Workshop Report

October 3-6, 2003

Catalina, CA

Sponsored by the National Science Foundation Biocomplexity in the Environment Program through DEB 0119960 to Whitman College, C.S. Weiler, P.I.

Photo Credits and explanations

Human activity is represented by a composite satellite image “The Earth at Night”. The composite image was developed by Gene C. Feldman, NASA, and W.T. Sullivan, III, University of Washington (copyright 1985) from satellite photographs made by the Defense Meteorological Satellite Program of the U.S. Air Force. The colors depict sources of carbon dioxide emissions: White, City lights; Red, forest and agricultural fires; Yellow, gas flares.

The excitement of new professionals engaged in interdisciplinary work is illustrated in photographs from the DISCCRS and DIALOG symposia organized by C. Susan Weiler. Six DIALOG symposia were held between 1993 - 2004, at the Bermuda Biological Station for Research and in Guanica, Puerto Rico. The 2003 DISCCRS symposium was held in Guanica, Puerto Rico. Photo captions reflect the October 3-6, 2003 Workshop recommendations.

Meeting the Needs of Interdisciplinary Ph.D. Graduates in a Changing Global Environment

Workshop Report
October 3-6, 2003
Catalina, CA

For the purposes of citation, please use:

Weiler, C.S. and the Workshop Participants. (2004).
Meeting the Needs of interdisciplinary Ph.D. Graduates
in a Changing Global Environment.
Report from an October, 2003 Workshop. 20 pp.

Copies of this document are available from:

C. Susan Weiler
Biology Department
Whitman College
Walla Walla, WA 99362
509-527-5948
weiler@whitman.edu
or from
http://marcus.whitman.edu/~weilercs/biocomplexity/

Foreword

There is only one way to begin this report: by thanking the National Science Foundation (NSF) for creating the Biocomplexity in the Environment (BE) Program. We all build on the work of others, and individuals and institutions have been striving to develop a framework for interdisciplinary activities for some time. It has not been an easy process. The BE initiative has provided a powerful catalyst for such endeavors. I especially thank Penelope Firth in the Division of Environmental Biology for nurturing the idea of holding a workshop to develop recommendations to enhance interdisciplinary understanding and networking among recent Ph.D. graduates. The original goal was to develop a program for Ph.D. graduates engaged in work at the land-water interface (LWI). The scope later expanded to include climate change and impacts (CC). By the time the LWI/CC workshop was held, the NSF Advisory Committee for Environmental Research and Education had issued its 10-year outlook on complex environmental systems. While the LWI/CC workshop participants were drawn from those two areas, the recommendations are robust and fit nicely in the broader context of complex environmental systems.

When one looks at funded BE projects, it should be no surprise that oceanographic projects are well represented. Marine stations and oceanographic research vessels have traditionally served as nodes for interdisciplinary scientific activities, providing a natural way to initiate and solidify lifelong interdisciplinary collegial interactions and friendships. The development of this workshop provides a perfect example of interdisciplinary communications in action over time. In 1984, I met Anthony F. Michaels on a research cruise when he was a student at the University of California at Santa Cruz and I was becoming established at Whitman College. In 2002, nearly two decades after we met, I needed to locate a social scientist to serve as mentor for a group of recent Ph.D. graduates engaged in climate-change research. Tony was then immersed in interdisciplinary work as Director for the University of Southern California's Wrigley Institute for Environmental Studies. I knew I could trust his recommendations for a social scientist with a solid interest in environmental issues and with the interpersonal skills to be a good mentor. Tony led me to Ronald B. Mitchell, a political scientist at the University of Oregon. A rapport quickly developed and Ron went on to serve as a mentor for the 2003 Dissertations Initiative for the Advancement of Climate Change Research (DISCCRS) symposium. We are now collaborating on a new proposal. With this established interdisciplinary relationship, it was natural to invite both Ron and Tony to co-organize the LWI/CC workshop. The result was more than I could ever have accomplished alone.

We often hear about the funding and institutional barriers to interdisciplinary work, which can be daunting at times. But the rewards of these efforts are enormous — partly because the work is so important, but also because it is just plain fun to do collaborative work when you both respect and enjoy the people you are working with. There can be no greater pleasure.

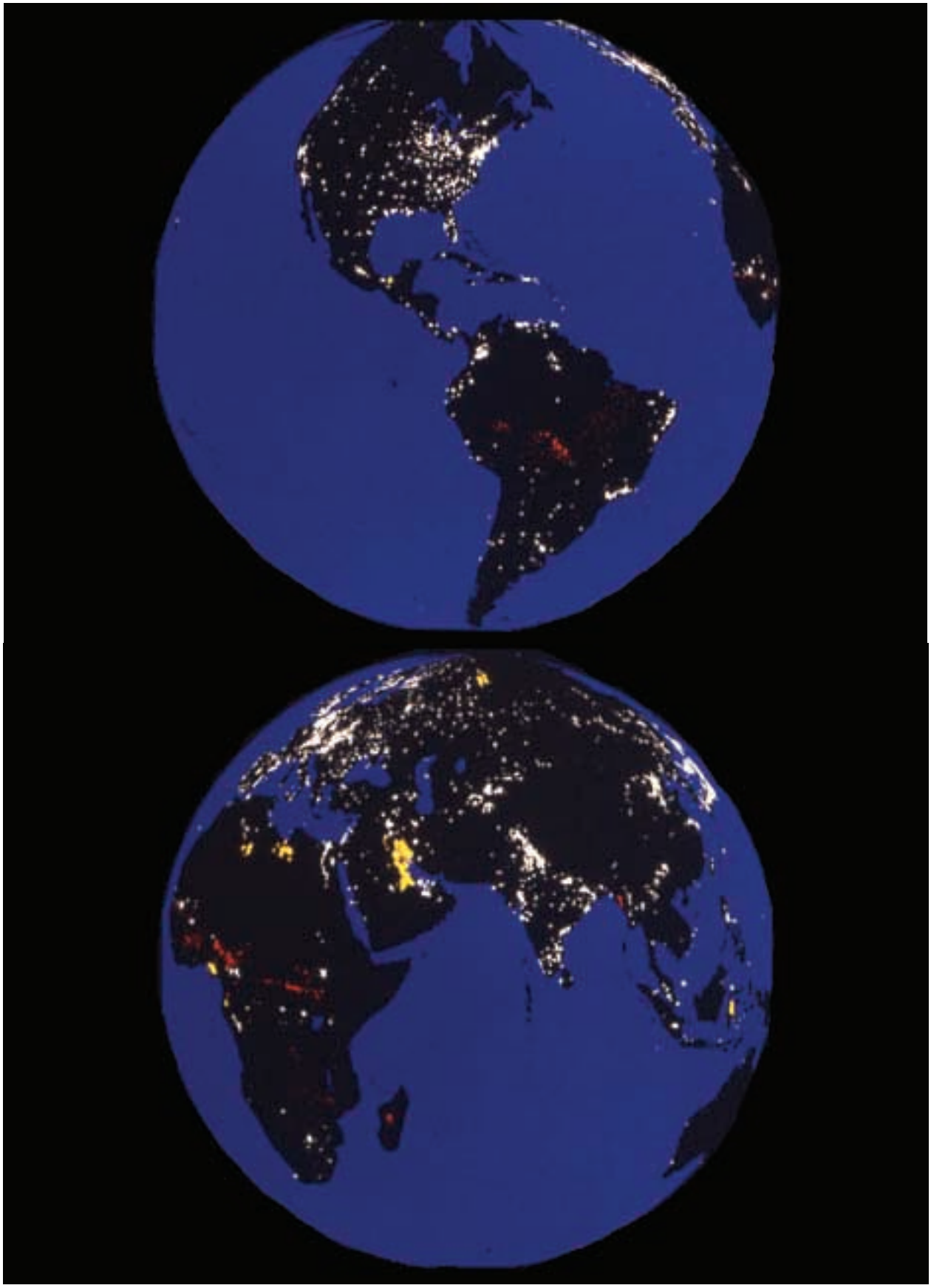
Collegial ties occur quickly and strongly through intensive interactions in a natural environment removed from the day-to-day cares of the world. The Wrigley Marine Science Center on Catalina Island was a perfect setting for this Workshop, and the staff handled the on-site logistics flawlessly. I thank the Wrigley Institute for partially defraying the participant support costs. This enabled us to include more people than we could otherwise have supported.

Tony, Ron, and I were able to assemble a truly remarkable group of recent Ph.D. graduates and established professionals dedicated to improving the career trajectories of recent graduates embarking on interdisciplinary careers. The recommendations simply could not have occurred without the enthusiasm of, and synergy created by, the 39 Workshop participants (see pp. 8-9 for their names and contact information). On behalf of the emerging professionals who will benefit from their insights, I thank them all for sharing their time and ideas so generously.

C. Susan Weiler
Whitman College
February 2004

Table of Contents

Interdisciplinary graduates should practice communication skills to ensure their work is understandable across disciplinary boundaries.



Earth at Night

City lights

Forest and Agricultural Fires

Gas flares

Meeting the Needs of Interdisciplinary Ph.D. Graduates in a Changing Global Environment

Introduction

Obtaining a Ph.D. degree requires extraordinary depth of training, but post-doctoral success in one's discipline is not enough to solve global environmental problems. Whether caused by human or natural forces, global change demands a level of understanding that exceeds the lifework of any single Ph.D. graduate. This level of problem solving requires an understanding of multiple complex interactions and feedbacks between physical, chemical, geological, and biological processes in the atmosphere, ocean, and earth. Insights from human ecology, economics, sociology, political science, other social sciences, and the humanities must also be fully integrated if we are to understand systems and reverse or mitigate impacts (Lubchenco, 1998). Despite advances in technology and unprecedented knowledge, understanding of complex environmental systems (Pfirman et. al., 2003) is limited and the ability to synthesize across disciplines is rudimentary at best. Our ability to make informed decisions is consequently limited. We must improve our ability to conduct multidisciplinary and interdisciplinary research; both depth and breadth are needed.

The terms "multidisciplinary" and "interdisciplinary" have been defined various ways, depending on the user and the context. The definitions of Schneider et al. (1995) are used throughout this report:

> *Multidisciplinary* refers to knowledge from multiple disciplines derived from disciplinary methods, practices and paradigms, independent of problems such as global change.
>
> *Interdisciplinary* is used to denote integration of knowledge from multiple disciplines combined in an original synthesis, in order to explain the behaviour of a complex system or to address a problem of practical significance.

If society is to understand and resolve these complex environmental transformations, today's graduates must form global alliances that traverse traditional disciplinary boundaries, and even learn to speak multiple disciplinary languages to effectively collaborate with other experts and scientists. Strong collaborations and contacts outside one's specialty and across institutional and geographic boundaries are desperately needed. While difficult to accomplish, interdisciplinary interactions often lead to new breakthroughs, insights, and paths of inquiry Success in transcending these boundaries could therefore return enormous benefits to society through rapid advances in knowledge.

How can new professionals be prepared for the kind of interactions required to understand global environmental changes, mitigate impacts, and build resilience in the face of change? The workshop described in this report was convened to address this question.

While change is needed at all educational levels, this workshop focused specifically on the needs of recent Ph.D. graduates engaged in work related to climate change and impacts or issues at the land-water interface. The 39 participants included recent Ph.D. recipients, through established professionals nearing retirement. Most were from academia though several represented alternate careers. Leaders of scientific societies and integrative leadership programs also participated.

Leadership training is needed at all professional levels to address the specific needs of different populations such as recent graduates, pre-tenure/early professionals, and tenured/established professionals. Many excellent programs exist, but more are currently needed and the demand is likely to intensify due to the increasing focus on complex environmental systems (Pfirman et al. 2003). Financial resources are likely to constrain program scope. The October 2003 workshop consequently focused on real-world low-cost solutions that could be distributed electronically and through a brief (one week) meeting, rather than an 'ideal' program. The recommendations, if followed, would serve to jump-start interdisciplinary careers and prepare graduates for more advanced and resource- and time-intensive leadership programs such as the ones represented at the October, 2003 workshop.

The charge to the Workshop participants was to develop recommendations for bringing together Ph.D. graduates across the natural and social sciences, humanities, mathematics and engineering with an interest in transcending the traditional disciplinary boundaries to understand environmental change and address impacts. Prior to the Workshop, each participant was invited to suggest at least one possible program element. These were compiled (pp. 10-14) and distributed before the meeting to facilitate on-site interactions.

Workshop Overview

The Workshop began Friday evening with a welcome and introductions. Saturday included overviews of the various leadership programs represented at the meeting (Aldo Leopold Leadership Program, Dissertations Initiative for the Advancement of Limnology and Oceanography (DIALOG), Dissertations Initiative for the Advancement of Climate Change Research (DISCCRS), Donella Meadows Leadership Fellows Program, Ford Foundation Fellowships For Minorities Program, Inter-American Institute for Global Change Research (IAI)/ University of Miami (UM) Summer Institutes, Pew Fellows Program in Marine Conservation) followed by perspectives of established integrative researchers. Stephen Schneider (Stanford University) provided insights on "The Right Stuff" for building a successful integrative career. Tony Michaels (University of Southern California) described NSF's new Complex Environmental Systems initiative and addressed the issue of training science as a profession (establishing collegial relationships, securing funds, managing budgets, managing staff, and publications). Cathy O'Riordan (American Geophysical Union) presented an overview of the role of scientific societies in training new scientists for leadership positions, while Terry Root (Stanford University) shared some tips on communicating beyond the ivory tower. Robert Harriss (National Center for Atmospheric Research) created a vision for expanded use of the internet in fostering interdisciplinary dialogue and learning, while Robert Frodeman (University of Colorado/Cooperative Institute for Research in Environmental Sciences) used climate change as a case study for integrating the humanities with the sciences. Mary Jo Larson (George Mason University) proposed a systems approach for building leadership to advance ecological security. Electronic versions for most of the speakers' presentations are available on the Workshop website (Weiler, 2003a: http://marcus.whitman.edu/~weilercs/biocomplexity/).

A glance at the ideas presented by participants before the meeting (pp. 10-14) reveals that communicating across disciplines is a major concern for emerging interdisciplinary professionals. To illustrate possible strategies for enhancing communication, two communication exercises were presented on Saturday evening. Edie Farwell led a session on "Developing and Articulating a Vision" which she has used successfully with interdisciplinary groups connected with the Donella Meadows Leadership Fellows Program. A paper by Donella Meadows was provided as background reading, along with a set of Manifesting Principles. Rosalind Reid (Sigma Xi, the Scientific Research Society) led "Picturing Research: Creating Visual Tools for Cross-disciplinary Communication," an exercise she developed to facilitate interdisciplinary interactions at the annual Sigma Xi meetings. Both were well received and recommended for students, new professionals, and established workers.

On Sunday, participants broke into six groups to devise a model program designed to meet the needs of recent Ph.D. recipients embarking on interdisciplinary careers. The DISCCRS and DIALOG (Weiler, 2003b: http://aslo.org/phd.html) were used as straw men (defined as "setting up as an opponent to be easily defeated"). After group discussion, participants reconvened to present their recommendations and propose a whole-group synthesis.

Workshop Recommendations

Participants agreed that an ideal program for recent Ph.D.'s would include electronic resources that could be distributed globally plus an in-person meeting for a small group. Due to time limitations, the Oct. 3-6, 2003 Workshop focus was on the in-person symposium component of the model program, recognizing the symposium and symposium-related activities would serve as an incubator for reports and resources that could be electronically distributed to a broad audience.

While paper and electronic resources enable researchers to learn about each others' work, in-person meetings catalyze development of sustained collegial relationships. The frantic pace of most scientific society meetings generally does not provide an opportunity to gain exposure to distant disciplines, let alone establish collegial relationships. Sustained interactions over several days would jump-start the process of establishing professional contacts across disciplines.

The chemical oceanography community has relied on such symposia since 1976 (Green & Sackett 1988). The success of DISCO, the Dissertation Symposia in Chemical Oceanography (http://www.aibs.org/meetings/) led to the Dissertations Initiative for the Advancement of Limnology and Oceanography (DIALOG, http://aslo.org/phd.html) in 1993, the Physical Oceanography Symposia (PODS, http://www.aibs.org/meetings/) in 2002 and the Dissertations Initiative for the Advancement of Climate Change Research (DISCCRS, http://aslo.org/phd.html) in 2003. Such symposia have been enormously popular (Green & Sackett, 1988; Friddell & Bleckner, 2003). While they have become a sort of 'rite of passage' for oceanography graduates, and DISCCRS included a small social-science component, as yet none of these have integrated the full spectrum of disciplines relevant to the study of climate change and impacts or issues at the land-water interface.

Workshop participants agreed that a program integrating across disciplines would be beneficial. While DISCO, DIALOG, DISCCRS and PODS are a start in the right direction, an integrative program should include additional elements and a different emphasis. The focus should be on communicating and interacting across disciplines, plus real-world advice with career-oriented strategies. Interdisciplinary communication training would foster understanding and collegial interactions, while

practical career-building skills specifically for would-be interdisciplinarians would help graduates launch their careers.

Workshop recommendations are summarized below.

Communication Skills: Communication skills are increasingly important for all disciplines, but aspiring integrative professionals face unique challenges. As Susi Moser expressed it, "To succeed, interdisciplinarians must be 'multi-lingual': Not 'native speakers' in every discipline, but with at least a working knowledge of ideas, concepts, procedures, and terminology used by other experts." Yet even basic training or exposure to faculty and students from divergent backgrounds is sketchy or missing from most graduate-education programs. Workshop participants agreed that communication training should therefore be an integral part of the model program. Communicating across disciplines should run like the thread Ariadne gave Theseus as a guide through the labyrinth, and tie together every activity throughout the week-long meeting.

Career-building Skills: As Steve Schneider expressed it, we are in a cultural/professional "fractal." Graduates need to know what the professional landscape is and how to do socially relevant work without killing oneself, professionally or personally. Graduates should be taught how to survive in a changing landscape—or, in the words of Tony Michaels, we need to "teach them how to dance on a shifting stage." Training should address why integrative studies are necessary and how to bridge the natural/social science divide. New Ph.D.'s are increasingly interdisciplinary, but institutions are not and the jobs just aren't there yet. Graduates should be informed about both the opportunities and challenges of interdisciplinary work, and provided with guidance on how to build successful careers.

Target Audience: Most complex environmental systems transcend national borders. The program should therefore be fully international in scope, including participants from both developed and developing countries. Ideally the meeting would include participants centered on a broad range of disciplines, from natural and social science and the humanities as well as engineering, mathematics and modeling or even professional fields such as business and law. To help graduates obtain a broad perspective of issues and establish a useful peer network, the symposium should be broadly advertised to yield an applicant pool representative of the graduate population. While the program may target those wishing to pursue research careers, integrative graduates must work beyond the traditional ivory towers. It is important that their peer network include graduates working in industry, state, local and Federal governments, and non-government organizations (NGO) as well as academia. An application review committee should be used to identify outstanding candidates. Excellence should be the primary criterion for selection. Diversity of disciplines, institutions and backgrounds should be sought following the same philosophy and guidelines used by the National Science Foundation. There was considerable discussion concerning the eligibility window for the recent Ph.D.'s who were the focus of this Workshop. Some felt that any pre-tenure professional should be eligible while others felt that a 2-year or possibly 3-year post-Ph.D. eligibility window should be used.

Symposium Size: Forty was considered to be the absolute maximum size for the symposium. While more participants would allow additional disciplines to be represented and provide greater opportunities for networking, there was strong consensus that 25 participants for a week-long meeting would be ideal, in order to bring relationships to the level of friends rather than distant colleagues.

Symposium Location: Workshop participants agreed that the physical surroundings should be an integral part of the symposium. A retreat-style facility is important, so that participants can forget about their normal routine and stay focused on the event. A relaxed atmosphere helps to make minds receptive to ideas and linkages. While the surroundings do not need to be exotic or luxurious, it is important that the food be of high quality so that bodies and minds are in top condition. Field stations combine appropriate locales with excellent meeting facilities and a cost-effective venue. It would be useful to have a symposium location that has access to individuals or sites where integrative projects are taking place. A shared aesthetic experience can be inspirational. It can also be used as an organizational structure for the week, to provide a context for ongoing discussions over the week and/or as a case study (for example: A Long-Term Ecosystem Research (LTER) site, a particularly threatened and unique human ecosystem as the Everglades, or locations with access to local stakeholders). A visit to a site, presentations by local workers or stakeholders, followed by a debriefing and brainstorming session, could be used to teach participants to think in a systems way. Alternately, experienced professionals from other localities could be brought in for the symposium.

While a site or theme (e.g., invasive species) may be used as a case study, the symposium should not exclude people who do not work in that area. Rather, the site/theme should be used as an organizational tool or catalyst for the week's activities.

Symposium Elements: Participants agreed the following elements should be included as part of a week-long symposium.

- **Communication Training**: It is worth repeating that all meeting activities throughout the week should reinforce the "formal" communication training. Resources should be made available through the program's web page to reach the broadest possible

audience. Symposium participants should begin work before attending the symposium through selected readings and while preparing for their talks and posters. To facilitate interactions at the symposium, participant resumes and photos should be collected and distributed before the meeting so participants can use that information to relate their work to that of others who will be attending. While preparing for their oral and poster presentations, participants should be given guidelines to ensure their work is understandable to the broad audience represented by the symposium participants. This beginning should be coupled with training/discussion early in the symposium on establishing common languages, explaining why integrative projects are necessary, putting such work in a professional and social context, etc. Participants should be given feedback on their scientific presentations. Exercises such as 'picturing research' or 'creating a vision' could serve as ice breakers and mixers so that participants immediately begin to engage with each other. Skilled professionals with training in communication skills should be utilized throughout the meeting, for formal presentations, informal interactions, and as discussion facilitators.

- **Team Building Skills**: Teamwork is essential for building successful multidisciplinary and interdisciplinary collaborations. Training in this area is routinely provided in the for-profit sector where efficiency is the goal. Such training should become commonplace for academic professionals. Ideally there would be a combination of formal presentations by skilled trainers, coupled with insights of the academic mentors based on their successful interdisciplinary careers. Small-group discussions would provide opportunities for participants to practice communication and teambuilding skills--see Appendix, pp. 15-20 (Drobot et al. 2003) for an example of a report developed at the 2003 DISCCRS symposium.

- **Mentors**: While the focus of the meeting should be on establishing peer relationships among the recent Ph.D. participants, it was felt that there should be a tiered group of mentors to provide early-, mid- and late-career perspectives on building successful interdisciplinary careers. Ideally there should be a one-to-five ratio of mentors to participants. The early- and mid-career mentors could provide real-time insights on early-career development, while senior mentors could provide holistic overviews of the field and long-term perspectives. Hopefully these mentors would become an integral and sustained part of the participants' professional network. At least some of the mentors should be successful interdisciplinary researchers who have been engaged in outreach to the media, stakeholders, managers, policy makers, k-12 students or the general public. Mentors should come from within and beyond academia. Mentors should provide the following:
  - **Big picture**: The symposium should include presentations by the senior mentors, to provide an overall context for the week—for example by addressing questions such as what does it mean to be interdisciplinary and do integrative science. Some sort of overview presentation on the meeting theme could be used to provide a context for the participant presentations over the week.
  - **Success stories**: Mentors should discuss both successful and unsuccessful integrative projects, with a goal of showing participants what makes a project work. A panel of mentors or agency representatives might also provide an historical perspective on integrative projects and funding.
  - **Tangible tools for the professional toolbox**: There needs to be a focus on useful information that can be taken home and utilized. For example, tips on how to secure an interdisciplinary position, how to develop a tenure review packet, how to obtain funding, where to publish, how to feather a professional nest, how to build a meaningful legacy.
  - **Realistic assessment of status quo**: Mentors should be realistic—tell the truth about what the reality *is*, versus what it *ought* to be. They should also provide tips on how to survive in the current institutional environment and work on long-term goals while seeking the training needed to be an effective interdisciplinary professional.
  - **Positive outlook**: Participants should walk away feeling confident, hopeful and energized. While the assessment should be realistic, the focus should always be on solutions, not problems. Positive language should be used at every step.

- **Participant Presentations**: There was consensus that the symposium must include a strong element of information exchange. Participant presentations provide an ideal opportunity to inform the group about individual work and collaborative interests, and to practice communication skills. Oral presentations would need to be short to provide time for other activities. Brief oral presentations providing an overview of participant's major field of interest could be coupled with in-depth poster presentations. Posters could be displayed during the week-long symposium so that all participants can review the posters between sessions. The oral presentation should be a sort of mini-plenary address, with an introduction to the broader field of participant's interest as well as an overview of that person's specific work. To foster connections with other participants and the meeting theme, if there is one, the speaker should articulate any interdisciplinary links or identify interdisciplinary topics of particular interest. The presentation should conclude with a statement of the participant's interdisciplinary professional goal(s). Five minutes

per talk may be too short to effectively convey the essence of the presenter's professional identity, but anything over 10 minutes per presentation is probably too long.

- **Professional Training**: Some of the Workshop participants felt that communication skills and research content should be the only mission of the week. Most of the participants (and all of the recent graduates who participated) were insistent in recommending that professional training be provided as well. Workshop participants considered how best to provide this training. Some graduate programs, such as the Wrigley Institute at the University of Southern California, offer graduate-level courses to provide professional training including proposal development, managing a lab, and other real-world skills. Until such courses are the norm, electronic resources and the symposium could provide essential training for recent Ph.D. graduates. Areas of particular interest are highlighted below:

  - **Communicating beyond academia**: Participants were keen to discuss communicating beyond academia, and particularly with the media. Many expressed concern about losing scientific integrity, or compromising their professional standing by working with the media or stakeholders. Insights by established scientists who have successfully worked with the media, coupled with training by media and communication specialists, would be helpful in this regard.

  - **Proposal development**: With the current funding success rate, all graduates planning to pursue research careers need training in proposal development. This is especially true for graduates wishing to tackle interdisciplinary questions. Training is needed at virtually all levels—from identifying a viable project and an appropriate funding source, through identifying potential collaborators and ultimately developing a collaborative proposal.

    Recent graduates are generally unfamiliar with Federal funding and most are completely naive when it comes to other sources of funding. A resource guide for funding sources should be developed and made available from the program web site. If possible, representatives from various funding agencies should be present at the symposium to answer questions. Presentations should focus on opportunities and tools for successful collaborative proposals. The agency representative needs to be both informative and candid, doing more than simply reporting what is on the web site. However, information from the web site that might be of particular use to recent graduates pursuing integrative careers should be highlighted.

    The key is to train these integrative thinkers to come up with well-posed problems that can be addressed by an integrative team within the confines of a normal grant cycle. While it is good to show examples of how large integrative projects get started, these emerging professionals need to know how to work with a small nucleus of colleagues on a relatively modest scale.

    A popular idea proposed at the Workshop was to require participants to read and review a successfully funded interdisciplinary proposal and, for comparison, perhaps an unfunded proposal as an example for group feedback; the mentors or one or more of the participants might provide already-submitted proposals for use in this context. At the symposium, participants could form review panels and then compare their proposed recommendations with the actual review and recommendations. This learning experience provides valuable insight into the proposal review process. Ideally Federal agency representatives and the PI would be present to take part in discussions.

    Some commented that such a proposal should be used as a unifying force throughout the meeting. The model proposal used at the meeting should be representative of something the participants might develop over the next few years—something on a manageable scale, perhaps a collaboration between two or three scientists from different natural- and social-science disciplines and institutions. An international example would be particularly useful. Agency representatives (national or international), or representatives from large international programs can be enormously helpful in putting together a central interdisciplinary element. They can provide experts, case studies, results, an overarching context, etc.

    Another possibility would be for participants to organize around a topic related to the meeting location, and draft a proposal around this topic/question. Using the local environment would enable participants to meet with a broad range of stakeholders. In conjunction with either of the above, participants could identify topics and work in small groups to develop collaborative proposals using the talents of all those in their group, with mentors and funding agency representatives on hand to provide insights and guidance.

- **Other**: The elements identified above were the most fundamental topics and ones that Workshop participants agreed should be done by everyone. The rest of these topics might be offered in the context of break-out sessions where participants could choose among several options including the following:

- **Education outreach**. Participants interested in k-12 outreach or engaging the general public could receive training or share successful strategies.

- **Collaborative proposal development**. Participants who want to develop a collaborative proposal could work on such a project.

- **Communicating with media**. Participants could develop stories based on their research, or role play. A specialist, or a panel with a reporter, senior scientist with media experience, and media specialist might be used.

- **Working with stakeholders**. Participants and mentors could discuss working with citizen groups, or city, county, state planners and the like. A case study would be useful in this context.

- **Public policy**. New Ph.D.s at the Workshop were particularly concerned about how to work on policy issues without losing scientific credibility. It would be useful to have at least one early- or mid-career scientist with successful experience to share insights and lead a discussion.

- **Career development**. Participants are likely to be interested in alternate careers, job-hunting strategies, tenure/promotion, soft-money positions, balancing family and career, dual-career issues, and related topics. Meals or informal evening discussions could provide opportunities for participants to discuss such topics with each other and/or the mentors.

- **Publishing strategies**. Participants and mentors could share insights on where to publish, and especially how to market interdisciplinary papers since these often have difficulty finding an appropriate venue.

- **Interdisciplinary teaching**. Such courses are a particular challenge, in part because they are likely to involve team teaching. Insights from mentors and participants with successful experience would be particularly useful in this context.

◆ **Field Trip**: The meeting format is likely to be very intense. To keep up energy, the weeklong symposium should include a half-day field trip, to provide a block of time for sustained informal interactions and relaxation.

◆ **Informal Time**: There should be a block of time each day that participants could use to relax alone, set up one-on-one meetings with mentors, or participate in small-group discussions. Such time is not a luxury. Teambuilding is more than just bringing people together. The human dimension cannot be overlooked. Free time is absolutely needed for strong personal relationships to develop and collegial networks to be established. While the web provides a quick and inexpensive way to identify potential collaborators, there is simply no substitute for one-on-one interactions. Friendships formed at the symposium will help build understanding and trust across disciplinary boundaries. Sometimes such relationships will lead to collaborative projects. Just as importantly, collegial networks will expand with time as symposium participants recommend students and colleagues to each other. And, professional friends are sometimes needed to provide a sounding board for work or career related issues.

Conclusion

The need for interdisciplinary collaboration and communication is well documented. A changing global environment demands an interdisciplinary approach to problem solving. The Oct. 3-6, 2003 Workshop focused on the issues needed to train recent Ph.D. graduates to meet the current challenges and opportunities. Meeting these challenges will require cadres of professionals who are able to think and work collaboratively across all disciplines: mathematics, engineering, technology, social and natural sciences.

Due to limited time, the Workshop focused on the symposium component of a model program utilizing both electronic resources available to everyone and a weeklong meeting for a relatively small group. Participants agreed that a centralized web page and electronic distribution list for individuals interested in interdisciplinary research careers would be of tremendous value. The weeklong meeting should provide fertile ground for ideas and resources that could be disseminated to a broad audience via the web. And, materials developed for the symposia, such as a resource guide for funding sources and interdisciplinary journals, job-hunting tips, or other professional-development and communication-training documents, should have wide appeal; they could and should be broadly distributed. The web page could also be used as a people locator for those interested in establishing collaborative relationships. A distribution list could be used to post time-sensitive material such as job advertisements.

This workshop was limited in scope and short in duration. It addressed only the specific needs of recent Ph.D. graduates who are currently entering the workforce with the hope of building a successful interdisciplinary career. However, most of the recommendations from this workshop could be used in other contexts (short sessions in conjunction with scientific society meetings or longer courses as part of academic training).

All readers of this document are encouraged to think about how they can effect change within and beyond their own institution and, or generally, throughout the course of graduate education and early-career development.

References

Drobot, S. D., Porinchu, D. F., Arzayus, K. M., Barber, V. A., Delissio, L. J., Smith, L. M., Warren, J. M., et. al. (2003). The 'Ideal' Climate Change Ph.D. program. DISCCRS, Dissertations Initiative for the Advancement of Climate Change Research, Working Group Report. http://aslo.org/phd/disccrsclimatechange.pdf

Friddell, J. & Blechner, T. (2003). Advancing ideas, methods in interdisciplinary climate change research for new Ph.D.'s. *Eos* 84 (33): 314, 320. http://aslo.org/phd/disccrsympreport.pdf

Green, E.J. & Sackett, W.M. (1988). DISCO 10-year retrospective survey results. *Eos* 69(44): 1015, 1017-1018, 1021.

Lubchenco, J. (1998). Entering the century of the environment: A new social contract for science. *Science* 279: 491-497.

Pfirman, S. & AC-ERE (2003). Complex Environmental Systems: Synthesis for Earth, Life, and Society in the 21st Century, A Report summarizing a 10-year outlook in environmental research and education for the National Science Foundation.

Schneider, S.H., Stoltman, J., & Waddington, D. (1995). Education and Global Environmental Change. In: Global Environmental Change Science: Education and Training. Edited by David J. Waddington, 1995, Springer-Verlag Berlin in cooperation with NATO Scientific Affairs Division.

Waddington, D.J., Ed. (1995). Global Environmental Change Science: Education and Training. Springer-Verlag Berlin in cooperation with NATO Scientific Affairs Division.

Weiler, C.S. (2003a). Biocomplexity LWI/CC workshop: Designing a capstone experience for recent Ph.D.s embarking on interdisciplinary careers. http://marcus.whitman.edu/~weilercs/biocomplexity/

Weiler, C. S. (2003b). Programs for Recent Ph.D.s. http://aslo.org/phd.html

Acknowledgments

This Workshop was co-organized by C. Susan Weiler, Ronald B. Mitchell and Anthony F. Michaels and supported by the U.S. National Science Foundation through grant #DEB 0119960 to Whitman College. The University of Southern California kindly defrayed expenses at the Wrigley Marine Science Center.

Brief (less than 10 minutes) oral presentations should be used by participants to inform each other about research, professional and collaborative interests.

Poster sessions provide opportunities to explain and discuss research in greater depth than is possible in the short oral presentations.

Unstructured time should be incorporated into the agenda to enable participants to discuss issues of mutual interest and establish lasting collegial relationships.

Participants should practice working in small groups to discuss emerging research, professional & societal issues and develop communication and teambuilding skills. See pp. 15-20 for an example of a working-group report from the March, 2003 DISCCRS symposium.

Workshop Participants

Alcock III, Frank R.
Division of Social Sciences
New College of Florida
5700 North Tamiami Trail
Sarasota, FL 34243

Bassman, John H.
Department of Natural Resource Science
Washington State University
Pullman, WA 99164-6410

Caldwell, Meg
Environmental and Natural Resources Law & Policy Program
Stanford Law School
559 Nathan Abbott Way
Owen House Room 6
Stanford, CA 94305-8610

Farwell, Edie
Donella Meadows Leadership Fellows Program
Sustainability Institute
3 Linden Road
Hartland, VT 05048

Frodeman, Robert
Ce. for Science and Technology Policy Research
University of Colorado/CIRES
1333 Grandview Ave., Campus Box 488
Boulder, CO 80309-0488

Graham, William M.
Dauphin Island Sea Lab
101 Bienville Blvd.
Dauphin Island, AL 36528

Harriss, Robert C.
Environmental & Societal Impacts Group
National Center for Atmospheric Research
Foothills Laboratory
Boulder, CO 80307-3000

Hayes, Marshall
Centre Scientifique de Monaco
Av. Saint Martin
Monte Carlo 98000
Monaco

Hellmann, Jessica J.
Department of Biological Sciences
University of Notre Dame
107 Galvin Science Center
Notre Dame, IN 46556

Holloway, Tracey
Gaylord Nelson Inst. for Environmental Studies
University of Wisconsin
1710 University Ave., Room 201A
Madison, WI 53711

Joergensen, Kirsten
Environmental Policy Research Centre
Free University of Berlin
Ihnestr. 22
Berlin 14195
Germany

Larson, Mary Jo
Institute for Conflict Analysis and Resolution
George Mason University
Falls Church, VA 22044

Leavitt, Steven W.
Laboratory of Tree-Ring Research
University of Arizona
105 W. Stadium, Bldg. #58
Tucson, AZ 85721

McCarthy, Elena
Marine Policy Center
Woods Hole Oceanographic Institution
Woods Hole, MA 02543

McKinley, Galen A.
Program in Atmospheric & Oceanic Sciences
Princeton University
300 Forrestal Road
Princeton, NJ 08544

Michaels, Anthony F.
Wrigley Institute for Environmental Studies
University of Southern California
Los Angeles, CA 90089-0371

Mitchell, Charles E
Dept. of Ecology and Evolutionary Biology
Cornell University
E145 Corson Hall
Ithaca, NY 14853-2701

Mitchell, Ronald B.
Department of Political Science
University of Oregon
Eugene, OR 97403-1284

Moir, Rob
Office of Institutional Advancement
Hampshire College
Amherst, MA 01002

Workshop Participants

Moser, Susanne C.
Environmental & Societal Impacts Group
National Center for Atmospheric Research
P.O. Box 3000
Boulder, CO 80307-3000

O'Riordan, Catherine A.
Society Activities Manager
American Geophysical Union
2000 Florida Avenue, NW
Washington, DC 20009

Osherenko, Gail
Marine Science Institute
University of California at Santa Barbara
4510 Bren Building
Santa Barbara, CA 93106-5131

Pedynowski, Dena
Center for Environmental Science and Policy
Stanford University
Institute for International Studies
Encina Hall, E501
Stanford, CA 94305-6055

Podesta, Guillermo
Rosenstiel School of Marine & Atmospheric Science
University of Miami
4600 Rickenbacker Causeway
Miami, FL 33149-1098

Post, Eric
Department of Biology
Penn State University
208 Mueller Lab
University Park, PA 16802

Pyrtle, Ashanti J.
College of Marine Science
University of South Florida
140 7th Avenue South
St. Petersburg, FL 33701

Reid, Rosalind
Sigma Xi, The Scientific Research Society
99 Alexander Drive
P.O. Box 13975
Res. Triangle Park, NC 27709

Robinson, Cynthia
Aldo Leopold Leadership Program &
Pew Fellows Program in Marine Conservation
New England Aquarium
Central Wharf
Boston, MA 02110-3399

Root, Terry L.
Center for Environmental Science and Policy
Stanford University
Inst. for International Studies
Stanford, CA 94305

Schneider, Stephen H.
Department of Biological Sciences
Stanford University
Stanford, CA 94305

Schreurs, Miranda
Department of Government
University of Maryland
3140 Tydings Hall
College Park, MD 20742

Schultz, Martin
Department of Engineering and Public Policy
Carnegie Mellon University
Center for Study and Improvement of Regulation
5000 Forbes Avenue
Pittsburgh, PA 15213—3890

Still, Christopher J.
Geography Department
University of California
at Santa Barbara
3611 Ellison Hall
Santa Barbara, CA 93106

Van Deveer, Stacy D.
Department of Political Science
University of New Hampshire
Durham, NH 03824

Weiler, C. Susan
Biology Department
Whitman College
34 Boyer Avenue #206
Walla Walla, WA 99362

Young, Oran
Donald Bren School of Environmental Science &
Management
University of California at Santa Barbara
Donald Bren Hall 4518
Santa Barbara, CA 93106-5131

Zawada, David G.
Physical Sciences Inc.
20 New England Business Center
Andover, MA 01810

Pre-Workshop Suggestions for Model Program

Before the Oct. 3-6, 2003 Workshop, participants were instructed, in the space of one paragraph, to describe one possible element to include in a Capstone Program for interdisciplinary Ph.D.s. The contribution was to be something that could be distributed through a webpage, distribution list or other electronic resource, or covered in a meeting of no more than one-week duration. Their suggestions are presented below.

Communicating Across Disciplines

Define and Illustrate Biocomplexity

Contributed by Steve Leavitt

Depending on the make-up of the first class of Ph.D. students at the capstone experience, it may be useful to have "terrestrial" grads define and illustrate biocomplexity in their area of expertise, whereas the "marine" or "aquatic" people could do likewise for their area. Social Scientists working in these 2 realms could either expand on the human aspects of these systems, or explain how the human components of these systems differ from the natural/physical scientific elements (perhaps in our ability to "quantify" certain human elements).

On a similar vein, "hot" areas (or questions) in biocomplexity research could be illustrated by members of the capstone group, or perhaps they could be provided on a web site they could view beforehand and discuss at the meeting. An example would be, "what happens to soil carbon storage [or the capacity to store carbon in general] in systems where biocomplexity is changing?"

Define 'Interdisciplinary' and Examine Research Approaches

Contributed by Dena Pedynowski

The terms "disciplinary," "interdisciplinary," and "multidisciplinary" are frequently exhorted, invoked, and generally, circulated through funding opportunities, academic course descriptions, and research programmes … However, what do these concepts mean? How do researchers, funding organizations, and interdisciplinarians themselves use and understand the idea of the "interdisciplinary"? These questions are not simply abstractions. How "interdisciplinary" is understood can have implications for the obstacles and opportunities that aspiring interdisciplinary researchers face. My suggestion for the Capstone programme is in two parts. First, participants can be encouraged to examine their own perceptions and experiences of what it means to be interdisciplinary. Second, these perceptions can then be critically examined in light of the scientific process and the different methods (research techniques) and the different methodologies (epistemologies, claims about "reality") of social and biophysical science research. Such an exploration is especially critical at the social and biophysical science interface, where methodologies can be controversial, conflicting, or simply poorly understood, e.g. qualitative vs. quantitative analysis. This can be an opportunity for recent Ph.D graduates to broaden their awareness of research approaches as well as re-evaluate the assumptions and epistemologies of their own work.

Learning to Speak the 'Other One's' Language

Contributed by Susi Moser

To succeed, interdisciplinarians must be "multi-lingual": Not "native speakers" in every discipline, but with at least a working knowledge of ideas, concepts, procedures, and terminology used by other experts. The idea proposed here is intended for a week-long symposium (but with some effort can be adapted into an e-based dialogue exercise).

Two participants are matched up, one from a different discipline than the other. Their job is to explain to the other what their research was all about, using "plain English" to explain and explore what is meant by and behind a particular theory, methodology, concept etc. For ease, participants could use their recently completed Ph.D. research project as a starting point. The listener would be allowed to ask as many questions as needed to understand as fully as possible the underlying ideas, assumptions, paradigms, disciplinary evolution, and how the discipline deals with a given research challenge/question. The activity could be done in as little as 1 hour or 1-2 days. I can imagine this as an early activity in such a symposium, where participants get to know each other. After each has an understanding of the other one's background and research, they could be asked to introduce their partner and project to the rest of the group, thus reconnecting the pair work with the rest of the group. This would be a good (if challenging) way to see whether the listener understood and can represent the other one's work.

The goals of this activity would be to learn: (1) to communicate across disciplinary language barriers; (2) to communicate expert knowledge in a commonly understood language; (3) to appreciate and respect alternative approaches to research; (4) to develop some self-reflective understanding for the power of expert knowledge; and (5) to begin growing a complementary humility needed to cooperate effectively in interdisciplinary projects. A special benefit may be that each participant gets some new idea(s) of how to build on their recently completed research project.

Describe Your Partner's Research

Contributed by Cathy O'Riordan

To improve the exchange of research ideas and concepts across disciplines, the workshop could begin with brief introductions of each participants research. The twist is that the group is split up into 3 or 4 smaller groups of partners from different backgrounds (a social scientist with an aquatic ecologist) and each pair is given about 10-15 minutes to learn about their partner's research and how it relates to the other fields involved in biocomplexity. Then each person has about 2 minutes to describe the research of their partner to their group. This is an excellent exercise in communicating ideas and in listening carefully. It could be conducted as an after-dinner activity on the first evening.

Picturing Research

Contributed by Roz Reid

"Picturing Research" is a workshop I've been doing with chapters and at the Sigma Xi Annual Meeting, but it strikes me that it might be an interesting activity for this group. Maybe even an icebreaker, if you're in need of one. What we do is search for a shared visual language with which to tell each other about our research. Usually I give a short slide show with tales from the history of scientific illustration and some behind-the scene examples from our work at American Scientist. I seat people at tables where there are big sheets of flip-chart paper and colored markers. After the slides I challenge them to draw pictures of their work without resorting to the shorthand of their fields—spectra, histograms, whatever. The idea is to search for what I call a common visual language. People start sketching, talking, trying to think of visual metaphors. I ask them to present their drawings to their table; then each table selects someone to give a short presentation to the larger group. This workshop has been lots of fun whenever I've given it, particularly in mixed groups of senior and junior scientists and students. It's a good leveler, maybe because everyone is limited to simple marker drawings, and the younger participants often have novel visual ideas.

Vision of Future Work and Impacts

Contributed by Edie Farwell

I would like to see a component in this program that helps participants see and articulate - both individually and as a group - a vision of where they would like their work to go. And a vision of how they would ideally like climate change and land/water issues to be in the world. Too often scientists and environmentalists articulate the problems and frustrations, but not the vision of where they want the world/their issue to be. Developing and articulating a vision gives it power, and makes the steps to get to that vision more tangible.

Framing Interdisciplinary Research Questions

Contributed by Frank Alcock

As a precondition for fruitful interdisciplinary research, I think that it is important to frame research questions in a manner that is accessible to numerous disciplines. A common tendency is for researchers to pose questions that can be answered by members of their own discipline, or, even worse, only make sense in the context of their particular discipline. In addition to thinking about how your research can be framed in a manner that contributes to research agendas outside of your discipline, an exercise that I think new Ph.D. recipients could benefit from is to think of questions that they could pose to researchers from other disciplines, the answers to which would be of value to their own research.

Interdisciplinary Team Project

Contributed by Tracey Holloway

As a primary objective of the week-long workshop is to facilitate interdisciplinary interaction, I would suggest structuring activities where participants work in small groups on "real" projects. Such projects could include outlining a future research proposal, or designing an interdisciplinary class. Using DISCCRS as a model, the first 2 days of the workshop would involve short individual presentations on thesis research. As each participant listens to his/her colleagues' talks, he/she could note which other participants would be interesting to collaborate with. Following the individual presentations, each participant's "wish list of collaborators" could be collected and used to create 5-person groups in which each person would be with at least one of his/her desired collaborators. Such a structure would ensure that groups have enough real overlap of interests to fuel an interesting discussion and plan. The thought exercise of identifying common interests would likely lead to additional informal networking. Groups would be asked to briefly present the fruits of their collaborations.

Interdisciplinary Team Project

Contributed by Galen McKinley

I would make sure that in the week-long symposium, there is the opportunity for participants to actually work together on an interdisciplinary problem. Participants would be divided into working groups with a similar distribution of social and natural scientists. They would be asked to develop, as a group, a research plan for a selected global change problem. This project would ideally span a couple of days, and might even have background reading associated with it before arrival. Getting people to work together in this way could be a great opportunity to actually confront the challenges of interdisciplinary work.

Capacity Building

Advice from/Examples of Successful Interdisciplinary Scientists

Contributed by Astrid Schnetzer

One of the insights that I very much agree with is that one needs to stay specialized in one's field and at the same time gain "enough" expertise in the other fields that are part of complex biosystem research. But how does one do this? I believe that examples of senior scientists who have successfully followed an interdisciplinary career should be heard or made reference to. For example, how do they decide who to include in a multi-investigator research project and what have they learned along the way? So in some sense my idea is to hear as much as possible from people who are experienced in working in interdisciplinary research groups and make time for discussion with graduates or fellows like me who just started out on the road.

Training on the Human Dimension of Complex Systems

Contributed by Monty Graham

In thinking about ways to get early career scientists to consider a human social dimension as part of complex biological systems, it seems a starting point could be a crash-course in human nature (i.e., what some might call 'Sociology for Scientists'). Central to such a mini-course would be getting these young scientists to consider how their research applies to human nature in terms of five fundamental characters of humanity: morals, ethics, values, ideals, and laws. As part of the mini-course, I would like to see an exploration of the relationships between these human characters, how they vary regionally within a country, across religious, ethnic or gender boundaries, and how they can be incorporated within complex biological-human systems. I can think of several formats for building discussions during the workshop (e.g., a focus on fishing practices or on farming near the coast), but the participants should be given some material in advance to cut any kind of lecture to a minimum. The kind of social diversity I would expect of the workshop should provide a basis for some very stimulating discussions.

Web-based Curriculum for Organizing and Managing Interdisciplinary Research

Contributed by Martin Schultz

Recent Ph.D. graduates engaged in interdisciplinary research on global environmental change spanning the physical, natural, and social sciences have a wide variety of backgrounds. While these graduates should all know how to do research, they may have varying levels of awareness of the issues, perspectives, and methods specific to interdisciplinary research, which offers unique challenges in terms of the integration of the various disciplines. A concise, web-based resource would offer recent graduates a self-paced online course covering up-to-date material on these issues, perspectives, and methods. The benefit of working through this material for recent graduates is that they are then confident of the level and scope of their knowledge. The web-based format is accessible and efficient in terms of both time and cost. The formality of a curriculum (as opposed to a random collection of resources) helps ensure that specific learning objectives are communicated and achieved. It is also important that the resource be concise and specific. If it is not concise, people will not use it and if it is too general it will not be meaningful. I do not profess to know what should be in the curriculum. However, I suggest that some part of the week-long symposium be used to assess educational needs of the recent graduates that are participating in the program so that the resource is well-targeted.

Identifying the Right Team

Contributed by Sheldon Drobot

In my experience, one thing that has been really difficult is finding the right team to collaborate with. Everything I have read points out the need to have an engaged group that is interested in putting in the time and effort to pull off interdisciplinary research. Even before assembling the team though, young researchers have one major obstacle – how do you locate people with the needed skill-set? My idea is not earth-shattering, but it is relatively cheap and easy to implement – a web-based database of researchers interested in interdisciplinary research, listing their contact information, specialty areas, and some room for additional notes. For example, say I am a sea ice researcher and I am interested in examining how interannual variations in sea ice affect near-shore environmental conditions and native communities that live along the coast. For this team, I have identified that I need a sea ice expert (myself), an economist, an anthropologist, a near-shore ecologist, and a fisheries expert, etc. Perhaps I have been lucky enough to have met an economist, who in turn knows a fisheries person, but we are stuck for an anthropologist. We then would search the on-line database to find the missing link.

Building Capacities to Advance Ecological Security

Contributed by Mary Jo Larson

I would like to see program elements that build [human/social/professional] capacities to advance ecological security, including teamwork, strategic communication, multilateral negotiations, leadership and action research.

Communicating Beyond Academia

Balancing Environmental Advocacy with Intellectual Integrity

Contributed by Ron Mitchell

Many scholars, both new and more seasoned, are frequently reluctant to engage in environmental advocacy because of the fear that it will undercut their credibility with other scientists. It appears that, and there frequently in fact is, a tradeoff between political influence and academic stature. How does one avoid the Scylla of being an "ivory tower academic" whose ideas are having little impact on the public or the policy community and the Charybdis of being a "policy-wonk wanna-be scientist" who "real" scientists dismiss as having dated, misinformed, or outright wrong interpretations of the science? This is not just a question for individuals but also for institutes. How do institutes successfully manage the tension among "basic" research, "applied" research, and involvement in current policymaking? Having a few scholars who have successfully managed that tension talk to the group would be particularly valuable.

Media Training

Contributed by Jessica Hellman

Many students in environmental studies are strongly motivated to resolve global ills, and these scholars often draw upon several fields to address their research questions. Over time, they gain skills of inquiry and integration. But one skill they often do *not* learn during academic training is how to engage the public on policy topics related to their research. The media is one key outlet for engaging society on environmental issues. Given this educational short-coming, I suggest that media training be part of a capstone learning program for recent Ph.D.s. As a young scholar, I've already found myself in interviews and even "off-the-record" discussions with reporters. I wish I was more aware of the "dos" and "don'ts" in such situations. In a symposium or workshop setting, senior scholars could share their experiences in working with the media, and reporters and producers could share their thoughts on what catches the interest of viewers or readers. This is similar to that offered by the Aldo Leopold program but targeted to professionals very early in their career.

Thinking about the Users of Science

Contributed by Bob Frodeman

As shown by the increasing attention given to the second criteria ("societal impact") in the review of NSF proposals, I suggest that the demand side of the science-society relation be highlighted. That is, what types of information are various parts of the public looking for? A visit and a presentation from policy makers such as someone from the Hill and a regional water manager would help recent graduates learn something about how they view science and what types of insights are most useful. This emphasis could be made part of a "policy and values" segment of the proposed 1-week seminar. Other elements to be covered could include: recent developments in the philosophy of science; the science wars; the scientist and "advocacy;" and the relation between expertise and democracy.

Professional Development

Strategies for Interdisciplinary Teaching

Contributed by Charles Mitchell

Increasing interdisciplinary teaching is a key step towards the long-term furtherance of interdisciplinary science. However, there are many challenges in interdisciplinary teaching, particularly if the goal is to integrate social and natural sciences. Faculty who have taught successful interdisciplinary courses could discuss useful strategies. Discussing strategies to overcome both logistical / administrative and conceptual challenges would be useful. Highly interdisciplinary courses might often require a team teaching approach, so covering strategies relevant to team teaching in general would also be useful. Another approach would be including a series of guest lectures, so discussion of strategies for effectively integrating guest lectures into courses would be relevant. More conceptually, perhaps the central challenge to be overcome is how to keep students with diverse backgrounds and interests interested and learning?

Gender and Diversity Issues

Contributed by Sue Weiler

Gender and diversity issues are especially important for graduates embarking on interdisciplinary careers. Such work requires team effort. And, if we are to meet the needs of society and our best intentions, such teams will be diverse in every sense of the word. To be effective, some sort of session on diversity should be mandatory for all—otherwise, the people who need the training most will be the last to attend. I would like to see gender and diversity issues covered both as a web-based resource—an annotated bibliography hot-linked to text would be great—and as a session at the week-long meeting. Mentors who are women or from under-represented minorities should be included as role models. At the symposium they could lead a discussion, perhaps centered on a paper that all would read before the symposium. The paper would need to be short to ensure it is read. Profiles of successful interdisciplinary scientist could be developed as a web-based resource, and care should be taken to include women and minorities.

Gender and Diversity On-Line Resources

Contributed by Cathy O'Riordan

Sue, your idea regarding diversity sparked an on-line resource idea. Some good programs are currently underway that would be available to these grads. They should be encouraged to seek out these opportunities. I'm thinking of the WISC program through AAAS and MentorNet for students and young scientists, and I'm sure that there are many others. These links would be great resources.

Social Skills 101 for New Faculty

Contributed by John Bassman

New Ph.D. grads starting a faculty position may run into challenges not before experienced as either a graduate student or post-doc. Not the least of these are social interactions with other scientist, faculty members, and students. The following topics might be addressed by experts during one or more sessions over the course of a week-long symposium.

1. Faculty meetings/faculty interactions in multi-disciplinary units
   Young faculty, especially in interdisciplinary units, may find it difficult to carve out their own niche amongst a group of more senior faculty or even peers. They may be unsure of speaking out on issues for fear of retribution or looking silly. Others may be less inhibited where they should exercise some constraints. How to behave in a beehive of primadonnas?
   - How to choose your battles
   - Making meaningful contributions without alienating senior or other junior faculty
   - Holding your own in a unit with little depth – problems associated with interdisciplinary units with few or no other members with similar expertise (i.e., no one to talk to).
2. Teaching
   - Dealing with problems associated with new course assignments in subject areas peripheral to main expertise
   - Young faculty member dealing with students about same age –how to command respect, establish proper rapport
   - Skills for becoming a mentor for graduate and undergraduate students
3. Interdisciplinary research
   - Working on research teams with divergent expertise while exercising leadership in a specific area
4. Reviewing manuscripts and proposals
   - Being a diplomat while enforcing scientific rigor.

Strategies to Stimulate Interest/Demand for Interdisciplinary Ph.D.s Given the Current Academic 'Job Maket'

Contributed by Chris Still

I think it would be useful to discuss ways for upcoming interdisciplinary grads to best pitch their talents on the job market. I am thinking primarily of the academic job market, which has been very competitive lately. It seems to me that interdisciplinary Ph.D.s are often at a disadvantage in competing for academic jobs with other Ph.D.s who had a much more narrow focus. Despite all the attention given to the importance of multi- and interdisciplinarity lately, most traditional academic departments still hire specialists. If only one or two chapters of your dissertation are focused on a given discipline, it can be difficult to compete with other candidates who have 4-5 chapters in this area. Given this situation, it is hard to advise current graduate students to explore a range of topics for their dissertations. How do you stimulate interest/demand in interdisciplinary Ph.D.s? How can interdisciplinary Ph.D.s market their unique skills during the hiring process?

A field trip would provide opportunities for informal interactions and a chance to learn about a local environment.

A field station with on-site housing and communal meals provides an atmosphere condusive to establishing the collegial networks vital for life-long professional interactions. Meals provide a relaxed opportunity to discuss issues of common interest (for example, issues involving women in science).

Appendix

The 'Ideal' Climate Change Ph.D. Program

DISCCRS

Dissertations Initiative for the Advancement of Climate Change Research Working Group Report, 2003

http://aslo.org/phd/disccrsclimatechange.pdf

Co-chairs:

Sheldon D. Drobot, Polar Research Board, The National Academies

David F. Porinchu, Department of Geography, California State University, Long Beach

Contributing Authors:

Krisa M. Arzayus, Geochemistry Department, Skidaway Institute of Oceanography

Valerie A. Barber, Department of Forestry Sciences, University of Alaska-Fairbanks

Lisa J. Delissio, Department of Biology, Salem State College

L. Micaela Smith, BP America

Jeff M. Warren, Forestry Sciences Laboratory, USDA Forest Service

Working Group Participants:

Alexandra Amat, Krisa M. Arzayus, Bradly M. Baker, Valerie A. Barber, Gladys R. Bernal, Thorsten Blenckner, Edwin J. Castellanos, John C. Chiang, Lisa J. Delissio, Jeffrey A. Dorale, Sheldon D. Drobot, Zewdu A. Eshetu, Jason P. Evans, Julie E. Friddell, Cynthia A. Froyd, Hezi Gildor, Christopher D.G. Harley, Sean M. Higgins, Christian Hogrefe, Tracey Holloway, Kelly A. Kryc, Mary Jo Larson, Wendy M. Loya, Fernando R. Martins, Galen A. McKinley, Carrie Morrill, MaryLynn Musgrove, Mitchell A. Plummer, David F. Porinchu, Christopher R. Pyke, Bernhard K. Reichert, Andy J. Ridgwell, Tamara N. Romanuk, Astrid Schnetzer, L. Micaela Smith, Rodney T. Venterea, Mark P. Waldrop, Lois J. Wardell, Jeff M. Warren, William E. Wright

Organizer:

C. Susan Weiler, Whitman College

http://aslo.org/phd.html

1.0 Introduction

The threat of climate change is one of the most pressing issues facing humanity in the coming century. In order to increase resiliency and prepare for vulnerabilities associated with climate change, society will look to science to provide answers. However, the science of climate change is complex and multi-disciplinary; many aspects of climate-change research, particularly dealing with adaptation and impacts, require a much broader perspective and greater scientific knowledge than a Ph.D. candidate typically gains in a traditional discipline. How then can graduate programs meet both the disciplinary demands of traditional programs and the interdisciplinary needs of climate-change research in order to best train the next generation of scientists? While there are no simple answers, a symposium brought together 40 recent Ph.D. recipients from 36 institutions and 11 countries (Table I), in part to help address this question by discussing an 'ideal' climate-change Ph.D. program. Sponsored by the American Meteorological Society, American Geophysical Union, American Society of Limnology and Oceanography and Ecological Society of America, the Dissertations Initiative for the Advancement of Climate Change Research (DISCCRS) seeks to bridge the gap between student and new professional. (http://aslo.org/phd.html for program details and information about future symposia) The DISCCRS Symposium, held March 10-15, 2003 in Guanica, Puerto Rico, was the first in what is hoped will become a series. The DISCCRS symposium participants were competitively selected for excellence and diversity of research, with all participants having completed their Ph.D.s after January 1, 2000. The main goal of the symposium was to foster interdisciplinary connections and early professional development. However, the forum also provided a unique opportunity to ask these new professionals to reflect on their recent graduate experience and offer some practical advice on how institutions could best meet the needs of the next generation of climate-change researchers.

The 40 participants were organized into five Working groups and charged with designing the 'Ideal PhD Program for Climate-Change Studies'. Over a three-day period each group was asked to highlight the best features of their particular graduate programs and use their experience and collective imagination to brainstorm about the 'ideal' program. After small-group discussion, participants re-convened to report and discuss their results. Finally, at least one representative from each of the groups was self-selected to summarize the group discussions and write a final report. This report outlines the DISCCRS participants' views on how to develop an 'ideal' climate-change program, one which produces well-trained, highly qualified Ph.D.s that are solidly grounded in their traditional disciplines, yet also are capable of interacting and collaborating with scientists from different disciplines. The components of an 'ideal' climate-change program are discussed in this report, including a suggested approach to course design and the roles of faculty in professional development. This is followed by a representative list of interdisciplinary programs that attempt to provide a more holistic approach to climate-change science. The comments in this report are expressly related to the contributing authors (hereafter the Working Group), and they may not reflect views held by other recent graduates or the institutions the DISCCRS participants work for. However, as recent recipients of Ph.D.s in a wide variety of disciplines and countries, the Working Group believes that this document offers a rare opportunity to express the views of the upcoming generation of scientists with an interest in climate change.

2.0 Elements of the 'Ideal' Ph.D. Program

The interdisciplinary nature of climate-change research necessitates that a group of researchers, with varied backgrounds and interests, work together to address related research questions. Although climate change is an interdisciplinary field, the Working Group believes that students should retain a specialization in a discipline housed within a traditional department, since a 'jack-of-all-trades is a master of none', and the advancement of science often requires specialized knowledge. However, it is equally important for young profession-

Table I. Institutions granting PhD degrees to the 40 participants of the 2003 DISCCRS symposium. Thirty-six institutions and eleven countries are represented. Unless otherwise stated, the universities listed are in the United States.

Australian National University (Australia)
Boston University
Brazilian Institute of Space Research (Brazil)
Center for Scientific Research & Higher Education (Ensenada, Mexico)
College of William and Mary
Columbia University
George Mason University
Indiana University at Bloomington
Kansas State University
Massachusetts Institute of Technology
McMaster University (Canada)
New Mexico Institute of Mining and Technology
Princeton University
Rutgers University
State University of New York at Albany
Swedish University of Agricultural Sciences (Sweden)
UniversitÈ Pierre et Marie Curie (France)
University of Alaska at Fairbanks
University of Arizona
University of California at Berkeley
University of California at Davis
University of California at Los Angeles
University of California at Santa Barbara
University of Cambridge (United Kingdom)
University of Colorado at Boulder
University of East Anglia (United Kingdom)
University of Hamburg (Germany)
University of Minnesota-Twin Cities
University of Nebraska
University of South Carolina at Columbia
University of Texas at Austin
University of Vienna (Austria)
University of Washington
Uppsala University (Sweden)
Washington State University
Weizmann Institute of Science (Israel)

als to be exposed to collaboration and cross-fertilization as students, or they will experience difficulty in interacting with researchers from other disciplines once they graduate. To meet the conflicting demands of depth and breadth, the Working Group recommends that students be exposed to collaboration and cross-fertilization under the auspices of an interdisciplinary Climate Change Center/Program (CCC/P). The Working Group strongly believes that students trained in fundamentals, yet adequately exposed to collaboration with other disciplines through their affiliation with a CCC/P, will yield the best results for students, universities, and climate change science as a whole. Unfortunately, this places the graduate student in the tenuous position of having to maintain depth in their core discipline while maintaining breadth of exposure and learning in cognate disciplines. Therefore, coursework and related experiences for the graduate student in climate change science must facilitate this balance between specialization in a core discipline and opportunities for exposure to wider, related fields of study. Additionally, while the graduate student's research topic needs to remain firmly grounded in their core discipline, the significance and impact of their research should be disseminated to the wider climate change research community.

It is not sufficient to merely assemble an interdisciplinary group of researchers under the umbrella of a CCC/P, there also must be strong interaction amongst the members. Faculty, departmental, and institutional support for interdisciplinary research and interaction must be robust in order to successfully educate future climate-change scientists. By creating a CCC/P, universities can pool the resources of many departments without the need to create a new department (which could negatively affect traditional disciplines). Such a center or program would create a critical mass of people, knowledge and resources. With an interdisciplinary center, large universities can concentrate researchers from different backgrounds in one location (either physically or virtually), which often fosters the kind of interdisciplinary research needed in climate-change science. In smaller colleges, the concept of an interdisciplinary program could effectively train graduate students by drawing together resources from smaller departments, even though a critical mass does not exist in any one department.

Regardless of program size, faculty must be effective mentors in order to create an 'ideal' climate-change Ph.D. program. This entails treating the student with respect as a collaborator and assisting the student with job placement following completion of the degree. Additionally, students should have significant interaction with professors from different disciplinary backgrounds, thereby fostering an interdisciplinary mindset to research. Finally, universities must support faculty that are involved in the interdisciplinary program or center, by recognizing the value that these programs offer, and appropriating the necessary funds and providing release time to develop and support interdisciplinary faculty and programs.

2.1 Program Structure

The 'ideal' climate-change Ph.D. envisioned by the Working Group involves the development of a non-degree granting CCC/P that incorporates faculty from the social, life, and physical sciences. The Working Group is concerned that the time and effort needed to create a degree-granting program would require a commitment of resources that in the current economic environment is unlikely to be tenable. The Working Group believes that students exposed to other disciplines through the CCC/P will develop the needed skills to be future leaders in the climate change community, regardless of their degree. Nonetheless, the Working Group would encourage universities to grant some form of recognition of the student's involvement in the CCC/P, such as a climate-change Ph.D. minor (see section 3 for a description of a such a degree as granted by the Institute of the Study of the Planet Earth (ISPE) program at the University of Arizona).

Coursework: The curriculum for an 'ideal' Ph.D. climate-change program consists of 1) a limited number of core courses in theory and research methods that are vital to climate-change science, and 2) traditional disciplinary courses that provide students with depth of knowledge in their chosen discipline. The coursework associated with the CCC/P should introduce students to the multitudes of perspectives and sub-fields housed under climate change science. Hopefully, these classes will serve to increase student awareness of the interrelationships between the earth's surface and atmospheric processes, ecological systems, and human activities. The Working Group advocates a lecture-based class focusing on the history of climate change and a seminar series that covers 'hot' topics in climate change as essential components of a CCC/P. Further course details are provided in Box 1.

Semester away/short courses: The semester away/short courses would expose students to alternative approaches and methodologies used to tackle particular research questions. Some time away from the home institution is highly encouraged for those who have spent their entire post-graduate career at the same institute or have undertaken graduate study at a small university with limited resources. It is likely that the CCC/P could more easily facilitate (compared with a traditional disciplinary department) these interactions with other departments and institutes that focus primarily on climate-change research. It would be beneficial to set up a semester away/exchange program (similar to undergraduate programs) at a sister university where students can interact with a wider group of climate science researchers. Short courses such as those offered at University College London (http://www.geog.ucl.ac.uk/ecrc/teaching.stm/) can also provide students with a similar experience, increase their skill set, and perhaps most importantly, help students develop contacts across the wider climate-change research community.

***Seminars*:** Informal interactions with faculty, visiting researchers, and other students are probably one of the easiest ways for students to learn more about the research being carried out in their field. The CCC/P could facilitate these interactions and provide a forum for these informal interactions. A (in)formal seminar series, in which graduate students and researchers from varied backgrounds conducting climate-change research present on all manner of topics in a central location, would do much to increase the exposure of students currently cloistered in their respective departments to the wider climate-change community. A well-attended weekly seminar series such as this can serve

to introduce students to the broad range of research topics that are of interest to their colleagues and may inspire their own research, thereby creating a more fertile research environment.

Role of professional societies: Every student should maintain membership with at least one professional society. Generally, responsibility for ensuring this falls upon the student's mentor or more broadly the department in which the student is enrolled. However, the CCC/P may be able to introduce the student to professional societies outside of their advisor's area of expertise.

Professional societies provide a wealth of information, including current news, legislative policy development, science findings, job opportunities and upcoming conferences. By attending regional and international conferences, the student is exposed to leading scientists, unpublished data, and cutting-edge ideas in climate-change research. It is at these meetings where the graduate student will begin to establish themselves in their discipline, and to form the network of associations with other scientists that is essential to the student's professional development.

Bulletin Board/Webpage: The presence of a bulletin board (both physical and virtual) serves as a clearinghouse for opportunities in climate-change research, fellowships, grants, short courses, and fieldwork. This board could also be used to post papers and articles pertaining to recent climate-change research.

Conferences/Outreach: It is important for students to communicate their work early and often at professional conferences and workshops. Dissemination of their research in these forums can provide students with valuable feedback from other scientists and further increase their exposure to the wider climate-change community. Moreover, the Working Group believes that scientists have a duty to present their research to peers and to the public. Some meetings with excellent multi-disciplinary attendees are: the American Geophysical Union fall and spring meetings, the Geological Society of America annual meeting, and the AAAS meetings. Additionally, students should take the opportunity to present their research to a wider "non-academic" audience. Unfortunately, these types of presentations typically are not encouraged by advisors during a student's graduate career. Many informal opportunities exist locally, and others could be easily created. For example, local libraries and museums often have a science lecture series for the public where university professors and graduate students discuss topics of public interest. Judging local science fairs is another form of outreach; often local schools are scrambling to find judges and welcome graduate students. The "Partner in Science" series, where students visit local elementary schools, is another outstanding outreach opportunity. Caution must be exercised because it is easy to get overextended in a graduate project, but it is increasingly important to present scientific results to the general public in order to best inform decision makers of relevant climate-change research. Other areas where a student might disseminate knowledge are through teaching at local community colleges, co-op classes, and short courses.

Box 1: Specific Courses/Lectures/Seminars

History of climate-change science: This class would develop the major themes, issues and concepts that have been addressed or have arisen from global/climate change research. It should encompass the key developments in the fields of geology, biology, hydrology, geochemistry and atmospheric science that have furthered our understanding of past and present climate change. Particular issues that can be used to demonstrate the value of multi-disciplinary approaches to climate-change research include the carbon cycle and atmospheric carbon dioxide, global warming, conservation and biodiversity, sea level rise, depleted ozone and other aspects of atmospheric chemistry, etc. The issues addressed in this class could also be used to introduce students to the policy/political aspects of global/climate change research. For example, a class could consider how climate-change research was used in developing the IPCC: Climate Change 2001 report.

Hot topics in climate-change research: Incoming students could present recent, cutting-edge research in their particular area of expertise or the area in which they plan to focus. This class would probably take the form of a seminar series that would largely be guided by student interest and input. This class may also serve as the venue for faculty affiliated with the program to present their own research. The goal of this class is to expose students to the cutting edge of the various subfields of climate-change research and to introduce them to novel techniques and methods that are being used to advance our understanding of the climate system.

Perspective on Global Climate Change: Climate, Environment and Society: This class would introduce students to the complex inter-relationship(s) that exists between the natural environment, the social environment, and climate change. Subject matter that could be addressed includes the human costs of global/climate change, obstacles to reducing greenhouse gas emissions, impact of deforestation on climate, climate change and development issues, etc.

Climate Change: Science and Policy Implications: Policy makers increasingly are using science to support their views on regulations and legislation. As we train the next generation of scientific leaders, we must educate them early in their careers on how science is used in policy environments. Historically, few programs have acknowledged, let alone given instruction, in science and policy. While science must remain politically neutral, scientists must understand the policy implications of their work.

2.2 Faculty

Even with an outstanding program structure, poor coordination of faculty, faculty that are more interested in protecting turf than collaborating across disciplines, or faculty lacking energy and vision could ruin the CCC//P and a student's academic training. All things being equal, the 'ideal' Ph.D. program would benefit from large and academically diverse faculty, faculty adept at mentoring students, and strong institutional support for the faculty participating in an interdisciplinary climate-change program.

Faculty size: It takes a critical mass of interested faculty members to establish a program of graduate study in climate change. Since the CCC/P envisioned here can draw faculty from several different disciplines and departments, it could successfully exist even in smaller colleges. However, the magnitude of resources available from different departments at the larger schools may create a more sustainable program. A large CCC/P can create an excellent environment for interactions among teams of researchers.

Faculty mentoring: Regardless of the graduate program's physical size, location, or structure, the student's development is highly dependent upon their major professor. A good major professor is first and foremost a good mentor, who will train and direct the student through the difficult transition from student to peer. The Working Group feels an in-depth discussion of mentoring is beyond the scope of this paper, but we recommend interested readers to examine the DISCCRS Working Group Report on Mentoring for recommendations (http://aslo.org/phd/mentoring.pdf).

***Institutional support for faculty*:** Climate-change research spans across many disciplines, ranging from the historical, to the physical, to the biological, to the social sciences, and ultimately impacts policy decisions. Traditional departmental sources of funding often do not exist for climate-change research, and faculty efforts to secure extramural funding are increasingly competitive. It is essential that universities embrace the interdisciplinary nature of the CCC/P and appropriate the necessary funds to support faculty interested in participating in the CCC/P. Incentives for faculty to design interdisciplinary courses, preferably to be team-taught with faculty members from different departments, would provide an excellent start for the CCC/P. A campus-wide conference or symposium on climate change is another excellent tool to highlight the value of, and publicize, new research based on the CCC/P structure.

Graduation: Graduates from the CCC/P likely will be employed in academia, government, or industry. The academic community needs highly qualified faculty, particularly in newly emerging fields such as climate change, and the CCC/P is an excellent venue for training the next generation of climate-change faculty. The breadth of knowledge gained by graduates of a CCC/P would be well-suited to teaching in undergraduate-only colleges, owing to their broad background, while the experience of interacting with researchers from other disciplines would suit the CCC/P graduates in research universities. The ability to work across traditional disciplinary field also would benefit graduates who are working in government labs, while both interdisciplinary experience and an introduction to science policy would lend graduates of the CCC/P an edge in government or NGO science-policy work. Finally, in the dynamic world of industry, the Working Group believes that CCC/P graduates would have an edge with their broad skill set.

3.0 Current Interdisciplinary Climate Change Ph.D. Programs

Strong interdisciplinary programs in climate science or global change maintain a delicate balance of providing core courses to bring students from a variety of backgrounds together and facilitate a basic understanding of core concepts in the field, while simultaneously providing opportunities for exposure to a broad array of interrelated fields in a hands-on capacity. A common thread is for students to develop a strong disciplinary background while always placing their work in the context of other fields. This ultimately leads to new research directions embracing multiple disciplines and impacting societally relevant issues. Below are several program descriptions that highlight some successful programs in climate and global change science. This is by no means an exhaustive list; there are many successful programs. Our intent is to highlight some of the most critical elements of a successful graduate program, that our group has some experience with. These include well-attended seminar series, flexible course designs, internal and external collaborations, and mechanisms for communication among a spectrum of disciplines.

Stanford University, The Earth Systems Program
http://pangea.stanford.edu

The ESP program is currently only available at the undergraduate and master's level, although a Ph.D. program is currently in the works. The program requires students to focus on one of seven areas of study in order to provide the student with adequate depth of knowledge in a particular subject area. However, it also encourages breadth of knowledge by requiring coursework ranging from biology and chemistry to economics and policy. In addition, students are required to complete a 270-hour internship, providing a hands-on, rigorous academic experience working on a supervised project of their choice. The master's seminar course puts students into interdisciplinary teams where they do original research on current environmental issues. It provides a true interdisciplinary research experience, similar to real world problems, particularly in situations where a variety of scientists are asked to evaluate the impact of a proposed policy or provide ideas for addressing an environmental problem.

University of Arizona, The Insitute for the Study of Planet Earth (ISPE)
http://www.ispe.arizona.edu/index.html

ISPE seeks to provide disciplinary and interdisciplinary research training in the context of the environment of the Earth over both temporal and spatial scales. A main goal of the institute is to forge new paradigms in University partnership with society's decision-makers. Unique opportunities for graduate students include a Ph.D. Minor in Global Change, a Global Change Workshop, and NASA Space Grant Fellowships. The Ph.D. minor provides students with a broad understanding of critical concepts and state-of-the-art skills in the rapidly emerging fieldof global change. Four courses are required: global biogeochemical cycles, the climate system, the global change workshop, and one elective. Students also include two faculty members from the committee on global change on their dissertation committees and work with them throughout their degree

program. The global change workshop provides a forum for investigating global change impacts in an interdisciplinary context. The fellowships are awarded to exceptional students interested in promoting the understanding of space-related research to the public and who are studying in a variety of disciplines ranging from space and earth sciences to public policy as well as global-change related fields.

University of Colorado, Boulder; The Institute of Arctic and Alpine Research (INSTAAR)
http://instaar.colorado.edu

INSTAAR facilitates interdisciplinary research specializing in high-altitude and high-latitude regions of the world, as well as non-cold-region Quaternary studies, geochronology, and earth system dynamics. Research is also undertaken to understand the affect of natural and human induced physical and biogeochemical processes on the local, regional, and global scales. INSTAAR'S Teaching Mission is directed towards fostering an appreciation and understanding of the biological, chemical, and physical processes operating in continental and ocean environments. INSTAAR students are registered for degree programs in an appropriate department and college, such as Engineering, Biology, Geography, Geological Sciences, and Atmospheric and Ocean Sciences, for their primary coursework and teaching experiences, while maintaining their primary research home with INSTAAR. Students benefit from affiliation with INSTAAR by being exposed to interdisciplinary classes and research opportunities, field work opportunities, 30 scientific laboratories and facilities, the Mountain Research Station, international educational experiences, and volunteer outreach opportunities. Students also profit from a weekly colloquium by INSTAAR scientists or invited scientists, as well as a weekly Graduate Student Seminar Series.

National Science Foundation, Integrative Graduate Education and Research Traineeship (IGERT) Program
http://www.nsf.gov/home/crssprgm/igert/start.htm
http://atlas.islandinstitute.org/igert/

The IGERT program has been developed to meet the challenges of educating U.S. Ph.D. scientists, engineers, and educators with the interdisciplinary backgrounds, deep knowledge in chosen disciplines, and technical, professional, and personal skills to become in their own careers the leaders and creative agents for change. The program is intended to catalyze a cultural change in graduate education, for students, faculty, and institutions, by establishing innovative new models for graduate education and training in a fertile environment for collaborative research that transcends traditional disciplinary boundaries. It is also intended to facilitate greater diversity in student participation and preparation, and to contribute to the development of a diverse, globally-engaged science and engineering workforce. The program comprises approximately 100 award sites across the country in areas of academic interest including biological sciences, computer and information science and engineering, engineering, geosciences, mathematical and physical sciences, and social, behavioral and economics. Ph.D. students awarded IGERT fellowships receive stipend and tuition support, plus funds for research materials, which varies for each program.

4.0 Conclusion

The training of the next generation of climate-change researchers is of utmost importance as climate change and its associated impacts take on increasing local, regional, and global relevance. This report seeks to address this issue by highlighting aspects of a successful climate-change Ph.D. program; a program which seeks to balance traditional disciplinary training with exposure to the broader, interdisciplinary climate-change community. While the heart of any Climate Change Center/Program (CCC/P) lies in the motivation of the students, the dedication and mentoring of the faculty, and the existence of strong institutional support, it is equally critical that the structure of the program remains flexible and allows for individual creativity and growth. The creation of a CCC/P, as envisioned by the Working Group, will have a number of benefits for society and for climate-change research as a whole; it will better prepare recent graduates to communicate their research in climate-change science to the public and policy makers, it will help facilitate collaboration amongst researchers from fields that traditionally do not have strong ties, and it will likely improve job placement for graduates of these Centers or Programs. As the current academic system evolves to face the increasingly interdisciplinary and interconnected nature of the world we live in, the Working Group is hopeful that next generation of climate-change scientists produced by Climate Change Centers/Programs, such as described above, will be better prepared to contribute to the debate and conversation associated with this important societal concern.

Acknowledgments

DISCCRS is supported by the National Science Foundation's Geosciences Directorate and the National Aeronautics and Space Administration's Office of Earth Science through NSF EAR 010521 to Whitman College. Program information is available at http://aslo.org/phd.html. The Working Group thanks C. Susan Weiler for organizing the DISCCRS symposium and suggesting 'The Ideal Ph.D. Program for Climate-Change Studies' as a topic for discussion among the 40 participants at the 2003 DISCCRS Symposium. We thank all participants for input and particularly Astrid Schnetzer, Andy Ridgwell, Zewdu Eshetu for comments during our organizational meeting.