers decide on adaptation strategies to reduce the impacts of climate change on aquatic ecosystems. The four lines of research used in this project that have taken place in the Moyle Laboratory are (1) development of a statewide aquatic conservation strategy, (2) documenting the changing status of all species of inland fishes of California, (3) developing distribution maps of native inland fishes, and (4) predicting the effects of climate change on all inland fish species.

*Conservation strategy.* Research on aquatic conservation strategies can be found in Moyle publications dating back to the 1980s, and reflect evolving ideas of how it should best be done. The earlier work is summarized in Moyle (2002). Current thinking is based on the concept of *reconciliation ecology* that recognizes that humans are integral parts of all ecosystems and therefore in the process of choosing what species we want to have with us in the future. With climate change

likely to reduce habitat available to native fishes, there is increasing need to work at a regional level to provide special protection to the best remaining habitats and to find ways to protect fish assemblages by developing ‘natural’ flow regimes in regulated streams. The final product of this project will be a document that recommends a new state-wide strategy, including identifying a number of key waterways that should have management focused on protecting aquatic biodiversity. The strategy will also include criteria for choosing potential refuge lakes and streams.

*Changing status of California fish fauna.* The last major evaluation of the status of all inland fishes of California was Moyle (2002). However, reports on declining native species (“fish species of special concern”) were produced for the California Department of Fish and Game in 1989 and 1995 and a updated version of these reports is underway, to be completed in late 2011. For the new version, we have created 7-metric system for making repeatable assessments of all native species: area occupied, estimated adult abundance, dependence on human intervention for persistence, environmental tolerance under natural conditions, genetic risks, vulnerability to climate change, and importance of anthropogenic causes of decline. Each metric is scored on a 1-5 scale, using specific criteria, based on background presented in a written narrative. The result is a numeric score related to status. We have scored not only special concern species, but all native species in California. This metric scoring system can be used for regional faunas, as well as for scoring the state fauna repeatedly through time, documenting status trends. For this project, we will explain and post the methodology, with our initial results presented in the first year; there will be links to species narratives (e.g., the new California Fish Species of Special Concern report) as they become available.

*Distribution maps.* We have worked with the UC Davis Information Center for the Environment for about 20 years, producing various iterations of distributional maps for California fishes. We are currently working with them to produce a new generation of GIS-based maps, with documentation, that has its genesis in a project funded by the USFS to produce maps for occurrences of Sensitive Species on USFS land. At the same time, we are working with CDFG to improve existing distribution maps through their GIS shop. Our goal is to ultimately create maps that show present distributions of native fishes that will be available on line for use and modification, with links to sites showing the USFS and CDFG maps. For this project, our goals is to have maps available for all Species of Special Concern and Sensitive Species by the end of year one (about 65 species), to use as models for mapping the entire California native fish fauna. We expect to have maps for all native species by the end of year two.

*Predicting effects of climate change.* We currently have a project, funded by the California Energy Commission, to show the different vulnerabilities of native and non-native fish species to climate change. For each species, we develop a vulnerability score, based on a protocol originally developed for USEPA (ref). The score is based on 10 metrics for baseline vulnerability (module1), plus 10 metrics for vulnerability to climate change (module 2). Module 1 metrics are: Current population size (last 10 years); Long-term

population trend; Current population trend (last 10 years); Long-term range trends; Current range trend (last 10 years); Current vulnerability to stressors other than climate change; Future vulnerability to stressors other than climate change; Life span and reproductive plasticity; Future vulnerability to stochastic events and Current dependence on human intervention. The Module 2 metrics are: Physiological/behavioral tolerance to temperature increase; Physiological/behavioral tolerance to precipitation change; Vulnerability to change in frequency or degree of extreme weather events; Dispersive capability; Degree of habitat specialization; Likely future habitat change due to climate change (by 2100); Ability of habitats to shift at same rate as species; Availability of habitat within new range; Dependence on exogenous factors; and Interactions with non-native (alien) species. These scores should be available by January 2012, along with a ranking of species based on vulnerability to climate change.

*Integration.* The proposed project is designed to allow improvement of the data bases after the supporting projects are completed, if needed, and then use the combined scores from the status and climate change evaluations to rank species in terms of potential for extinction in the next 50-100 years. We will then look for geographic clusters of the most vulnerable species to suggestion regional conservation strategies. These strategies will include identifying ‘natural’ refuge streams and lakes, those that have the greatest potential to ‘resist’ climate change effects, and identifying regulated, or otherwise altered streams, that have the greatest potential for being improved as refuges to support vulnerable native fishes. The climate change refuge stream list will be not be exhaustive but focus on providing good examples, which can be used as the basis for an agency-lead statewide effort to identify and establish refuges. The final products will be a website where all the information discussed above will be posted and a report summarizing the results of our studies. We also anticipate a number of peer-reviewed papers being produced as a result of the studies, including a review paper on the future of the California fish fauna, but, given the lengthy peer-review process, we do not anticipate publication by the end of the project.

### **Products/Data Sharing:**

Assuming the stated time for the two year project is September 30, 2011, we anticipate the following products.

Year 1 (September 30, 2012)

1. Creation of a project page and links on the California Fish website maintained by Dr. Lisa Thompson, UC Cooperative Extension  
<http://calfish.ucdavis.edu/>.
2. Posting of vetted data bases on California fish status and California fish vulnerability to climate change, along with detailed explanations of methodology
3. Posting of links to agency websites with supporting material created by the UCD Moyle lab.
4. Posting of descriptions of and links to distribution maps on the website UCD’s Information Center for the Environment.

5. Progress report of results of integrating data sets. This will include a first draft of a list of 'most vulnerable' species and potential regional clusters of species needing special conservation efforts to prevent extinction.

Year 2 (September 30, 2013)

1. Completed posting of all relevant materials and links on the California Fish website.

2. Final report on status and conservation of California fishes in relation to climate change that will include (1) ranked list of native species, by vulnerability, with brief narratives (or links to narratives) for each species; (2) ranked list of non-native species, by likelihood of increasing abundance in relation to climate change; (3) regional clusters of most vulnerable native species, (4) recommendations for a statewide conservation strategy; (5) regional lists of potential refuge waters.

**Measuring results:** The ultimate measure of success will be adoption of management agencies of our vulnerability ratings and conservation strategies. While we can measure 'hits' on the website as one measure of use, ultimate success will be beyond the time-frame of this study. Otherwise, success can only be measured in terms of amount of material posted on the website, on development of papers based on the research, and number of citations to the work.

	Yr 1 (request)	Yr 2 (request)	Partners
<b>Salaries</b>			
Graduate Student @ \$3488/mo 50% for 12 mo	\$20,928.00	\$22,183.60	
Project Manager (C. Lawrence, PhD @ 2.5% of \$6148/mo 12 mo/yr )	\$1,844.40	\$1,844.40	
<b>Total of Salaries</b>	\$22,772.40	\$24,028.00	\$250,000
<b>Benefits</b>			
Graduate Student @ \$1.3%	\$272.06	\$288.38	
Project Manager Benefits (31% Yr 1, 34.2% Yr 2)	\$571.76	\$630.78	
<b>Total of Benefits</b>	\$843.90	\$919.16	
<b>Supplies and Expenses</b>			\$50,000
Required Liability Insurance	\$182.03	\$180.24	
<b>Total of Supplies and Expenses</b>	\$182.03	\$180.24	
<b>Other Direct Costs</b>			
Grad Student Fees @ \$4947/qrtr, 3 qrtrs	\$14,841.00	\$14,841.00	
<b>Total of Other Direct Costs</b>	\$14,841.00	\$14,841.00	
<b>Total Direct Costs (TDC)</b>	\$38,639.33	\$39,968.40	
<b>Indirect Costs (@ CESU rate, 17.5% TDC)</b>	\$6761.88	\$6994.47	
<b>Total</b>	\$45,601.21	\$46,962.87	\$300,000
<b>Grand Total</b>			\$392,564.08



---

Jack E. Williams, Ph.D.  
*Senior Scientist*

329 Crater Lake Avenue  
Medford, Oregon 97504  
Phone: 541.772.7724  
FAX: 541.772.7725  
e-mail: [jwilliams@tu.org](mailto:jwilliams@tu.org)

March 29, 2011

Dr. Peter B. Moyle  
Wildlife, Fish and Conservation Biology  
University of California  
1 Shields Avenue  
Davis, CA 95616

Dear Peter:

I am writing in support of your proposal to evaluate climate change for fishes in the California Landscape Conservation Cooperative area. This subject is of great importance to Trout Unlimited (TU) and our members and we are pleased to cooperate with this proposal.

Trout Unlimited has been working with the U.S. Geological Survey and U.S. Forest Service on the potential influence of changing climate on the persistence of salmonids of the Inland West for several years. Our broad-scale analyses were recently published in 2010 in U.S.G.S. Open-File Report 2010-1236. We covered nearly all the western salmonids except those in California. Developing a better understanding of how native and alien fishes of California will respond to warmer temperatures, more variable flow conditions, and increased disturbance regimes would not only round out our understanding of western fish responses, but would be valuable to TU in our restoration efforts currently underway or planned in California.

Improving our understanding of how individual fish species and entire communities of fishes are likely to respond to climate change can help inform our restoration projects along the North and Central Coasts, in the Sierra Nevada, and in the Central Valley. We have several local chapters and national office staff involved in trout, salmon and steelhead restoration efforts around the state. We are particularly interested in how climate change is likely to alter current relationships between native and alien fish species. One of the greatest threats our native salmonids face is negative interactions with alien salmonids and other non-native species such as smallmouth bass. The synergistic effects of climate change and non-native species are likely to be a potent force in the decline of our native fishes. If we can obtain a better understanding of these relationships among species, we will be better able to inform decisions about reconnecting stream systems, restoring instream flows, and using instream barrier proactively to stall alien fish invasions.

Over the years, we have worked closely with you and your students on a variety of projects. Currently we have close working relationships with UC-Davis on studies on restoration of Sierra Nevada meadows and in restoration of Eagle Lake rainbow trout. This project will benefit and expand on both of these collaborative efforts.

Trout Unlimited has a variety of GIS and mapping resources that could be made available for this project through staff in our Boise, Idaho office. One of our GIS specialists, Kurt Fesenmyer,

has been involved in several fish conservation projects in California and will be available to assist you and your students as necessary.

I would be glad to address any questions from the staff associated with the California LCC proposal review. I can be contacted per the letterhead information provided on the first page.

I will look forward to hearing of progress on this proposal.

Regards,

*Jack E. Williams*

JACK E. WILLIAMS, Ph.D.  
Senior Scientist

Cc: Chuck Bonham, California Director for TU  
Kurt Fesenmyer, Boise Science Staff

**CALIFORNIA ENERGY COMMISSION**

1516 NINTH STREET  
SACRAMENTO, CA 95814-5512  
www.energy.ca.gov



Dr. Peter B Moyle  
Center for Watershed Sciences  
University of California  
1 Shields Avenue  
Davis CA 95616

Dear Dr. Moyle:

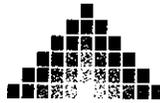
As you know, the Energy Commission has a strong research program on regional climate change science. Working with you in the past has been very rewarding. For this reason, I will be pleased to work with you on your proposed project to the California Landscape Conservation Cooperative, Effects of climate change on inland fishes of California. As you indicate in the proposal, your project takes the information you are developing for the Energy Commission on climate change and California fishes, combines it with additional information, and then makes it more accessible to policy makers. This is clearly a good use for the database you are developing with the Energy Commission's funds and fits in well with the goals of the Energy Commission project of which your study is a part, the Vulnerability and Adaptation Study.

We look forward to continued cooperation on your studies on the effects of climate change on California fishes.

Sincerely,

A handwritten signature in black ink, appearing to read "Guido Franco", followed by the date "3/28/2011".

Guido Franco  
Technical Lead for Climate Change Research  
Public Interest Energy Research Program  
California Energy Commission



RESOURCE RENEWAL INSTITUTE  
Innovations for a Sustainable Future

April 5, 2011

Dr Peter B. Moyle  
Center for Watershed Sciences  
University of California  
1 Shields Avenue  
Davis CA 95616

Dear Dr Moyle:

The Resource Renewal Institute is pleased to work with you and to provide guidance on your proposed project to the California Landscape Conservation Cooperative, *Effects of climate change on inland fishes of California*. As you know, RRI is a non-profit organization set up to catalyze long-term environmental change through comprehensive management strategies. With programs focusing on land, water, biodiversity, human health, and climate change, RRI implements best practices from around the world.

Your work on California native fishes has long given us inspiration here at RRI. Understanding the effects of human land-use patterns on California's aquatic ecosystems is of profound importance to our work. Few examples illustrate the crisis in freshwater better than the state of our native freshwater fishes. Your current research program should prove to be increasingly useful for helping organizations like ours to make decisions about where to best devote energy and resources to conservation of land, water, and biodiversity. We appreciate that you are attempting a new synthetic approach to native fish conservation, as a key to protecting aquatic ecosystems throughout California, and then making the information more accessible to policy makers. This information will be especially useful in the context of climate change, which is making it increasingly difficult, yet increasingly urgent, to set conservation priorities.

I am looking forward to continuing to work with you on this exciting and useful project, as well as other projects.

Sincerely,

Huey D. Johnson  
President

**PETER B. MOYLE**

**Department of Wildlife, Fish, and Conservation Biology & Center for Watershed Science  
University of California, Davis, 1 Shields Avenue, Davis Ca 95616**

Web site <http://wfc.ucdavis.edu/www/Faculty/Peter/petermoyle>

**EDUCATION**

1964	University of Minnesota	<b>B.A.</b> -	<b>Zoology</b>
1966	Cornell University	<b>M.S.</b> -	<b>Conservation</b>
1969	University of Minnesota	<b>Ph.D.</b> -	<b>Zoology</b>

**UNIVERSITY POSITIONS**

1969 - 1972	Assistant Professor, Biology, California State University, Fresno, CA
1972 – present	Assistant to Full Professor, University of California, Davis, California
2002-present	Associate Director, Center for Watershed Science UCD

**AWARDS (since 2000)**

Distinguished Ecologist, Colorado State University (2001); Outstanding Mentor Award, UCD (2003); President's Chair in Undergraduate Education, UCD (2003-2006, with J. Mount). Outstanding Achievement Award, Association of Fisheries Research Biologists (2007); Award of Excellence, highest award of American Fisheries Society (2007), Brown-Nichols Award (2011)

**OTHER (selected)**

Editorial Boards *Environmental Biology of Fishes*, *Biological Conservation*, *University of California Publications in Zoology*. Expert testimony: State Water Resources Control Board, congressional hearings, state legislative hearings, etc. Head, Delta Native Fishes Recovery Team (1993-1995); Member, Sierra Nevada Ecosystem Project Team (1994-1996); Board Member, The Natural Heritage Institute; Board member, California Trout. Member, National Research Council Committee on Endangered Fishes in the Klamath Basin (2002-2003). Member, Editorial Committee, University of California Press (2006-2011). Member, San Joaquin River Restoration Technical Advisory Committee (2007-2011). Teach basic courses in fish biology, conservation, fisheries, and watershed ecology.

**RECENT PUBLICATIONS**

Author or co-author of over 190 peer-reviewed publications, including 12 books/monographs.

- Moyle, P. B. 2002. *Inland Fishes of California*. Berkeley: University of California Press 502 pp.
- Lund, J., E. Hanak., W. Fleenor, W., R. Howitt, J. Mount, and P. Moyle. 2007. *Envisioning futures for the Sacramento-San Joaquin Delta*. San Francisco: Public Policy Institute of California. 284 pp.
- Moyle, P.B. J.A. Israel, and S. E. Purdy. 2008. *Salmon, Steelhead, and Trout in California: Status of an Emblematic Fauna*. UC Davis Center for Watershed Sciences. 316 pp. (available at [Caltrout.org](http://Caltrout.org)).
- Lund, J., E. Hanak, W. Fleenor, W. Bennett, R. Howitt, J. Mount, and P. Moyle. 2010. *Comparing Futures for the Sacramento-San Joaquin Delta*. Berkeley, University of California Press.
- Marchetti, M. P. and P. B. Moyle. 2010. *Protecting life on Earth: an introduction to the science of conservation*. University of California Press. 243 pp.
- Brown, L. R., S. D. Chase, M.G. Mesa, R. J. Beamish, and P. B. Moyle, editors. 2010. *Biology, management, and conservation of lampreys in North America*. American Fisheries Society Symposium 72, Bethesda MD .
- Hanak, E., J. Lund, A. Dinar, B. Gray, R. Howitt, J. Mount, P. Moyle, and B. Thompson. 2011. *Managing California's Water: From Conflict to Reconciliation*. San Francisco, PPIC. 482 pp