4-2011

Research on Coupled Human and Natural Systems (CHANS): Approach, Challenges, and Strategies

Marina Alberti
University of Washington

Heidi Asbjornsen
University of New Hampshire, Durham

Lawrence A. Baker
University of Minnesota

Nicholas Brozović
The University of Illinois at Urbana-Champaign

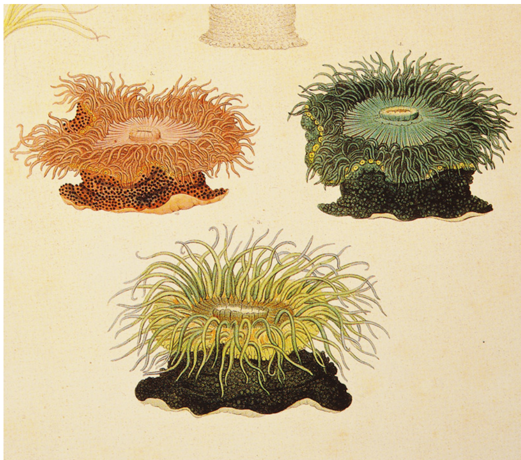
Laurie E. Drinkwater
Cornell University

See next page for additional authors

Citation Details

Marina Alberti, Heidi Asbjornsen, Lawrence A. Baker, Nicholas Brozovic, Laurie E. Drinkwater, Scott A. Drzyzga, Claire A. Jantz, José Fragoso, Daniel S. Holland, Timothy (Tim) A. Kohler, Jianguo (Jack) Liu, William J. McConnell, Herbert D. G. Maschner, James D. A. Millington, Michael Monticino, Guillermo Podestá, Robert Gilmore Pontius, Jr., Charles L. Redman, Nicholas J. Reo, David Sailor, and Gerald Urquhart 2011. Research on Coupled Human and Natural Systems (CHANS): Approach, Challenges, and Strategies. Bulletin of the Ecological Society of America 92:218–228.

Authors
Marina Alberti, Heidi Asbjornsen, Lawrence A. Baker, Nicholas Brozović, Laurie E. Drinkwater, Scott A. Drzyzga, Claire A. Jantz, José Fragoso, Daniel S. Holland, Timothy A. Kohler, Jianguo Liu, William J. McConnell, Herbert D. G. Maschner, James D. A. Millington, Michael Monticino, Guillermo Podestá, Robert Gilmore Pontius Jr., Charles L. Redman, Nicholas J. Reo, David J. Sailor, and Gerald Urquhart



Meeting Reports

Research on Coupled Human and Natural Systems (CHANS): Approach, Challenges, and Strategies

A symposium on Complexity in Human–Nature Interactions across Landscapes held at the 2009 meeting of the U.S. Regional Association of the International Association for Landscape Ecology in Snowbird, Utah.

William J. McConnell, James D.A. Millington, Nicholas J. Reo, Marina Alberti, Heidi Asbjornsen, Lawrence A. Baker, Nicholas Brozović, Laurie E. Drinkwater, Scott A. Drzyzga, José Fragoso, Daniel S. Holland, Claire A. Jantz, Timothy A. Kohler, Herbert D. G. Maschner, Michael Monticino, Guillermo Podestá, Robert Gilmore Pontius, Jr., Charles L. Redman, David Sailor, Gerald Urquhart, and Jianguo Liu (see end of article for the authors'affiliations).

Understanding the complexity of human–nature interactions is central to the quest for both human well-being and global sustainability. To build an understanding of these interactions, scientists, planners, resource managers, policy makers, and communities increasingly are collaborating across wide-ranging disciplines and knowledge domains. Scientists and others are generating new integrated knowledge on top of their requisite specialized knowledge to understand complex systems in order to solve pressing environmental and social problems (e.g., Carpenter et al. 2009). One approach to this sort of integration, bringing together detailed knowledge of various disciplines (e.g., social, economic, biological, and geophysical), has become known as the study of Coupled Human and Natural Systems, or CHANS (Liu et al. 2007*a*, *b*).

In 2007 a formal standing program in *Dynamics of Coupled Natural and Human Systems* was created by the U.S. National Science Foundation. Recently, the program supported the launch of an International Network of Research on Coupled Human and Natural Systems (CHANS-Net.org). A major kick-off event of the network was a symposium on Complexity in Human–Nature Interactions across Landscapes, which brought together leading CHANS scientists at the 2009 meeting of the U.S. Regional Association of the International Association for Landscape Ecology in Snowbird, Utah. The symposium highlighted original and innovative research emphasizing reciprocal interactions between human and natural systems at multiple spatial, temporal, and organizational scales. The presentations can be found at ‹http://chans-net.org/Symposium_2009.aspx›. The symposium was accompanied by a workshop on Challenges and Opportunities in CHANS Research. This article provides an overview of the CHANS approach, outlines the primary challenges facing the CHANS research community, and discusses potential strategies to meet these challenges, based upon the presentations and discussions among participants at the Snowbird meeting.

What is the CHANS approach?

The CHANS approach builds on a long tradition of scholarship on human–nature interactions, and CHANS scholars may equally find themselves at home in research communities addressing human–environment systems, social–ecological systems, ecological–economic systems, or population–environment systems. What distinguishes the CHANS approach is an explicit acknowledgement that human and natural systems are coupled via reciprocal interactions, understood as flows (e.g., of material, energy, and information). Of particular interest in studying these interactions is the understanding of feedbacks, surprises, nonlinearities, thresholds, time lags, legacy effects, path dependence and emergence (Liu et al. 2007*a*) across multiple spatial, temporal and organizational scales. Strategically, the CHANS approach seeks understanding of such complexity through the integration of knowledge of constituent subsystems and their interactions. Operationally, this involves linking submodels to create *coupled* models capable of representing human (e.g., economic, social) and natural (e.g., hydrologic, atmospheric, biological) subsystems and, most importantly, the interactions among them.

The integration of knowledge from multiple disciplines implied by this strategy is essential for understanding such systems, but is quite challenging (Baker 2006, Baerwald 2009). Most fundamentally, researchers coming from social *versus* natural science perspectives are trained with different sampling approaches, with different units and methods of analysis, and different perspectives on the goals of science (Geertz 1973, Lélé and Norgaard 2005). Moreover, just what counts as a "model" varies considerably across disciplines and projects, and might include, inter alia: conceptual diagrams that map out relationships and processes among system components, graphical and analytical models, numerical models with hypothetical or empirically derived parameters, or computer simulations, including agent-based models (see Fig. 1). Despite this wide and seemingly disparate range of modeling approaches, the presentations at the Snowbird meeting demonstrated that relatively abstract conceptual frameworks of the system(s) under investigation, alternatively known as box-and-arrow, or spider, diagrams, are ubiquitous. These frameworks facilitate communication, not only within project teams, but with other scientists and with project stakeholders. CHANS scientists use these diagrams somewhat apologetically, recognizing that they grossly oversimplify the complexity of the systems they study. Yet the diagrams are useful in identifying the crucial system components and flows, and the consequences of linkages between subsystems, as well as in facilitating communications among collaborators and others. The construction of a shared conceptual model is an essential step in collaborative, interdisciplinary research (Heemskerk et al. 2003). Although sometimes overlooked, these are far from trivial issues, and the development of stylized integrative models is often an initial step in quantifying complex interactions.

It is important to note that a research strategy based on the coupling of subsystems may be less a reflection of researchers' views of the world than a temporary accommodation for the sake of analytical

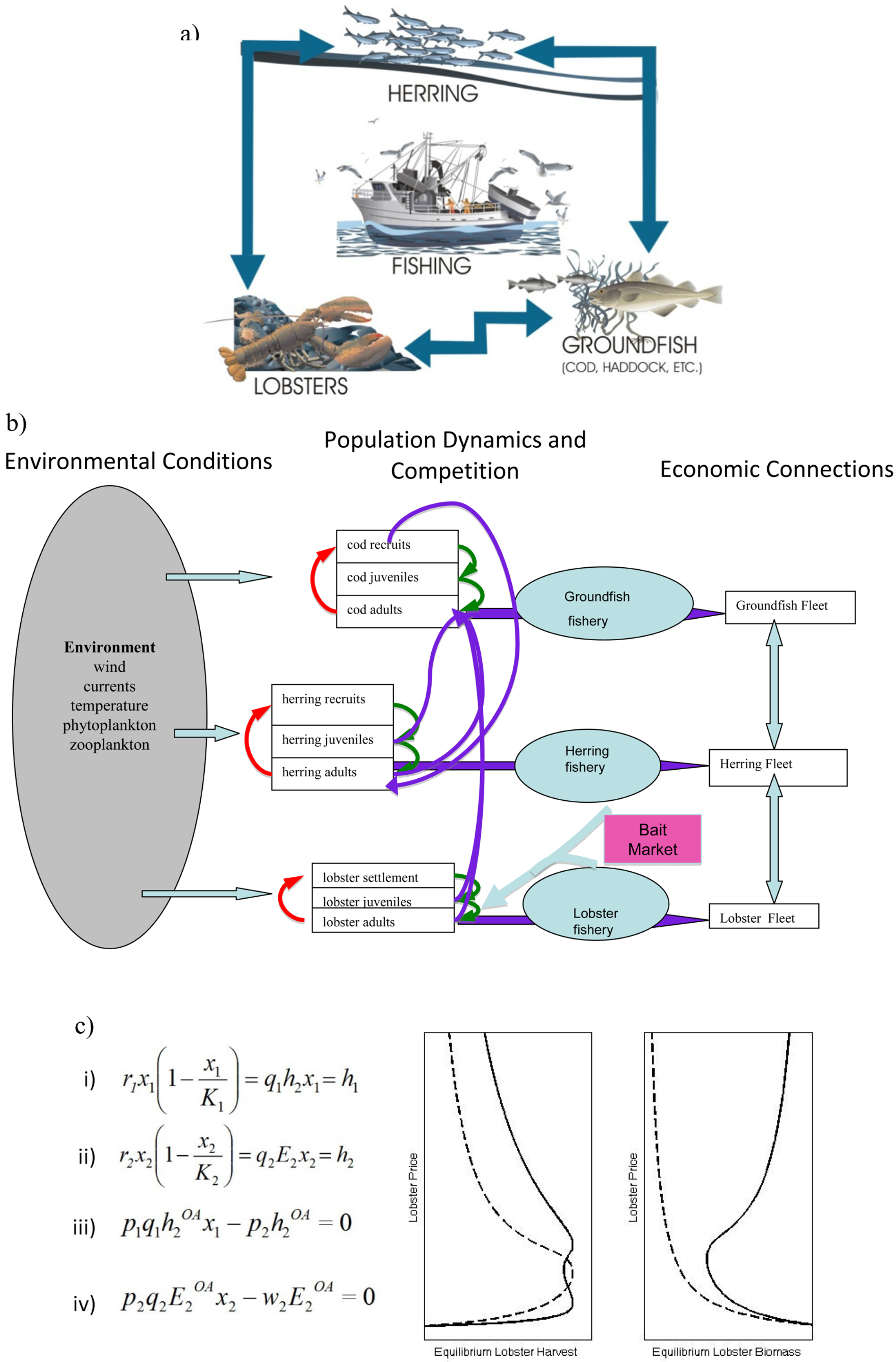

a)
HERRING
FISHING
LOBSTERS
GROUNDFISH
(COD, HADDOCK, ETC.)
b)
Environmental Conditions
Population Dynamics and Competition
Economic Connections
Environment
wind
currents
temperature
phytoplankton
zooplankton
cod recruits
cod juveniles
cod adults
herring recruits
herring juveniles
herring adults
lobster settlement
lobster juveniles
lobster adults
Groundfish fishery
Herring fishery
Lobster fishery
Bait Market
Groundfish Fleet
Herring Fleet
Lobster Fleet
c)
i) $r_1 x_1\left(1-\frac{x_1}{K_1}\right)=q_1 h_2 x_1=h_1$
ii) $r_2 x_2\left(1-\frac{x_2}{K_2}\right)=q_2 E_2 x_2=h_2$
iii) $p_1 q_1 h_2^{OA} x_1 - p_2 h_2^{OA} = 0$
iv) $p_2 q_2 E_2^{OA} x_2 - w_2 E_2^{OA} = 0$
Lobster Price
Equilibrium Lobster Harvest
Lobster Price
Equilibrium Lobster Biomass

Fig. 1. Coupled human and natural system models at different levels of detail are useful for different purposes. This example has three levels of detail. At the most simplified level an illustrative diagram (a) shows general linkages in the system of three interdependent fisheries in the Gulf of Maine. A model at this level of detail is useful for facilitating discussion about the structure of the system and the particular components and linkages under investigation. These discussions can foster the development of models at an intermediate level of detail (b), which are useful to help specify linkages in more detail and focus research on important processes. In this particular case the intermediate model highlights the importance of environmental conditions on the early life history of fish and their population dynamics, shows predator–prey relationships between fish species, and indicates that the reliance of lobster fishermen on herring for bait and the movement of capital and labor between fisheries must also be considered. Intermediate levels of detail facilitate the conceptualization of the structure and parameters required for a more detailed level which uses mathematical models of the system (c) (Ryan et al. 2010). Equations specify relationships between lobster harvest, biomass, and price. Graphical plots present the results of the equations for a given range of system parameters. For example, the solid curves in the plots of Fig. 1c show the equilibrium open-access levels of lobster harvest (h_1) and biomass (x_1) under the constraints of the supply of bait from a second fishery (h_2) (i.e. the curves are the solutions to the Eqs. i – iv at left for various lobster prices, p_1 and p_2). The dashed curves in the panels are the solutions for the respective open-access harvest and biomass relationships for a fishery that is not constrained by the supply of bait from a second fishery. In the unconstrained model, lobster biomass eventually shrinks with increase in lobster price. In the constrained model, lobster biomass first declines and subsequently rises with lobster price, as the demand for bait reduces bait population, thereby limiting effort and catch in the lobster fishery. These three models (a, b, c) of the same system (in this case a fishery) at different levels of detail have proven useful to improve understanding and communication between researchers, stakeholders, and communities.

tractability. One of the key questions raised in the Snowbird discussions concerned the different ways in which the role of humans in ecosystems can be conceived (e.g., humans as invaders, humans as disrupters, humans as managers, humans as components). Various research team members and inhabitants of the systems being studied may have differing worldviews (i.e., the way they describe the world, what it is to be human in that world, and the role humans play in that world [Cordova 2007]). Differences in worldview may become a contentious issue; however, these differences can become a significant asset whereby multiple perspectives on basic system configuration help build robust alternative hypotheses or understandings of complex issues. Participatory research approaches (e.g., cooperating in research with a range of stakeholders) can help to ensure that diverse worldviews are valued rather than ignored or treated as obstacles to positive project outcomes.

Issues of stakeholder engagement and participatory research arose in the workshop discussions because CHANS research tends to be characterized by a strong emphasis on addressing real-world problems. It would be unfair, however, to characterize CHANS research as purely applied. In fact, one of the first questions that arose in the Snowbird workshop concerned a possible dichotomy between abstract and contextualized CHANS research. Participants suggested that it may be best to understand CHANS research as occupying Pasteur's quadrant (Fig. 2) where the focus is on "useful" research. Judgment of the broad utility of research projects is generally conferred by evaluation of funding proposals and research manuscripts, with some agencies (e.g., U.S. National Science Foundation) requiring that proposals explicitly address the "broader impacts" of the proposed research. Scientists also take cues on the utility of their work from society, including study area residents who can provide contextualized feedback and local perspectives, and who may adopt tools, frameworks, and other research products.

Many CHANS projects have carefully crafted approaches for engaging with stakeholders and communities. Elements of this engaged scholarship occur at various project phases including, but not limited to, initial framing of research projects and proposals, project guidance (e.g., through stakeholder steering groups composed of resource managers, indigenous peoples, farmers) and co-authoring publications with local contributors. Stakeholders can also engage directly in model construction and evaluation. For example, one participatory modeling approach asks stakeholders to "co-construct" models using intensive interactive methods such as role-playing games (e.g., the companion modeling approach

Quest for fundamental understanding?	**Yes**	Pure basic research (**Bohr**)	Use-inspired basic research (**Pasteur**)
	No	"Soaking and poking"	Pure applied research (**Edison**)
		No	**Yes**
		Considerations of use	

Fig. 2. Pasteur's Quadrant (Clark 2007, after Stokes 1997)

of Castella et al. [2005]). Conventional means of evaluating quantitative models (e.g., comparison of empirical and predicted system states) can be complemented by participatory approaches that intend to improve model credibility by consulting the stakeholders that the model presumes to represent (e.g., Millington et al., *in press*). Participatory approaches like these are not intended to replace conventional model validation approaches, but instead are complementary and should help overcome problems of non-uniqueness, or underdetermination (Oreskes et al. 1994). Conventional validation approaches cannot be ignored, but empirical model validation must be interpreted properly and in a useful manner (Pontius et al. 2008).

Challenges and strategies

CHANS scientists are confronted with two major sets of concerns of a practical nature. One arises from the incentive structure of highly disciplinary academic institutions, while the other involves the composition and management of research teams and integration of the work done by team members from different disciplines.

The number of early-career scholars taking CHANS approaches to address social and ecological issues is growing. However, the interdisciplinary nature of CHANS research poses unique challenges to pre-tenure faculty, who are naturally and appropriately focused on looming tenure-and-promotion decisions. Those decisions generally hinge on criteria that prize sole or first-author publications in top disciplinary journals and leadership roles (e.g., principal investigator) on large research grants. Most tenured faculty members, let alone those in earlier career stages, are ill-equipped for the complex tasks involved in brokering and leading broad-based interdisciplinary research teams. These teams must bridge departmental, disciplinary and cultural boundaries to be successful. Joining such teams as a co-principal investigator may be rewarding in many respects, but existing tenure and promotion processes often provide strong disincentives to such an undertaking. Consequently, some participants in the Snowbird discussions suggested that the conduct of such interdisciplinary work may best be left to more senior colleagues who may face less rigid measures of performance than junior faculty. Other participants, however, were determined that this would be a mistake, as junior faculty are usually more open to new ideas and more driven to apply them than their more seasoned colleagues, and outdated incentive structures are in urgent need of modernization.

Graduate students and junior faculty interested in engaging in CHANS research would be well advised to recognize that the choice of department and university is crucial because the level of support and rewards for interdisciplinarity varies widely among institutions. To evaluate universities' and departments' interdisciplinary proclivities, those seeking tenure-track positions should use the interview process as an opportunity to gather information by speaking directly to higher administrators and faculty from all the relevant (not just the hiring) departments about support for interdisciplinary work. Candidates should be aware that while administrators may express interest in interdisciplinary science because of increasing funding support for such work, institution-specific incentive structures may not recognize the co-PI roles and multiple-author publications that often emerge from CHANS projects, and may, in effect, penalize co-PIs for the additional time required to produce interdisciplinary manuscripts. Asking faculty and administrators about their knowledge of, and level of interaction with, scholars from other departments can provide insight about the interdisciplinarity of an institution. Prospective faculty members should scrutinize the actual research of department faculty for examples of interdisciplinary scholarship.

Likewise, there are concerns about the role of graduate students in CHANS projects, as in related interdisciplinary activities (Rhoten and Parker 2004). Opinions in the CHANS community appear to be divided on whether it is appropriate to involve students in the synthesis portions of research, or if it is perhaps better to have them focus on disciplinary contributions to satisfy their graduate committees or external examiners and better position themselves for more traditional tenure-track opportunities. Important considerations may include the topic of investigation, the time and resources required to implement the research, and the capabilities, interests, and future career goals of the particular student. In some cases, a highly interdisciplinary CHANS-oriented thesis may be both appropriate and desirable, whereas in others, a more traditional single-discipline approach would serve the student best. In the latter case, students may still gain valuable CHANS experience and skills by participating and interacting with CHANS research teams, even where their own research focus may be more narrow.

A related set of issues concerns the composition and management of interdisciplinary teams and integration of their work. There is consensus that the best projects are characterized by good communication. Researchers, as teams, have to learn how to listen to each other and, as individuals, have to learn how to discuss their work in ways that others outside their field can easily comprehend. These skills will help scholars to build large and diverse networks of colleagues and potential collaborators, as is occurring now within CHANS-Net. Importantly, these same communication skills also help CHANS scholars craft research questions that are clear and understandable across disciplinary boundaries, which in turn helps with writing fundable proposals (see Box 1). Scholars working in interdisciplinary research teams have to gain fundamental knowledge about one another's disciplines. Reading summary papers is a useful entrée into the core concepts and methods of an alien discipline. But it is also critical to learn about the culture and norms of collaborators' disciplines (Boulton et al. 2005), including typical expectations about the rewards, outcomes, authorship conventions, and funding agency requirements. These seemingly peripheral tasks are in fact vital to the success of interdisciplinary research, but take time to complete successfully. We suggest that collaborators seeking to initiate CHANS projects engage in a discussion of these differences among cultures during the proposal stage.

In general, the participants concurred that it takes longer to develop multidisciplinary projects than in traditional single-disciplinary research, and longer to produce publications, but CHANS research may ultimately lead to more productivity than traditional research. Equally important, by helping unravel the myriad interactions and feedbacks that typically characterize the many complex issues facing society today, CHANS projects often allow for the discovery of new knowledge and applications that are of tremendous value to society, and which otherwise would not have been possible with more traditional disciplinary approaches.

In order to gather more systematic information about the backgrounds, motivations, and experiences of interdisciplinary researchers, and the factors promoting or inhibiting fruitful interdisciplinary research, a confidential online survey is currently being conducted ‹http://survey.forestry.oregonstate.edu/chans›.

Box 1. Keys to launching effective CHANS research projects.

Identify the goals and final products of the project

- Goals and products could include answers to scientific questions, hypothesis testing, a simulation model or decision-support tool, policy or management recommendations, or education.
- Identify and articulate analysis boundaries and scales of interest: spatially, temporally, and in terms of physical processes.
- A preliminary conceptual model may help initiate discussion among potential collaborators; the conceptual model need not be correct in what it is illustrating, but rather serve to "break the ice" and generate discussion.

Build a team around the identified goals and products

- Identify project manager(s) and submanagers, where the submanagers may be discipline specific and responsible for a particular component of the project.
- It may also be beneficial to assign to one person responsibility for overseeing and maintaining the project timeline. It might be advantageous for this person not to be a manager or submanager to minimize potential conflicts.

Once the team is together, reexamine the initial goals and final products

- Methods necessary to accomplish project goals and products should now be developed.
- It is important to recognize that the final products may change in response to the project team's vision and analysis. Team members must be prepared to be flexible, to reevaluate the project's conceptual framework and methods as a partnership matures.
- Potential challenges of complexity and uncertainty should be discussed at this point; where in the project may they later manifest themselves? How may they be overcome?
- Each team member should be recognized as "a tool in a toolbox," each providing a unique contribution that works in tandem with the other tools (e.g., the compass and ruler) to build the entire project.

Concluding remarks

CHANS researchers are contributing to a transition in the broader scientific community. Scientists are moving from ignoring connections between worldview and scientific inquiry to seeking diverse research partnerships that capitalize on different perspectives and approaches. This move accompanies a shift from a time when all scientific understanding of human–environment interactions was built through piecemeal disciplinary inquiry, toward a time when both disciplinary specialization and integrated study of holistic systems are valued. CHANS research, and even possibly the use of the term CHANS, can facilitate this transition by challenging scientists, policy makers, and resource managers to conceptualize reciprocal interactions between humans and natural systems explicitly.

The growing participation in CHANS-Net attests to the dynamism of the field, and future work will no doubt extend to other kinds of systems around the world, incorporating broader sets of components and interactions, and questions of profound relevance for sustainability. We expect this will inevitably lead to a need for an ever-broader array of expertise. Among the fields under-represented currently are environmental psychology, political science and public policy, engineering and landscape architecture, economics, and the humanities in general (e.g., history). Engaging such communities of scholars is an important target for the coming years if research in this area is to have more practical impact on the issues it addresses.

Increasing the range of expertise will inevitably magnify the challenge of communicating across disciplines. Effective communication requires a shared language, and CHANS scientists currently use what has been characterized as a trading, or pidgin, language (Baerwald 2009). The conceptual diagrams in widespread use today (e.g., Fig. 1b) are part of this pidgin, borrowing from disciplinary terminology and understandings, with the result that couplings between subsystems may sometimes be represented in ways that appear rather crudely "bolted together." Another important target, then, is the transformation of this pidgin into the equivalent of a creole language, with a coherent grammar and syntax capable of supporting more sophisticated representations of the coupling of subsystems and comparative analysis across research sites. This transformation will also facilitate improved communication with stakeholders outside the academy. Successful integrated inquiry based on broader engagement within and outside the academy using shared languages will depend in large part on continued support for CHANS scientists from their academic institutions, their peer communities, and from nonacademic research partners.

The CHANS approach is emerging from its infancy, characterized by the use of rudimentary language skills in describing deeply complex systems. With proper support, it stands to contribute to a better understanding of the multifaceted interactions between human and natural systems, and thus inform societal choices in pursuit of sustainability.

Acknowledgments

The CHANS Symposium and Workshop at the 2009 meeting of the U.S. Regional Association of the International Association for Landscape Ecology were supported by a grant from the National Science Foundation to the Center for Systems Integration and Sustainability at Michigan State University for the establishment of the International Network of Research on Coupled Human and Natural Systems (CHANS-Net.org). We thank Tom Baerwald and many other participants at the symposium and workshop for their insightful presentations and useful discussion. The authors have all received individual research support from the NSF Dynamics of Coupled Natural and Human Systems program and/or its precursor, the special competition in Biocomplexity in the Environment.

Literature cited

Baerwald, T. 2009. Facilitating the conduct of naturally humane and humanely natural research. Keynote address to the Annual Meeting of the U.S. Regional Association of the International Association of Landscape Ecology, 12 April 2009.

Baker, L. 2006. Perils and pleasures of multidisciplinary research. Urban Ecosystems 9:45–47.

Boulton, Andrew J., Debra Panizzon, and Julian Prior. 2005. Explicit knowledge structures as a tool for overcoming obstacles to interdisciplinary research. Conservation Biology 19(6):2026–2029.

Carpenter, S. R., et al. 2009. Accelerate synthesis in ecology and environmental sciences. BioScience 59(8):699–701.

Castella, J. C., T. N. Trung, and S. Boissau. 2005: Participatory simulation of land-use changes in the northern mountains of Vietnam: the combined use of an agent-based model, a role-playing game, and a geographic information system. Ecology and Society 10(1):27.

Clark, W. C. 2007. Sustainability science: a room of its own. Proceedings of the National Academy of Sciences USA 104(6):1737–1738.

Cordova, V.F. 2007. Matrix: a context for thought. *In* K. D. Moor, K. Peters, T. Jojola and A. Lacy, editors. How it is: the Native American philosophy of V. F. Cordova. University of Arizona Press, Tucson, Arizona, USA.

Geertz, C. 1973. Thick description: toward an interpretive theory of culture. *In* The interpretation of cultures: selected essays. Basic Books, New York, New York, USA.

Heemskerk, M., K. Wilson, and M. Pavao-Zuckerman. 2003. Conceptual models as tools for communication across disciplines. Conservation Ecology 7(3):8.

Lélé, S., and R. B. Norgaard. 2005. Practicing interdisciplinarity. BioScience 55(11):967–975

Liu, J., et al. 2007*a*. Coupled human and natural systems. Ambio 36:639–649.

Liu, J., et al. 2007*b*. Complexity of coupled human and natural systems. Science 317(5844):1513–1516.

Oreskes, N., K. Schrader-Frechette, and K. Belitz. 1994. Verification, validation and confirmation of numerical models in the earth sciences. Science 263(5147):641–646.

Millington, J. D. A., D. Demeritt, and R. Romero-Cancerrada. *In press.* Participatory evaluation of agent-based land use models. Journal of Land Use Science 6(2) [doi: 10.1080/1747423X.2011.558595].

National Science Foundation. 2008. Dynamics of coupled natural and human systems (CNH) program solicitation NSF 07-598. ‹http://www.nsf.gov/funding/ pgm_summ.jsp?pims_id=13681›

Pontius, R. G., Jr., et al. 2008. Comparing the input, output, and validation maps for several models of land change. Annals of Regional Science 42(1):11–47.

Rhoten, D., and A. Parker. 2004. Risks and rewards of an interdisciplinary research path. Science 306(5704):2046. [doi: 10.1126/science.1103628].

Ryan, R. W., D. S. Holland, and G. Herrera. 2010. Bioeconomic equilibrium in a bait-constrained fishery. Marine Resource Economics 25(3):281–293.

Stokes, D. E. 1997. Pasteur's quadrant: basic science and technological innovation. Brookings Institution, Washington, D.C., USA.

Authors' affiliations

Marina Alberti is with the Department of Urban Design and Planning, College of Built Environments at the University of Washington.

Heidi Asbjornsen is with the Department of Natural Resources and the Environment at the University of New Hampshire at Durham; formerly with the Department of Natural Resource Ecology and Management at Iowa State University.

Lawrence A. Baker is with the Minnesota Water Resources Center at the University of Minnesota and WaterThink, LLC.

Nicholas Brozović is with the Department of Agricultural and Consumer Economics at the University of Illinois at Urbana-Champaign.

Laurie E. Drinkwater is with the Department of Horticulture at Cornell University.

Scott A. Drzyzga and Claire A. Jantz are with the Department of Geography and Earth Science at Shippensburg University.

José Fragoso is with the Department of Biology at Stanford University.

Daniel S. Holland is with the Conservation Biology Division of the Northwest Fisheries Science Center in Seattle.

Timothy (Tim) A. Kohler is with the Department of Anthropology at Washington State University and the Santa Fe Institute in New Mexico.

Jianguo (Jack) Liu and William J. McConnell are with the Center for Systems Integration and Sustainability at Michigan State University.

Herbert D. G. Maschner is with the Idaho Museum of Natural History, and the Department of Anthropology, and the Center for Archaeology, Materials, and Applied Spectroscopy at Idaho State University.

James D. A. Millington is with Department of Geography at King's College London

Michael Monticino is with the Mathematics Department and the Institute of Applied Sciences at the University of North Texas.

Guillermo Podestá is with the Rosenstiel School of Marine and Atmospheric Science of the University of Miami.

Robert Gilmore Pontius, Jr. is with the Graduate School of Geography at Clark University.

Charles L. Redman is with the School of Sustainability at Arizona State University.

Nicholas J. Reo is with the School of Natural Resources and Environment at the University of Michigan.

David Sailor is with the Maseeh College of Engineering and Computer Science at Portland State University.

Gerald Urquhart is with Lyman Briggs College and the Department of Fisheries and Wildlife at Michigan State University.