Prospectus for Synthesis and Assessment Product 4.2

Thresholds of Change in Ecosystems

Lead Agency: USGS
Supporting Agencies: USDA, DOE, EPA, NOAA, NSF

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1. Overview: Description of Topic, Audience, Intended Use, and Questions to be Addressed

1.1 Description of Topic and Questions to be Addressed

One of the primary goals of the Ecosystems research element of the Climate Change Science Program (CCSP) is to enhance the understanding and ability to predict and forecast effects of climate change on ecosystems. Over the past several decades, numerous scientific publications and reports have described and discussed historical and potential effects of climate change and variability on ecosystems and their constituent biota and processes. Because temperature, precipitation, and related climate variables are fundamental regulators of biological processes, it is reasonable to expect that significant human-induced changes in the climate system, both its mean state and its variance structure in space and time (including occurrence of extreme weather events), will have measurable effects on the distribution, condition, composition, structure, and functioning of ecosystems. Such changes in ecosystems may, in turn, alter linkages and feedbacks between ecosystems and regional climate systems (e.g., altered albedo, changes in rates of energy and gas exchange). Because ecosystems produce a wide array of goods and services valued by humans, climate-induced changes in ecosystems could have significant effects on human communities and economies.

Numerous scientific publications document effects of changing climate conditions on ecosystems. Many of these observed changes involve changes in the timing of species life cycle or life history phenomena. Such phenological changes may significantly alter demographic processes in single species as well as interactions among species (e.g., predation, mutualism, trophic relations). In other cases, documented changes involve significant alterations in the distribution of species, including range shifts, expansions, or contractions. Changes in the spatial extent and distribution of ecosystems, and in the location of major ecotones, have also been reported. Other changes may involve alterations in ecosystem function (e.g., primary productivity) or in related ecosystem processes such as biogeochemical cycling.

In spite of the great interest and importance in understanding and forecasting ecosystem responses to climate change and variability, it is often difficult to relate specific, observable changes in ecosystems to climate change in a rigorous, causal manner. This is partly because climate variables are linked to specific ecosystem responses through complex, nonlinear chains of interacting processes. Part of the difficulty is also related to the need to ‘downscale’ attributes of change in the climate system to understand ecosystem changes at regional or ecoregional scales. Moreover, effects of climate change

on ecosystems and their constituent species and processes are typically confounded with effects of numerous other human actions, including land use changes that fragment and degrade ecosystems at various spatial scales, pollutants, invasions of non-native species, and resource management and utilization practices. It is difficult to tease apart effects of climate change from these other effects. These challenges are made more difficult by the current paucity of long-term data and information for most ecosystem types and ecoregions, especially from experiments designed to ascertain cause-and-effect relationships. Nonetheless, significant progress is being made in linking observed changes in the climate system and climate-sensitive parameters (e.g., extent and duration of Arctic sea ice) with observed changes in the attributes of ecosystem change discussed above (e.g., Dennis and Shreeve 1991; Easterling et al. 2000; Schmitz et al. 2003; Parmesan and Galbraith 2004; Thuiller et al. 2005).

In the ongoing discussions of climate change effects on ecosystems, increasing focus is being placed on the existence and likelihood of abrupt state changes or threshold responses in the structure and functioning of ecosystems (Holling 1986; Scheffer et al. 2001; Higgins et al. 2002; Foley et al. 2003; Schneider 2004; Burkett et al. 2005; Hsieh et al. 2005). Various interrelated terms are employed in the scientific literature to characterize these types of discontinuous and rapid changes in ecosystems, including ecosystem tipping points, regime shifts, threshold responses, alternative or multiple stable states, and abrupt state changes. Such discontinuities in ecosystems are difficult to predict, and are likely to result in profound changes to natural resources that are sensitive to climate changes, as well as to human societies that depend on ecosystem goods and services. While the occurrence of threshold or abrupt changes in ecosystems are suggested by current ecological theory and models, and are documented in the paleoecological record, they are poorly understood quantitatively as well as in terms of the underlying causal mechanisms. It is unclear under what circumstances climate change, both in its mean state and in its variance in space and time, including occurrence of extreme weather events, might cause ecosystem threshold shifts, instead of more gradual, continuous changes in ecosystems and species.

This CCSP Synthesis and Assessment Product (SAP) 4.2 will address and synthesize the present state of scientific understanding regarding potential abrupt state changes or regime shifts in ecosystems in response to climate change. The assembled author team will rely on its expertise and knowledge of the relevant peer-reviewed literature to identify and synthesize results of those studies that provide the best available evidence upon which to define the circumstances in which abrupt changes in ecosystems in response to climate change might be expected. The resulting report will develop a conceptual framework within which to frame and discuss potential abrupt state changes or regime shifts in ecosystems in response to climate change. The report will identify specific difficulties or shortcomings in our ability to identify the likelihood of abrupt state changes in ecosystems as a consequence of climate change.

The specific questions to be addressed by this CCSP product include:

1. What specifically is meant by abrupt state changes or regime shifts in the structure and function of ecosystems in response to climate change?
    - How do we recognize such changes?
    - What are appropriate ecological variables or indicators for measuring such changes?
    - How does our ability to recognize sudden changes in ecosystems vary with the spatial or temporal scales of observation and analysis?

2. What evidence is available from current ecological theory, ecological modeling studies, or the paleoecological record that abrupt changes in ecosystems are likely to occur in response to climate change?
    - Does the available historical record elucidate whether a particular abrupt ecosystem change was due to an abrupt change in climate, or whether gradual climate change over time caused the ecosystem to cross a critical threshold?

3. Are some ecosystems more likely to exhibit abrupt state changes or threshold responses to climate change?
    - What are the specific processes or factors, physical and biological, that determine whether discontinuous responses are likely to occur in ecosystems in response to climate change?

4. If abrupt changes are likely to occur in ecosystems in response to climate change, what does this imply about the ability of ecosystems to provide a continuing supply of ecosystem goods and services to meet the needs of humans?

5. If there is a high potential for abrupt or threshold-type changes in ecosystems in response to climate change, what changes must we make in existing management models, premises, and practices in order to manage these systems in a sustainable, resilient manner?

6. How do we design and implement monitoring systems, at various spatial scales, in order to detect and anticipate abrupt or threshold changes in ecosystems in response to future climate change?

7. What are the major research needs and priorities that will enhance our ability in the future both to forecast and to detect abrupt changes in ecosystems caused by climate change?

1.2 Audience and Intended Use

The intended audience for this CCSP product includes research scientists, decision makers, resource managers, and other stakeholders who have interests in assessing and evaluating potential effects of climate change and variability on ecosystems, especially abrupt changes or regime shifts in ecosystems in response to climate change.

The intended use of this CCSP product is to provide information on the potential for abrupt changes or regime shifts in ecosystems in response to climate change, both change in the mean state of the climate system and on its variance in space and time, including the occurrence of extreme weather events. This product will address scientific and technical issues in a comprehensive, objective, and open manner. While based fundamentally on the relevant peer-reviewed literature, this product will be written to be accessible and useful to the well-informed general reader and decision maker.

2. Contact Information for Responsible Individuals at the Lead and Supporting Agencies

The US Geological Survey (USGS) is the lead agency for this CCSP Synthesis and Assessment Product, with the US Department of Agriculture (USDA), US Department of Energy (DOE), US Environmental Protection Agency (EPA), the National Oceanic Atmospheric Administration (NOAA), and National Science Foundation (NSF) as supporting agencies. Because USGS is the lead agency, the product will be subject to USGS guidelines implementing the Information Quality Act (IQA). Contact information for the lead and supporting agencies are listed below:

USSG (Lead)
Colleen Charles – colleen_charles@usgs.gov 703-648-4110

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3. Lead Authors: Required Expertise of Lead Authors and Biographical Information for Proposed Lead Authors

Based on discussions among the lead and supporting agencies, the following are proposed as lead authors for Synthesis and Assessment Product 4.2:

Craig D. Allen, Research Ecologist, USGS Fort Collins Science Center, Jemez Mountains Field Station, Los Alamos, NM; 505-672-3861, craig_allen@usgs.gov

Julio L. Betancourt, Senior Scientist and Paleo-Biogeographer, USGS Desert Laboratory, National Research Program, Tucson, AZ; 602-670-6821x109, jlbetanc@usgs.gov

Charles Birkeland, Assistant Unit Leader-Fish and Coral Reef Ecologist, USGS Cooperative Research Unit and University of Hawaii, Honolulu, HI; 808-956-8350, charlesb@hawaii.edu

F. Stuart (Terry) Chapin, III, Professor of Ecology, Department of Biology and Wildlife, Institute of Arctic Biology, University of Alaska, Fairbanks, AK, Lead PI-Bonanza Creek LTER Program; 907-474-7922, terry.chapin@uaf.edu

James E. Cloern, Senior Research Biologist, USGS National Research Program, Menlo Park, CA; 650-329-4594, jecloern@usgs.gov

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Anthony David McGuire, Assistant Unit Leader-Ecology, USGS Cooperative Research Unit and University of Alaska, Fairbanks, AK, co-PI, Bonanza Creek LTER Program; 907-474-7661, ffadm@uaf.edu

Patrick J. Mulholland, Aquatic Ecologist, Carbon & Nutrient Biogeochemistry Group, Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, TN; 865-574-7304, mulhollandpj@ornl.edu

Debra P. C. Peters, Research Scientist, USDA Agricultural Research Service, Jornada Experimental Range, Las Cruces, NM, Lead PI, Jornada Basin LTER Program; 505-646-2777, debpeter@nmsu.edu

Daniel Roby, Assistant Unit Leader-Wildlife, USGS Cooperative Research Unit and Oregon State University, Corvallis, OR; 541-737-1955, droby@usgs.gov

George Sugihara, Professor of Ecology, Scripps Institute of Oceanography and University of California at San Diego, La Jolla, CA, co-PI, California Current Ecosystem LTER Program; 858-534-5582, gsugihara@ucsd.edu

Development of this product will require an interdisciplinary group of lead and supporting authors with expertise and experience directly related to thresholds of climate change in ecosystems, who are acknowledged as experts based on their publication records and relevant accomplishments and contributions. The lead agency will work closely with the supporting agencies and proposed lead authors to develop the final list of lead and supporting authors for this product. Nominations for additional authors will be solicited during the public comment period, and should be submitted to the lead agency contact for this product. Brief biographical information for the proposed lead authors for this product is provided in Appendix A. The author team will also depend extensively on solicitation of relevant information from experts in the Federal and academic research community during the preparation of this report.

4. Stakeholder Interactions

In preparing this draft prospectus to develop SAP 4.2, careful consideration was given to feedback received from stakeholders at the December 2002 CCSP Planning Workshop for Scientists and Stakeholders, as well as the November 2005 CCSP Workshop on Climate Science in Support of Decision Making. This prospectus also reflects feedback on research priorities received from representatives of the ecosystem research community at the February 2004 Ecosystems Interagency Working Group Workshop (Lucier et al. 2006), held following publication of the CCSP Strategic Plan, which guided selection of questions to be addressed in preparation of SAP 4.2. Stakeholder input will also be solicited through the public comment period for this prospectus and the draft report put forth by the authors of SAP 4.2.

In addition, the authors in collaboration with the lead and supporting agencies may call upon a set of stakeholders to broaden the input for this study as necessary. This input, together with input received from sources noted above, would be considered carefully in defining the scope, organization, content, and expectations for the product.

5. Drafting Process: Materials to be Used in Preparing the Product

The lead authors will draft answers to the key questions in their respective sections. They will also prepare an introductory section to describe the topic, the audience, and the intended use of this product. The lead author for each section may assign primary responsibility for drafting to a specific contributing author. The scientific/technical synthesis of the document will utilize published, peer-reviewed scientific literature. Authors will consider the full range of relevant peer-reviewed information based on their expertise and perspectives. The final product, including an Executive Summary, will identify disparate views, where appropriate, and will carefully evaluate remaining sources of uncertainty and their effects on the responses to the questions and the main conclusions to be reached.

One initial workshop is envisioned as a means to help the research community provide input and identify divergent opinions on thresholds of climate change in ecosystems. The lead authors will be responsible for incorporating materials from contributing authors and from the workshop participants in the draft product.

6. Review Process

During its development SAP 4.2 will be reviewed following the process described in the Guidelines for Producing CCSP Synthesis and Assessment Products, and in the companion Recommendations for Implementing the *CCSP Synthesis and Assessment Guidelines*, including (1) a first draft for expert peer review, (2) a second draft posted for public comment, and (3) a third draft for final review and approval through the CCSP Interagency Committee and the Committee on Environment and Natural Resources (CENR) / National Science and Technology Council (NSTC).

The expert peer review for the product will fully comply with requirements of the Information Quality Act (PL 106-554, §515(a)) ("IQA"), the IQA Lead Agency's Information Quality Guidelines, and the requirements of the Office of Management and Budget's (OMB) Final Information Quality Bulletin for Peer Review ("OMB Bulletin).

The public is invited to nominate Expert Reviewers to participate in the peer review of the draft CCSP SAP 4.2. Nominations should be e-mailed or sent to Colleen Charles (colleen_charles@usgs.gov) at the U.S. Geological Survey, 12201 Sunrise Valley Dr., MS 301, Reston, Virginia 20192 by June 15, 2007. Nominations must include an up-to-date curriculum vitae and listing of publications. Peer reviewers who are Federal employees will be subject to Federal requirements governing conflict of interest (see 18 U.S.C, 208, 5C.F.R. Part 2635 (2004)). Reviewers who are not Federal employees will be screened pursuant to the National Academy of Sciences policy for committee selection with respect to conflict of interest.

The lead agency for this product will select qualified reviewers based on their expertise, published work, and stature within and across scientific communities. For the preparation and review of this product, the USGS will establish a committee under applicable provisions of the Federal Advisory Committee Act (FACA), as implemented by the Department of the Interior (DOI). The lead agency will also screen for real or perceived conflict of interest and independence from the lead and supporting agencies for that report, and ensure that the full slate of reviewers selected reflects a balance of scientific and technical perspectives. At least three independent reviews will be obtained from non-climate scientists, selected by the lead and supporting agencies, to comment on how understandable and useful the draft product is to non-specialists.

Following expert review, the lead authors will revise the draft product by incorporating comments and suggestions from the reviewers, as the lead and supporting authors deem appropriate. The lead agency will prepare the required peer review report, including a summary of peer review comments and the agency's response to the review. The peer

review report will be posted on the lead agency's web site and linked to the CCSP web site.

Following this expert review process, the second draft will be released for public comment following CCSP guidelines. The public comment period will last at least 45 days. The lead and supporting authors will prepare a third draft, taking into consideration the comments submitted during the public comment period. The scientific judgment of the lead and supporting authors will determine responses to the comments. A summary of the public comments received for the product, along with a summary of responses to these comments, will be posted on the CCSP web site.

Following clearance by the lead agency (USGS), the third draft of the product will be submitted concurrently to the CCSP Interagency Committee and the CENR for final review and approval. If the concurrent CCSP Interagency Committee/CENR review determines that no further action is needed and that the product has been prepared in conformance with these guidelines and the IQA (including ensuring objectivity, utility, and integrity as defined in 67 FR 8452), they will clear the product for final production by the lead agency. If the CCSP Interagency Committee and/or CENR determine that further revision is necessary, their comments will be sent to the lead agency for consideration and resolution by lead and supporting authors. If needed, the National Research Council (NRC) will be asked to provide additional scientific analysis to bound scientific uncertainty associated with specific issues. Final clearance will require concurrence of all members of the CENR. The lead agency will produce the final product and it will be released in coordination with the Climate Change Science Program Office (CCSPO).

7. Related Activities, including Other National and International Assessment Processes

This CCSP product will build on previous Intergovernmental Panel on Climate Change (IPCC) assessments (e.g., First, Second, Third and Fourth Assessment Reports); the recent USGCRP National Assessment, *Climate Change Impacts on the United States: Potential Consequences of Climate Variability and Change* (including the Foundation and Overview reports and the several regional and topical assessment reports); NRC reports (e.g., *Global Environmental Change: Research Pathways for the Next Decade*, 1999; *Science Priorities for the Human Dimensions of Global Change*, 1994; *Sea Level Rise and Coastal Disasters: Summary of a Forum*, 2002; *Hydrologic Science Priorities for the U.S. Global Change Research Program: An Initial Assessment*, 1999; *Climate Change Science: An Analysis of Some Key Questions*, 2001); and other relevant national and international reports. It is expected that this CCSP product will provide input to future IPCC assessments, future National Assessments, and future NRC reports on climate change effects.

8. Communications: Proposed Method of Publication and Dissemination of the Products

The lead agency will coordinate production and release with CCSPO using the standard format established for all CCSP Synthesis and Assessment Products. The final product and the comments received during the public comment period will be posted on the CCSP web site. Similarly, the peer review report for the product, along with the lead agency's response to the review, will be posted on the lead agency website and linked to the CCSP web site. Once NSTC has cleared the document, the product will be prepared for both web and hardcopy dissemination. Final report production and layout will be managed by professional and technical editors. The number of hard copies of the product, and the means for dissemination and notification of availability, will be designed to ensure broad availability to the scientific community and to the public, including all stakeholders with a stated interest in the product.

As part of this process, a communications plan will be developed by the lead and supporting agencies along with the lead authors as appropriate. This plan will cover all aspects of the distribution and dissemination of information about this product. Various outlets and mechanisms will be considered in order to alert stakeholders to the product and its findings, and to invite them to participate in the public comment period.

9. Proposed Timeline

The timeline proposed for Product 4.2 is as follows

2007

April 2007	Public Comments on draft prospectus
May 2007	Final prospectus cleared & published on CCSP web site
May 2007	FACA review committee established
July/August 2007	First draft of product completed
September 2007	Expert review of first draft product completed
October 2007	Second draft of product completed
November 2007	Public comments on second draft product completed
December 2007	Third draft of product completed
December 2007	CCSP/CENR review of third draft product completed
December 2007	Final product published on CCSP website

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APPENDIX A – Biographical Information for Proposed Lead Authors

Craig D. Allen, Research Ecologist, USGS Fort Collins Science Center, Jemez Mountains Field Station, Los Alamos, NM; 505-672-3861, craig_allen@usgs.gov

Craig Allen is a research ecologist with the U.S. Geological Survey, and is Station Leader of the Jemez Mountains Field Station based at Bandelier National Monument. He received B.S. and M.S. degrees in geography from the University of Wisconsin (Madison), and a Ph.D. focused on forest and landscape ecology from the University of California (Berkeley). He has worked as a place-based ecologist with the Department of Interior in the Jemez Mountains since 1986. Craig conducts research on the ecology and environmental history of Southwestern landscapes, and the responses of Western mountain ecosystems to climate change, and provides technical support in the areas of conservation biology and ecological restoration to Bandelier National Monument and other land management agencies in the region. Recent and ongoing research activities involving a variety of colleagues and collaborators include: development of vegetation and fire histories in the Southwest; responses of semiarid forests and woodlands to drought, including extensive vegetation dieback; fire effects on Jemez Mountains salamanders, Mexican spotted owls, and nitrogen cycling; runoff and erosion processes in piñon-juniper watersheds; ecological restoration of Southwestern forests and woodlands; development of long-term ecological monitoring networks across landscape gradients in the Jemez Mountains; and determining elk movements and habitat effects in the Jemez Mountains. Since 2001 Craig has worked to help initiate natural resource inventory, monitoring, and research efforts in support of adaptive management at the new Valles Caldera National Preserve. Craig is one of the core PI's of the Western Mountain Initiative, an integration of research programs that study global change in mountain ecosystems of the western United States.

Julio L. Betancourt, Senior Scientist and Paleo-Biogeographer, USGS Desert Laboratory, National Research Program, Tucson, AZ; 602-670-6821x109, jlbetanc@usgs.gov

Julio Betancourt is a Research Hydrologist with USGS and an adjunct professor at the University of Arizona in Tucson. For the past 25 years, he has been based at the University's Desert Laboratory, a scientific institution with a 100-yr legacy in environmental research about deserts (http://wwwpaztcn.wr.usgs.gov/). He is a leading expert on the vegetation histories of arid and semi-arid North and South America during the last glacial-interglacial cycle. His research is also helping to define how decadal to multidecadal variability in ocean temperatures modulates U.S. climate and western ecosystems, and how this knowledge might be used to forecast landscape change.

Charles Birkeland, Assistant Unit Leader-Fish and Coral Reef Ecologist, USGS Cooperative Research Unit and University of Hawaii, Honolulu, HI; 808-956-8350, charlesb@hawaii.edu

Charles Birkeland received his PhD in Zoology from the University of Washington, Seattle, in 1970. From 1970 to 1975 he was a post doc at the Smithsonian Tropical Research Institute in Panama. From 1975 to 2000 he was on the faculty of the University of Guam Marine Laboratory. He was Director of the Marine Lab from 1979 to 1982 and was the third President of the International Society of Reef Studies from 1986 to 1989. He organized the 7th International Coral Reef Symposium in 1992. He coauthored a book on "*Acanthaster planci*: major management problem of coral reefs" and a textbook on "Life and death of coral reefs". He joined the Hawaii Cooperative Fishery Research Unit in Hawaii in June 2000. His research has been focused on thresholds ("tipping points") in effects of large-scale factors beyond which self-reinforcing processes or positive feedback mechanisms transform the population or ecosystem into another state (cause a "phase shift") and prevent a return to the original state (reviewed in Birkeland, C. 2004. BioScience 54: 1021 – 1027). He has organized and guided a BRD Global Climate Change field and laboratory project "Extrinsic and intrinsic factors affecting the resilience of corals to climate change, and their use in designing marine reserves" to determine the biochemical and physiological processes of acclimatization and the extent of genetic processes of adaptation in corals to stresses from the physical environment**.**

F. Stuart (Terry) Chapin, III, Professor of Ecology, Department of Biology and Wildlife, Institute of Arctic Biology, University of Alaska, Fairbanks, AK, Lead PI-Bonanza Creek LTER Program; 907-474-7922, terry.chapin@uaf.edu

Terry Chapin is Professor of Ecology in the Department of Biology and Wildlife at the University of Alaska Fairbanks, where he directs the Bonanza Creek Long-Term Ecological Research (LTER) Program and an interdisciplinary (IGERT) program in Resilience and Adaptation. He received his BA in biology at Swarthmore College in 1966 and my PhD in Biology at Stanford University in 1973. His research focuses on ecosystem ecology and on the resilience of social-ecological systems. His ecological research addresses the consequences of plant traits for ecosystem and global processes, particularly vegetation effects on nutrient cycling, fire regime, and biodiversity. He also studies vegetation-mediated feedbacks to high-latitude climate warming, as mediated by changes in water and energy exchange. His research on social-ecological systems emphasizes the resilience of northern regions to recent changes in climate and fire regime. This research entails studies of human and climatic effects on fire regime, the resulting effects on ecosystem services, wages, and cultural integrity, and the effects of local opinions about fire and national fire policy on the fire policies developed and implemented at regional scales. Most of his current research focuses on Alaska and eastern Siberia.

James E. Cloern, Senior Research Biologist, USGS National Research Program, Menlo Park, CA; 650-329-4594, jecloern@usgs.gov

James Cloern received BS and MS degrees in zoology from the University of Wisconsin and a PhD from Washington State University. He is a senior research scientist (ST3104) at the U.S. Geological Survey in Menlo Park, CA, where he has worked since 1976. Jim's research is focused on the ecology and biogeochemistry of estuaries and lakes, geared to understanding how they function as ecosystems. He leads a team investigation of San Francisco Bay that has included study of: primary production, algal and zooplankton community dynamics, ecosystem metabolism, the carbon budget, disturbance by introduced species, impacts of climatic/hydrologic variability, benthic and pelagic nutrient regeneration, use of stable isotopes and lipid biomarkers to characterize sources of organic matter, variability at time scales from hours to decades and spatial scales from centimeters to 100 kilometers. Jim has been a Fulbright Research Scholar, studying Mediterranean coastal ecosystems at the Centre d'Océanologie de Marseille while developing a serious appreciation for Cotes du Rhone. He has served on the editorial boards of *Limnology and Oceanography*, *Estuaries*, and *Oceanologica Acta*. He has mentored 11 postdoctoral scientists, served on thesis committees of 19 graduate students from 6 countries, is Consulting Professor in the Department of Civil Engineering at Stanford University, and has been Lecturer in the Earth Science Department at the University of California-Santa Cruz.

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Daniel Fagre is Research Ecologist and Global Change Research Coordinator for the Northern Rocky Mountain Science Center of the U. S. Geological Survey. He is stationed at Glacier National Park, Montana and is a faculty affiliate at the University of Montana, Montana State University, and several other universities. He's worked for the past 15 years with many staff, partners and collaborators in the Northern Rocky Mountains to understand how global-scale environmental changes will affect our mountain ecosystems. His diverse research programs have addressed glaciers, avalanches, amphibians, alpine plants, paleo-climates, snow chemistry and ecosystem dynamics of bioregions. He received his Ph.D. from the University of California, Davis, and has held positions in universities and several federal agencies. He helped establish the Western Mountain Initiative, a program to tie mountain science across different areas, and is active in several international science networks that address mountain issues. He co-authored a book on national parks and protected areas, published in 2005, and has another on a mountain ecosystem in press. He recently received the Director's Award for Natural Resource Research from the National Park Service.

Peter M. Groffman, Senior Scientist and Microbial Ecologist, Institute of Ecosystem Studies, Millbrook, NY, co-PI, Hubbard Brook LTER Program; 914-677-5343, groffmanp@ecostudies.org

Peter M. Groffman is a Senior Scientist at the Institute of Ecosystem Studies in Millbrook, NY; with research interests in ecosystem, landscape and microbial ecology, with a focus on carbon and nitrogen dynamics. He received his Ph.D in 1984 in Ecology

from the University of Georgia. Specific recent research efforts include investigation of; snow depth as a regulator of soil freezing and nitrogen dynamics; carbon and nitrogen cycling in urban watersheds and ecosystems, the effects of atmospheric nitrogen deposition on nitrogen gas fluxes, nitrate dynamics in riparian buffer zones, effects of a whole watershed calcium addition on soil nitrogen and carbon cycling, and the effects of exotic earthworm invasion on soil nitrogen and carbon cycling. Groffman was/is a member of the U.S. National Committee for Soil Science, the National Science Foundation Long Term Ecological Research Network Executive Board, the NOAA Gulf of Mexico Hypoxia Nutrient Reduction Workgroup and the Working Group on Aquatic Terrestrial Biogeochemistry at the National Center for Ecological Analysis and Synthesis. He was a lead author for the Second (Wetlands) and Third (North America) Assessment Reports of the Intergovernmental Program on Climate Change (IPCC). He currently serves on the editorial boards of *Ecology* and *Ecosystems*, and was chair of the Soil Ecology section of the Ecological Society of America from 1997 – 98 and the Wetland Soils Section of the Soil Science Society of America from 2002 - 2003.

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of climate change on aquatic ecosystem functioning and health, Journal of the American Water Resources Association 35:1373-1386)

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Dan Roby is currently the Assistant Unit Leader – Wildlife at the USGS - Oregon Cooperative Fish and Wildlife Research Unit and an Associate Professor of Wildlife Ecology in the Department of Fisheries and Wildlife at Oregon State University. He received a B.A. (Biology) from Antioch College (1974), a M.S. (Wildlife Management) from the University of Alaska (1978), and a Ph.D. (Biology) from the University of Pennsylvania (1986), where he worked under Robert E. Ricklefs on the relationship of diet to reproductive energetics in seabirds. In addition to his current position at Oregon State University, he has held faculty positions at Southern Illinois University – Carbondale (Assistant Professor of Zoology, 1988-1992) and the University of Alaska Fairbanks (Assistant Professor of Wildlife Ecology, 1992-1995). He has conducted research on the ecology of seabirds in Alaska, Hawaii, Greenland, Newfoundland, South Georgia, and Antarctica, as well as throughout the Pacific Northwest. His primary area of research interest is the physiological ecology and conservation biology of birds, with an emphasis on seabirds. His recent research includes impacts of avian predation on recovery of ESA-listed salmonids in the Columbia River Basin, bioenergetics of seabirds affected by the *Exxon Valdez* oil spill in Alaska, development of biomarkers of exposure to contaminants in birds, seabird/fisheries interactions, and effects of global warming on seabird populations at high latitudes, especially the Bering Sea. He served a Chair of the Pacific Seabird Group during 2004-2006.

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George Sugihara is a Professor for the Scripps Institution of Oceanography at the University of California San Diego. His research interests include complexity theory, catastrophic change in nonlinear systems, time series forecasting, food-web structure, species abundance patterns, conservation biology, landscape ecology, fisheries management and empirical climate modeling. Recently, George Sugihara lead an international team of ecologists, including Lord Robert May of Oxford University and Sir John Beddington of Imperial College to resolve a 30-year controversy showing that fishing increases the boom and bust behavior of fished stocks, thus putting fisheries at greater risk of collapse due to environmental change than anyone thought. The potential for catastrophic change in marine ecosystems was demonstrated quantitatively for the first time by Sugihara and his students a year earlier in their analysis of physical and biological data for the North Pacific basin over the 20th century. Both of these studies (supported by NOAA's Fisheries and The Environment program), appeared in *Nature Magazine*, and have been cited by Adm. Lautenbacher (Undersecretary of Commerce and Head of NOAA) as timely in view of current efforts to revise the Magnusson-Stevens Act for fisheries. Sugihara is currently a member of the NAS Board on Mathematical Sciences and its Applications, and is involved in an Academy report to the Federal Reserve System on "systemic risk in the financial sector" which among other things addresses the problem of market crashes (rapid transitions) as a generic property of complex systems.