



## **HDGC SUMMARY REPORT 2003 – 2004**

### **I. OVERVIEW OF ACTIVITIES**

This report summarizes the activities of the Center for Integrated Study of the Human Dimensions of Global Change during its eighth year, July 1<sup>st</sup>, 2003 to June 30<sup>th</sup> 2004, the final year of its full operation. In it, we maintained the core objective that has guided us from the beginning, finding ways to get the relevant sciences to work together in order to solve fundamental problems of human dimensions of global change. In so doing, we have tried to make the basic academic disciplines more useful by applying their results to important problems. Through these applications, we have also tried to strengthen the core disciplines. On the one hand, the applications provide tests of the precision and validity of existing results, methods, and theories. On the other hand, the applications can encourage the disciplines to consider issues that might not have arisen without these exogenous drivers (making the work relevant and comprehensible to other disciplines and practitioners).

As our confidence in integrated assessment increased, we have added a second major objective, communicating with citizens about the modeling process and content. In keeping with emerging philosophies of participatory management, we have viewed this as a two-way process. To the extent possible, those affected by a change should be involved in shaping models, to provide them information that they need, in order to understand the situations that they face, and to make decisions in their own best interests. They also provide their insights to models, typically developed by generalists, who cannot know local conditions as well as those living in them. As the modeling proceeds, citizens are entitled to receive its results in a comprehensible form. Our research has, in effect, sought to create the science needed to complete the bridge between science and citizens, just as it sought, initially, to create bridges within the scientific community.

A centerpiece of the Center's first four years was the nested, and interrelated set of ICAM models. They undertook the ambitious task of providing a comprehensive perspective on the drivers and consequences of global climate change. Those models, and the results coming from them, have become well known in the scientific and policy discussions over these issues. For the Center, they provided a common platform for many researchers to work on problems together; they identified and addressed conceptual issues, central to any integrated assessment; and they spun off many specific projects, whose importance was identified through ICAM's systematic approach for the big picture. ICAM has been elaborated, documented, and given away through our web site. Its results, development, and developers were integral parts of the research and policy community (e.g., the IPCC, US National Assessment). However, at our mid-course assessment, we decided to shift our focus from creating an encompassing global model to applying the methodology to regional models or ones that could illuminate cross-cutting problems, taking advantage of results from global models. Doing so also facilitated creating problems formulated in ways suited to citizen involvement (because they address issues that are subject to specific personal and policy choices). Many of those issues are far removed from our original climate focus.

A somewhat parallel process has been followed by the SYPR project, centered at Clark University and partially supported by the Center. It has created a platform for interdisciplinary and inter-institutional research, providing an integrated assessment of human-environment

interactions at a specific place, the southern Yucatan Peninsula. With that local, albeit still very large focus, it has been able to take advantage of the detailed examination of small-scale household decisions (which the successor models to ICAM have also considered). Creating the model has not only taken advantage of existing empirical research, but also helped to focus future fieldwork and generated innovative theoretical research, such as the agent-based approach to modeling change. The project, funded also by NASA, has demonstrated the understanding that can be gained from this integrated approach to studying the linkages between the social and biophysical subcomponents of the coupled human-environment system, including the changing vulnerability of that system, and made significant advances in spatially explicit modeling, both explanatory and integrated assessment in kind. (<http://earth.clarku.edu/lcluc/>.) The complementary Human Environment Regional Observatory looks at the relationship between water, climate change and LUCC in Massachusetts. (<http://www.clarku.edu/departments/HERO/>.) One focus of the collaboration with other HDGC researchers has been the development of statistical procedures of LUCC-model validation, the results of which are incorporated into the Geographic Information System software Idrisi, which is then distributed to 35000 users worldwide.

To these, we have added the Transboundary Protected Areas Research Initiative (TPARI), in conjunction with the University of Witwatersrand (South Africa) and the International Union for Conservation of Nature – South Africa, with collaborators from other universities in the United States (Bates, Georgia, the Savannah Consortium, based at the Universities of Virginia and West Virginia, and the ALAM Partnership, based at Yale and Georgia), Southern Africa, and Europe. The initiative considers the sustainability of Transboundary Protected Areas (TBPAs), viewed as coupled human-environment systems that operate across scales and boundaries. As a case study, it uses the Great Limpopo Transfrontier Park<sup>1</sup> (GLTP), in NE South Africa, SW Mozambique, and SE Zimbabwe. Its research objectives are to assess the nature of the social and natural transformations brought about by TBPAs, provide an independent research service, and make critical and constructive contributions to the policy decision-making process relating to the GLTP. Specific research themes include: (a) the eco-regional planning framework and linkages between planning processes across scales and boundaries; (b) historical vulnerabilities and adaptation of local people to climate variability, resource limitations and political ecologies; (c) the social and economic framework of the GLTP with an emphasis on land ownership and land reform; (d) tourism development and community-based tourism initiatives launched in the GLTP area over the last decade, with special emphasis of community-public-private partnerships; (e) the GLTCA decision-making process and governance. Having an academic independent base outside the region has afforded an unusual ability to create connections with the wide range of academic and other actors involved in research in the GLTP, regardless of their institutional affiliation. Throughout, the initiative has sought to enhance the benefits of research for local people.

The general approach has also been used as an organizing methodology for several critical topics that had been intensely studied, but in somewhat fragmented ways. Five initiatives will give a feeling for the extensions of the approach:

Center members played a central role in convening a Dahlem Conference, bringing together many leaders in this field. It has succeeded in moving forward ARIDNet, an international network of researchers concerned with arid lands, including several Center researchers. It is the sustained support for our activities that has allowed these relationships to develop over time. At its core is the “Dahlem Desertification Paradigm” (DDP), which provides a way to act on the realization that desertification cannot be framed in terms of single measures alone but must simultaneously involve both *biophysical* and *socio-economic* factors. These factors, and action implications, are determinable because a limited number of ‘slow’ variables determine the dynamics of linked

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<sup>1</sup> The GLTP consists of Protected Areas in South Africa, Zimbabwe and Mozambique

biophysical/socio-economic systems at different scales. ARIDNet has received five years of continuation funds from NSF.

We have just begun a collaboration with a marine biologist (Liana McManus) and anthropologist (Sarah Meltzoff) at the University of Miami to conduct an integrated gap analysis at three sites with critical issues in human-environment problems solving: Phang Nga Bay, Thailand; Ulugan Bay, Philippines and Galapagos Islands, Ecuador. Each demonstrates land-sea interactions at local, national, and international management hot spots. We are aiming to identify decision-making and coping mechanism vulnerabilities, looking at social organization in terms of leadership patterns that advance understanding the interactions among the various stakeholder groups who vie over access to natural resources. The field work is being developed in a way that should suit subsequent integrated assessment and communication.

An unanticipated opportunity to extend the Center's approach arose after September 11<sup>th</sup>. Through research, writing, and presentations, we have shown how integrated assessment provides an approach for ensuring concurrent treatment of risk analysis and risk communication. We have also conducted original empirical studies regarding risk perception and communication on these vital topics, showing the roles of cognitive and emotional factors. Center research begun before Sept. 11<sup>th</sup> had been examining the vulnerability of national electric networks to malicious damage. This research has clear extensions to the new situation, as does our ongoing work relating energy independence and the design of electricity networks to national security. The work has, we believe, provided a way to incorporate the social and behavioral sciences in management processes dominated by natural scientists and engineers. A Center member serves on the Department of Homeland Security's Science and Technology Advisory Committee.

We have continued to develop integrated assessments for biotechnology. Earlier work considered the information needs of citizens concerned with the viability of firms taking the social risks associated with these technologies, as well as those of regulators and industrialists applying real-option approaches to that task. We have begun collaborations with networks of specialists in the United States and in Canada to apply our approach, with the goal of developing better policies and technologies that should be possible with fuller, more widely shared, understandings of the technologies social, economic, and ethical impacts. The Canadian network uses integrated assessment to structure a scientifically informed dialogue about ethical issues. The US network uses xenotransplantation (in which engineered animals provide organs for humans) as a context for incorporating scenario planning in integrated assessments of highly uncertain processes.

We have teamed with researchers at Penn State and elsewhere to apply our approach and climate-related research to the challenge of providing decision makers with information and tools for making choices related to multiple stressors such as changes in land use and climate. Effective tools require integrative assessments, pulling together diverse factors in a way that reflects their underlying uncertainties. The Consortium for Atlantic Regional Assessment (CARA), in which we participate, is perhaps the leader in sustaining the momentum created by the US National Assessment of regional impacts of climate change. The Assessment as a whole was the topic of a workshop that we convened (in April 2004), bringing together organizers, participants, and independent observers

In each of these areas (and others), the framework created by the integrated assessment has identified basic research issues of importance in their own right. In some cases, these needs have arisen from challenges in adapting existing research; in other cases, from discovering holes in the disciplinary research. A sampling of these projects is described in the text below (and more fully in the appendices).

At our 2001 annual meeting, in consultation with Center members and our external advisors, we developed a strategic plan for the final three years of the NSF-funded Center. It attempts to replicate and extend the success of our integrated assessment experience in three substantive

domains, building on Center strengths, while looking at four crosscutting issues that arise in these applications (and many others).

The three domains are:

Transitions to sustainable energy systems

Environment and human health

Impacts of and adaptation to multiple stressors and extreme events

The four crosscutting issues are:

Capturing adaptive learning

Understanding and valuing non-marginal change

Representing equity and its implications

Rendering IA approaches and its finding from its application accessible

We did not know, at the time of that strategic planning session, about the change in the world that would come into view on the ensuing September 11<sup>th</sup>. With supplementary support from NSF, we began a series of studies into the roles of affect and personal experience in response to terror. We have subsequently become involved, through our research and public involvement, in trying to bring the Center's approach to this national service. To that end, we have added homeland security as a fourth focal domain. Our efforts have been recognized in the appointment of a Center member to the Department of Homeland Security's Science and Technology Advisory Committee, supplementary funding from the MacArthur Foundation, and some media attention, in addition to the usual publication and public service.

We have also proceeded with the reorganized administrative structure emerging from the 2001 meeting. One member of our Executive Committee has coordinated activities in each of the three domains. These are Granger Morgan for energy, Hadi Dowlatabadi for health, and Gary Yohe for extreme events. Baruch Fischhoff is Center Director, having replaced Hadi Dowlatabadi, who expanded our "satellite" activity at the University of British Columbia, joining Tim McDaniels, Robin Gregory, and their associates. Hadi is CRC Professor, sitting in the Sustainable Development Research Institute, while continuing as Adjunct Professor at Carnegie Mellon and as an active member of the Center and its Executive Committee. We have continued with our goal of better integrating the social sciences in Center activities. These sciences are, clearly, central to each domain and crosscutting theme. We have encouraged Center members to adopt the default assumption that their projects require physical, biological, and social science contributions. In that perspective, an explanation is needed when a narrower view is adopted.

The substantive report that follows is organized in terms of these domains, with examples of research drawn from each. Fuller reports appear in the attached appendices.

## **II. RESEARCH**

### **FOCAL DOMAINS**

#### *Transitions to sustainable energy systems*

Energy use is central to human activity. Current energy systems impose large burdens on the environment, at local, regional and global scales. In terms of global climate change, the primary culprit is carbon. Much of our research has focused on ways to reduce the burden that carbon-based fuels place on the environment. In each context, we have been committed to developing integrative methodologies, pulling together previously disparate strands of research. With the expansion of the Carnegie Electrical Industry Center, spun off from HDGC several years ago, this research has continued increasingly under other sponsorship. Although the research groups

overlap substantially and interact regularly, we report here only research directly supported by HDGC.

Industrial Carbon Management. *Industrial Carbon Management* (ICM) is the emerging field of dealing with the carbon associated with traditional fuels. There are basically three strategies for improved carbon management: (1) post-combustion separation after combustion in air, (2) pre-combustion separation, and (3) combustion in oxygen. A “revolution” is underway in thinking about ICM, arising from the realization that many powerful technologies are already commercially viable.

We have a big hydrogen economy. The US uses about 1.7% of its primary energy to produce H<sub>2</sub> from fossil fuel.

We move CO<sub>2</sub> distances of hundreds of kilometers in large pipelines.

We inject large quantities of CO<sub>2</sub> into deep geological formations for secondary oil recovery.

ICM’s apparent technological and economic attractiveness has major implications for the political economy of abatement and the design of abatement policies. ICM also carries novel environmental risks and raises serious inter-generational equity issues, which urgently require assessment.

In work this year, we have continued our coordinated set of projects on carbon sequestration. An approach to mitigate global climate change that is gaining in interest is to control CO<sub>2</sub> emissions by capture and sequestration of CO<sub>2</sub> from fossil fuel combustion sources. Power plants, which are the largest stationary sources of CO<sub>2</sub>, are the major targets for such efforts. However, there are major issues regarding the technical feasibility (due to scale of application, limited experience), economic viability (due especially to large energy penalties that lead to high costs), and environmental concerns (due to uncertainty regarding impacts and public acceptance of sequestration, secondary impacts on other pollutants, and the possibility of faster depletion of fossil fuel resources). In order to understand these issues, we have continued to elaborate our modeling framework for simulating the performance and costs of fossil-fuel based power plants with environmental controls (IECM) to include CO<sub>2</sub> control using an amine-based system for post-combustion CO<sub>2</sub> capture from coal-fired or gas-fired flue gas. Both new and retrofit cases on PC and NGCC plants can be simulated using this model. Last year, we also conducted an expert elicitation study to understand what experts in this field believe about the potential for improvements in the future amine systems. Results of the analysis indicated potential for cost reductions of 18-35% from improvements in four key process parameters.

Of course, there is a lot of CO<sub>2</sub> already “out there,” in the atmosphere. It is possible, in principle to capture CO<sub>2</sub> directly from the air. However, it may be prohibitively expensive or pose other problems. We have begun to explore the implications of air capture for climate policy using an Integrated Assessment Model. We have been focusing on a calcium carbonate air capture system at the process engineering level.

We have also begun a systematic assessment of proposed geochemical approaches to storing carbon. Our research involves comparing several different proposed strategies for engineering the chemical conversion of CO<sub>2</sub> gas into solid carbonate minerals and dissolved bicarbonate in solution. Each proposed idea is being examined and evaluated based upon technical feasibility, effectiveness (i.e. potential level of reductions), environmental impacts, safety, cost, distribution and equity, and public attitude. In addition to reviewing the current state of understanding of the technical, economic, and sociopolitical feasibility of these chemical approaches, our paper will provide a systematic examination of how these proposed methods of reducing atmospheric CO<sub>2</sub> concentrations compare to other mitigation strategies including both generally accepted approaches and more radical geoengineering strategies.

Although well understood by industry (in a general sense), these technologies are largely unknown to the general public, which must pass judgment on their acceptability. In some ways,

this is a conventional challenge in risk communication; ensure that people understand the technology and its impacts. In other ways, though, it is novel, insofar as the technology will, likely, evolve during the course of a project, as the engineering science improves. As a result, we have taken the challenge of adapting the mental models approach to a series of recently completed interviews with citizens, in order to develop materials and standards for communication about CCS. Study 1 involved face-to-face interviews with 18 non-technical respondents, who shared their beliefs after receiving basic information about the technologies and, again, after getting specific details. The second study involved a closed-form survey, measuring the prevalence of beliefs revealed in Study 1, and how they correspond with public acceptance of the technologies. It was administered to an opportunity sample of 126 members of the general public. Study results suggest that the public may develop misgivings about deep injection of carbon dioxide because it can be seen as temporizing, and perhaps creating future problems. Ocean injection was seen as more problematic than geological injection. Many respondents wanted to frame the issue in the broader context of alternative strategies for carbon management. Given the limits to current public understanding of many alternatives that will require an approach to public communication and regulation that is open and respectful of public concerns.

In addition to completing this project designed to anticipate public response to the prospect of large-scale sequestration, we have conducted a review of existing regulations that might be applied to the technology. We have attempted to anticipate potential regulatory obstacles by proposing a conceptual framework for appropriate regulation of deep geological injection. It incorporates the results of the mental models studies, as well as the technical realities revealed by our engineering studies.

Renewable Energy Sources. In many parts of the world, there is increasing interest in renewable energy sources. Some of these, like wind and geothermal, provide alternatives to carbon-based fuels. However, many involve alternative uses of carbon, whose environmental consequences are incompletely understood. That uncertainty also complicates their economic viability, in a future where there may be incentives for different treatments of carbon. Biomass energy has been seen both as a (nearly) CO<sub>2</sub>-neutral substitute for fossil fuels and as a means of offsetting industrial emissions by sequestering carbon in terrestrial ecosystems. Like CCS technologies, it is increasingly regarded as a feasible means to decouple the energy sector from atmospheric CO<sub>2</sub> emissions, due to its compatibility with the existing energy infrastructure. Our research on biomass energy, using either agricultural “wastes” or purposely grown crops, has looked at co-firing biomass with coal, coupling it with ICM, and the possibilities for distributed generation.

Modern biomass energy, which was first advanced as a solution to supposed shortages of fossil fuels, has emerged into the climate policy debate as an (almost) CO<sub>2</sub>-neutral substitute for fossil fuels. We have been comparing uses for biomass (e.g., ethanol vs electricity), aiming to systematically compare the economic efficiency of various end uses under given prices for emissions of CO<sub>2</sub> and other pollutants. We are also investigating the environmental cost of large-scale biomass production.

The transportation sector represents the single largest source of North America's greenhouse gas (GHG) emissions. About 25% of North America's GHG emissions come from transportation, a sector whose contribution is growing rapidly. Biodiesel is a renewable alternative fuel that can be used either as a substitute or in a blend with conventional diesel fuel used in transport. There are substantial environmental benefits to be gained by the adoption of biodiesel. In particular, net reductions in GHG emissions can be generated if wastes such as used vegetable oil or animal fats are used in production of biodiesel. This project is conducting an integrated assessment of biodiesel production in British Columbia, with a focus on the use of waste as input feedstock. It is also evaluating the availability of waste as feedstock, developing models for analyzing the

economic feasibility of biodiesel, and examining the role of policy and regulatory tools for promoting investments in biodiesel production.

Our research on the viability of large-scale wind power has focused on examining the possibility that large-scale extraction of wind power will alter climate by extracting energy and momentum from the planetary boundary layer. Simple scaling arguments suggest that this effect might be important. This is a collaborative effort that involves scientists at CMU, NCAR and GFDL. The results have such large potential impact on this industry that we are saying nothing about them, until they have undergone rigorous review, currently underway.

Finally, we have collaborated with an ongoing project (based at the University of California-Berkeley) looking at the political and economic realities of decisions regarding choices among renewable energy technologies. Using fieldwork in Thailand, as primary source material, it provides a detailed case study regarding solar energy, focused on hidden aspects of technology transfer, such as organizational and cultural constraints. Conflicting goals and cultures are found to hinder the uptake of otherwise attractive technologies, while confounding customary analyses of their efficacy. Its approach differs from 'technology assessments' by focusing on otherwise-hidden aspects of technology transfer, namely, the organizational and cultural constraints, found even when hardware is technically competent. Conflicting goal hierarchies between the major stakeholders and cultural difficulties hinder the smooth uptake of these technologies, leading to what have been incorrectly identified as technical failures. We identify the importance of more fully involving state policy decision-makers, planners and engineers.

Consumer Behavior. Energy would be less of a problem, if people used less of it. Our previous research looked at consumption in households. It asked questions like: Why do less than half of those who are informed about energy savings alternatives choose to use that knowledge? Why does facing full market forces only raise the proportion of those who use information to save energy expenditures from 22% to 37%? Why are expenditures of 10% of household income on residential energy insufficient market pressure to promote energy saving investments? What are the implications of the above for design of more equitable and efficacious public policy?

Our most recent work has turned to two rather different sectors, with energy choices considered along with other environmentally consequential ones. One of those sectors is small and medium-sized enterprises (SMEs). We are examining the diffusion of best practices in purchasing among the clients of a local cooperative known for its own sustainable and ethical business management practices – VancCity. An initial survey is identifying motivations, barriers and capacity for more sustainable procurement decisions among consumers. We will then use mailings, websites and personal contacts to introduce SME managers to a range of products already certified as being environmentally and socially acceptable by a federally funded institution. Follow-up surveys and tracking (using unique id vouchers) will be used to determine motivations, barriers and results of participating SMEs. The data gathered will be analyzed to explore whether response patterns are attributable to particular firm or product characteristics.

The second "sector" is adolescents, the focus of several projects. Society's ability to successfully adapt to change depends greatly on passing to the next generation the capacity to be agents of change. Such capacity includes knowledge of the forces of change and of collective and individual actions that can affect change. We have begun a project investigating teens' mental models of actions they can take to affect that change, designed to facilitate the design of educational programs that develop their capacity and desire for collective and individual action. The underlying integrated assessment will be formulated in terms of life-cycle analysis. That will guide both the mental models interviews and the educational interventions, serving as a template against which mental models can be compared.

*Environment and human health.*

The impacts of environmental changes on human health have long been recognized. They were most easily identified at the local level, the focus of early environmental regulation. Gradually, awareness grew for long-distance effects, such as acid rain and, most recently, climate change. These processes have physical, biological, and human determinants. Clearly, they call for integrated assessments. We are pursuing those in three domains: air pollution, water-borne pathogens, and mining. We have also been working on an analytical formulation of the conditions for ensuring adequately informing people about health risks.

Air Pollution. The challenges facing poorer nations are hardly represented by the body of science used to compile IPCC reports. For example, the proposed air quality gains as ancillary benefits of climate policy are entirely based on environmental conditions, exposure patterns and epidemiology of the US. These are hardly representative of the conditions prevailing for the majority of the world's population. We are creating an integrated assessment to answer the question: how will climate policy influence residential energy choices, air quality, exposure, and health effects in developing countries? Specifically how might climate policy retard (or accelerate) the transition from traditional, higher-polluting, non-commercial biofuels to commercial, relatively clean fossil fuels and or clean renewables? Differences in rural versus urban populations and indoor versus outdoor air pollution sources and exposure, and gender and age (i.e. women and children) will be critical. The findings will include emissions from fuel use, modeling of indoor air quality, exposure by activity, gender and age, and expected health impacts.

We have completed an analysis using the attribution of lung cancer risk as a demonstration of a new methodology for conducting bounding analyses. For cancers with more than one risk factor, the sum of probabilistic estimates of the number of cancers attributable to each individual factor may exceed the total number of cases observed when uncertainties about exposure and dose-response for some factors is high. Our method bounds the fraction of lung cancer fatalities not attributed to specific well-studied causes. Available data and systematically elicited expert judgment are used to attribute portions of the observed lung cancer mortality to known causes such as smoking, residential radon, and asbestos fibers; describe the uncertainty surrounding those estimates; and, quantify the interactions among them. An upper bound on the residual risk due to other causes is then inferred using a coherence constraint on the total number of deaths, a maximum uncertainty principle, and imprecise probabilities.

Water-related health problems. Clean water is critical to health. Earlier Center research placed vector-borne diseases in a fuller social, political, and economic context. It sought to refine the sometimes simplistic connections made between tropical diseases (e.g., malaria) and climate change. We have continued that approach to integrating social and environmental variables. One project considers waterborne disease outbreaks in British Columbia. Many of these events were associated with extreme weather such as floods and first run-off after prolonged droughts. A climate is a likely factor in explaining these events and predicting future ones. A more systematic perspective should also consider the changing demographics of the region's population. For example, it is the retirement haven of Canadians. Moreover, diseases (e.g. HIV) and medical interventions (e.g., chemotherapy) have affected the immune status of the population. Our goal is to assess the risk of waterborne illnesses among various sub-populations, and develop risk reduction strategies that consider institutional and personal behaviors. To this end, British Columbia has unique records, which allow examining each patient visit to hospitals and physicians and their possible connection to weather events and boil water advisories. We have also designed a survey to be administered (after each new boil water advisory) in order to develop a more complete picture of unreported ailments as well as those that have been recorded by the health-care system. By the project's completion, we plan to develop a systematic approach to water quality management that is contextually sensitive and can be used as a template for water quality management in other regions of the world.

The events of September 11<sup>th</sup> have led to many changes in society. In some ways, they have adversely affected the environmental, including a diversion of resources from long-standing environmental concerns. However, the connection between water quality and security issues has created new concerns and technologies for monitoring. Anticipating the development of a new generation of sensors, we are developing efficient algorithms for their use and placement within a water supply and distribution system in order to mitigate waterborne disease risk. The specific research examines the human dimensions of the global social changes related to the spread of terrorism. However, the general methodology has broader applications for the protection of public health, by leading toward an optimization model for the placement for sensors, given assumptions regarding the risks of contamination events. As a test of its generality, we have worked through the outlines of its application to the protection of local and tourist populations in developing contexts.

Multi-media health problems. Mining operations are known to have economic, environmental, health and social impacts. The economic and environmental effects of mining operations have been relatively well studied throughout the world. However, the health and social impacts of mining operations, especially the boom and bust cycle inherent to the industry, have been poorly characterized. Furthermore, mining companies are now facing increasing pressures to incorporate social and health indicators in their assessments. Using British Columbia's linked database of physician and hospital visits, plus census data, we are assessing communities on a series of health and social indicators to (1) evaluate the effect of the boom and bust cycle on community health and social well-being, and (2) to identify indicators most reflective of community health and social well-being which could then be operationalized for mining company assessments and policy recommendations.

Conditions for informed consent. Individuals and communities exposed to environmental and health risks are often held to have the right to being informed about the risks that they face. Communications procedures are often legally mandated, and ethically prescribed. However, these requirements are often fuzzy on what it means to be properly informed. Those exposed could actually be worse off as a result of these “protections.” They may have lost their legal and political right to claim that they were not told, despite not receiving pertinent, useful information. Their “failure” to understand incompetent communications may be invoked to undermine their standing. An objective of several of our projects has been to determine the critical information set, for understanding risks. In the last year, we have undertaken a project designed to translate that case-specific experience into general rules for determining the adequacy of environmental and health risk communications.

We are focusing on labels, as a structured form of risk communication, in order to simplify the analytical work. They are a common enough form, seen in green labeling, product warnings, etc. However, the project is conceptualized so that it could be extended to community consultations, and other mechanisms. The research examines the current paradigm of labeling regulation and the larger legal environment in which risk communication is regulated and evaluated. We argue that, within constraints of the law, information should be evaluated according to its impact on recipients' decision making. This research begins by creating a decision-specific model of the label, considering the best-available information of the product's risks and benefits for a heterogeneous population of recipients. It implements the model in steps of increasing behavioral realism. The first step is a normative, “objective”, characterization of the decision, modeling how it would look to a rational decision maker with the recipients' goals and interests and perfect understanding of all of the available scientific evidence (and attendant uncertainties) regarding the consequences of products risks and benefits. Subsequent steps examine, descriptively, the decisions that would be made by rational individuals, considering the information actually available to them in labels under different regulatory schemes. Further, weakening the rationality assumptions, it estimates choices that would be made by consumers acting in behaviorally realistic ways. The choices modeled in the descriptive analysis are compared to those in the

normative analysis. A final prescriptive analysis integrates regulatory philosophy and constraints and determines the adequacy or acceptability of labels as risk communication. This step will be looking for policy recommendations for incorporating such considerations in regulatory procedures, recognizing the resource constraints of the parties.

### ***Impacts of and adaptation to multiple stresses and extreme events***

A distinctive feature of many potential global changes is that they reflect the confluence of multiple stresses, combining in ways whose interactions cannot be anticipated, that human systems were not designed to bear, and that natural systems cannot withstand. They might reveal themselves in singular events that overwhelm systems or dramatically change their circumstances (e.g., shut-down of the Atlantic conveyor, warfare destroying critical infrastructure). A suite of Center projects develops and applies methods for understanding and managing such processes.

As described above, one involves the development of a synthetic framework for addressing global desertification and land degradation. Center funding has helped to support the creation and leadership of the Collaborative Research Network for Assessment, Research, and Integration on Desertification (ARIDnet). As mentioned, this international, multidisciplinary network of scientists and institutions work collaboratively on issues ranging from basic ecological mechanisms to human dimensions. It strives to (1) advance our basic ecological understanding of desertification, (2) develop modeling capability for predicting the rate, direction, and magnitude of land degradation, (3) examine the roles of economic, administrative, and social factors, and (4) match current ecological models and impact-assessment tools. The ultimate goal of ARID is to develop an assessment framework that is useful to scientists, land-managers, and policy-makers, especially in the context of the UN Convention on Combating Desertification (CCD).

Similarly, the LCLUC-SYPR project is an interdisciplinary and inter-institutional research effort focused on the human-environment system of the southern Yucatan, especially with respect to deforestation and agricultural expansion. Part of the largest expanse of mature seasonal tropical forests remaining in Mexico-Central America, the region struggles to accommodate sustainable development by increasing the well being of an increasing population of farmers, and yet preserve as much old growth forest as possible as part of the Calakmul Biosphere Reserve and related initiatives. The SYPR project has: [1] created a detailed understanding of the land-use and land-cover dynamics underway in the region, especially beginning in the late 1960s onwards; [2] developed a fine-tuned image classification for detailed land-change detection; [3] generated various spatially explicit models that explain and project current and future land changes in the region, and [4] provided state-of-the-art assessments of various global change issues, including carbon sequestration and biotic diversity. For the past several years, the SYPR project has collaborated as a part of the RASSP to develop a meta-template for vulnerability analysis and is now poised to undertake a vulnerability initiative. This initiative will build on its large data sets, analysis and assessments, and Mexican linkages (e.g., agencies, programs) to accomplish the following goals: [1] document the responses of local stakeholders and ecosystems and the synergies between them in regard to major environmental and socio-economic hazards operating in the region; [2] test a series of hypotheses about the operation of the coupled human-environment system of the region that are relevant to the systems vulnerability; [3] further develop satellite imagery classification and change detection; [4] create a suite of spatially explicit, econometric and integrated assessment models of the vulnerability of the coupled system. Through these analyses, the SYPR project seeks to determine the vulnerabilities of forests and households to increased and magnified severe storms (hurricanes), drought, landscape fragmentation, anthropogenic wildfires and invasive species, and to the thin and volatile market for chili and policy shifts. It will embed this understanding with spatially explicit models that explain and project vulnerability.

A domestic counterpart is Human-Environment Regional Observatory, in Central Massachusetts (HERO-CM). It is establishing long-term data acquisition and archives (spatially explicit and digital) on all matters dealing with human-environment relationships affecting land-use change (currently for 1971-1999, but possibly back to 1951). This is done within four teaching institutions, in order to stimulate integrative research and teaching, with an undergraduate focus. Important substantive topics include land change, urban sprawl, and brownfields. Methodologically, the project seeks to develop metrics and measure changes at different spatial scales over time. They should help landscape modelers to discern systematic landscape transition processes from stochastic transitions between specific land-use/cover categories. The approach compares the landscape of central Massachusetts at two times, looking at gains and losses within and between four land-use/cover categories. In the last two years, Center-supported research has led to creating a set of LUCC-related models/modules (e.g., GEOMOD, VALIDATE, ROC, SOFT CROSSTAB, LOGISTISREG), incorporated into the Idrisi GIS, distributed worldwide to 35000 users for supporting their LUCC-related studies. Our efforts have also supported the GISID master program of Clark University by providing the students with valuable analytical means. (See <http://www.clarku.edu/departments/HERO/>, [http://earth.clarku.edu/a\\_projects.htm/](http://earth.clarku.edu/a_projects.htm/) and [www.clarklabs.org](http://www.clarklabs.org)).

Our continuing work on multiple stressors in India previously focused on tropical cyclone impacts. In the past period, three different sets of studies have been conducted, all in the context of assessing vulnerability and adaptation to climate change for India. The first study relates to the methodology for assessing impacts of the extreme climate events (tropical cyclones in this case). Conventionally, the impacts of climate hazards such as cyclones or floods have been measured through the changes in human, social and economic capital typically represented by stock variables such as population, built property and public infrastructure, livestock etc. We develop an alternative approach where we explore using various statistical techniques whether the impacts can be detected in terms of changes in flow variables (typically economic output), when examined at an appropriate level of spatial and temporal resolution. The second study relates to methodology for identifying vulnerability hot spots. Usually, the vulnerable hot spots are identified by ranking different regions based on some index that quantifies vulnerability to some particular stress(es). The index presents a single value measure of vulnerability based on some meaningful criteria. The index approach to identifying hot spots leads to loss of information about how the different factors that went into making the composite index, interact with each other. We try to address this problem by considering the different components of vulnerability separately. We have considered vulnerability to be a composite of three factors – climate related hazard, exposure of the human systems to the climate hazard and the adaptive capacity of the people being exposed to the hazard. Rather than aggregating the different components of vulnerability into a single index number, we use multivariate techniques like cluster analysis with aim of pulling out the cluster of the most vulnerable districts and study how the different components of vulnerability interact with each other in making a place more or less vulnerable. The third study relates to exploring the spatial and temporal patterns in mortality related heat waves and cold waves across different states in India, with an emphasis on studying the role of acclimatization and gender differences in determining extreme temperature mortality. We plan to conduct a fourth study in which we develop an approach to assessing adaptive capacity for climate related natural hazards using multiple dimensions of vulnerability and development.

In a new project, we have completed the first phase in creating an integrated assessment model of the effects of global climate change in West Africa, focusing on water availability and agriculture. West Africa includes some of the poorest countries on Earth, with the least resources to respond effectively to climate change. Declining rainfall in recent decades, along with desertification, are already major challenges to agriculture that is mainly rain-fed. Several options, however, could help conserve water and improve agricultural yields, offering major benefits whatever future climate changes may bring. These options include expanded drip irrigation and adoption of a variety of farming methods to improve soil fertility and food

production without major reliance on industrial fertilizers. Consequent increases in soil organic carbon in arable lands could increase soil fertility while simultaneously sequestering carbon from the atmosphere. In this first stage, we convened an expert conference in Lagos, with individuals drawn from throughout the region. Led by a scientist from the region and a decision analysis from the US, the workshop translated a wide-ranging discussion in the prototype of an integrated assessment.

One project research within the ARIDNet framework has focused on the effects of climate variability, which will likely alter the distribution of precipitation, hence has the potential to intensify current rates of desertification. Since nearly all aridlands are characterized by extreme year-to-year weather fluctuations, it is often difficult to distinguish between short-term variability and long-term changes in ecosystem appearance, as well as between temporary and permanent changes. It is essential that we understand and quantify key feedbacks of water flux between the atmosphere, soil, and plants. We have been examining the specific hypothesis that inter- and intra-annual variability in the timing and quantity of precipitation accounts for the majority of the observed variability in plant-soil-atmosphere water dynamics in aridlands. It is conducted within two constraints: 1) that patch-level interactions between various components of water input, such as timing and frequency of precipitation events, is governed by the ecophysiological requirements of different plant functional types (e.g., shrubs, grasses, forbs, etc.); and 2) that topographic and edaphic characteristics at the landscape-level may influence the pattern of spatial redistribution and retention of water. We hope to answer questions like: What is the relative importance of variability in summer vs. winter precipitation to growth, physiology and water relations of key plant species? Are the dominant plants (e.g., shrubs) able to take advantage of small summer rains? What constitutes a “small, relatively unimportant” summer rain event? Is annual rain-use efficiency (production/total rain) a useful index?

An extension of this work to human dimensions will use spatial modeling and scaling process models of aridland ecosystems to larger spatial and temporal scales that are appropriate for studying desertification. Looking at the Chinese context, we are developing a project that includes modeling, land-use history, especially grazing by domestic livestock, and spatial pattern analysis, all related to questions about the rates of change in land degradation caused by human influences. In preparation, we are trying to understand the different conceptualizations of the problem in different sectors. For example, the term ‘desertification’ is rarely found in the Australian literature on rangelands while in American, it is commonplace. In Africa, “desertification” is used much by social scientists but mainly related to poverty questions.

Finally, we have begun to look at multiple stressors arising primarily from social source, namely, the impacts of Simultaneous Market and Environmental Pressure on Restructuring of inter-dependent Industries. Industrial restructuring in less industrialized countries has been associated with market opportunities created through globalization. Tanning and foot-ware industries have historically had a strong symbiotic relationship. However, technical change (e.g., man made materials), fashion, NAFTA and WTO have changed the landscape of foot-ware markets in N. America. These have changed the nature of economic links between these industries. One example, which is unique in its details, but typical in the kinds of issues that it present arises in Central Mexico, where an environmental disaster in Crystal Lake (downstream of Leon, Mexico) has put the local tanning industry under tight environmental scrutiny. This research compares development of tanning and foot-ware industrial complexes in Guadalajara and Leon to estimate the role of environmental pressures on industrial restructuring. We are particularly interested in whether size of firm and quality of product are critical variables in determining which firms are most capable of adapting to new operating milieu. We are looking at the *drivers* of structural change, the adaptive *responses* to these exogenous forces by the tanneries and shoe factories and, the restructuring *trajectories* of each industrial district.

## *Homeland Security*

Public perceptions of risk. With additional support from NSF and other sources, we have conducted a number of studies of risk perception and communication. Others arose from collaboration with Jennifer Lerner, Deborah Small, and Roxana Gonzalez, supported by an NSF SGER, granted soon after September 11<sup>th</sup>. They looked at the role of emotion in risk judgment. For example, exposure to a small dose of material drawn from the national news media was able to generate enough anger to reduce estimates of risk substantially. A paper currently under review shows the persistence of these effects over a year's time, the relationship of risk judgments to experience, and the appearance of a strong hindsight. A paper recently published demonstrates the failure to convey essential, and easily understood, information to citizens, regarding widely reported terrorist risk, leaving them unable to develop personal protective strategies. In addition to its theoretical interest, this research demonstrates the external validity and practicality of basic research conducted over the years.

In collaboration with Condé Nast Traveler magazine, we have surveyed readers about their travel decisions at different times in 2002 and 2003. We found that risk estimates for different destinations correlated positively with (a) one another, (b) concern over aspects of travel that can make one feel at risk (e.g., sticking out as an American), (c) worries about other travel problems (e.g., contracting an infectious disease), and (d) attitudes towards risk. Respondents' willingness to travel to a destination was predicted well by whether their estimate of its risk was above or below their general threshold for the acceptability of travel risks. Overall, the responses suggest orderly choices, based on highly uncertain judgments of risks. Worry played a significant role in these choices, even after controlling for cognitive considerations, thereby supporting the recently proposed "risk as feelings" hypothesis. Thus, even among people who have generally consistent and defensible beliefs, emotions may affect choices. These results emerged with people selected for their interest in and experience with the decision domain (travel), but challenged to incorporate a new concern (terror). Follow-up surveys, currently being analyzed, go through the Iraq War. In addition replicating initially observed patterns, respondents had trouble anticipating how their emotions would change over time, underestimating their ability to adapt to new situations. Though past experience with travel in times of terror reduced worry, travelers' current worry predicted their anticipated responses, even after controlling for their experiences. Thus, they seemed to adapt surprisingly quickly to the new circumstances, especially when they had direct experience with them. These results are consistent with psychological theory, and suggestive of the evolution of public responses what is likely to be an ongoing threat.

Risk analysis for engineered systems. In times of war, attacking infrastructure is a common military tactic – and electric power systems are obvious targets. Because electricity cannot be easily stored or rerouted, supply must match demand. In an integrated electric system, a disruption can bring down large parts of the network. This can have severe economic consequences, and pose a threat to human life, as has been seen in a variety of conflicts (e.g., Bosnia). Moreover, the rise of organized and systematic global terrorism has demonstrated that an attack on an electricity system is an issue for all countries, not just for those undergoing conflict or at war. One possible way to mitigate the impacts of conflict and other stresses on electric power systems is to change the architecture of the system from the current paradigm of large centralized generation with long-distance transmission to a more distributed system with small generators located close to end-users. The goal of this research is to evaluate and quantify the reliability and economic implications of large-scale distributed generation in areas of conflict.

Management of homeland security risks involves trade-offs between safety, wealth, privacy, convenience, and other social goods. With co-funding from the MacArthur Foundation, we've surveyed lay groups to determine how public preferences for managing mail security risks differs from measures actually implemented by the U.S. Postal Service. One of our members will be

giving a keynote talk at the annual meeting of the Health Physics Society on the costs and benefits of democratizing the radiation protection process.

## **CROSS-CUTTING ISSUES**

Elements of the four cross-cutting issues can be found in many of these projects, focused on the three central domains. We have also pursued them as topics in their own right. This section describes some of the dedicated and embedded studies.

### *Capturing adaptive learning*

Our research into how people adapt to change has focused on detailed sectoral analyses, using integrated assessment frameworks to bring together social and environmental changes. These build on the pooled wisdom and experience of the Center community. At this point, they do not seek a grand synthesis, but robust descriptions, in roughly comparable terms, creating a body of work that could sustain hypothesis testing regarding learning processes.

Wildlife-based management. As described earlier, the Transboundary Protected Areas Research Initiative (TPARI) is conducting integrated assessments of TBPA's in southern Africa as coupled human-environment systems that operate across scales and boundaries. Its objective is assessing the nature of the social and natural transformations brought about by TBPA's. Using the Great Limpopo Transfrontier Park (GLTP)? (which includes land in South Africa, Zimbabwe and Mozambique) as a case study, it focuses on environmental sustainability as well as issues of social justice. Research projects include: (1) The eco-regional planning framework and linkages between planning processes across scales and boundaries. (2) Historical vulnerabilities and adaptation of local people to climate variability, resource limitations and political ecologies. (3) The social and economic framework of the GLTP, with an emphasis on land ownership and land reform. (4) Tourism development and community-based tourism initiatives launched in the GLTP area over the last decade, with special emphasis of Community-Public Private Partnerships. (5) Decision-making processes and governance.

The empirical and research base that has been created by TPARI has allowed an innovative application of operations research approaches, for optimizing the design of wildlife reserves, in ways that recognize other local pressures. An integrated approach to decision analysis is needed for large-scale conservation planning in GLTP/CA for a broad range of conservation and socio-economic objectives and under highly politicized conditions. To sort through the complexities and provide a sound baseline for decision making, quantitative, multi-objective decision models can be employed to identify superior planning alternatives. These alternatives suggest ways in which GLTP/CA might be configured and identify appropriate management strategies for different areas of the park (for example: core areas, wildlife corridors, buffer zones, and development zones). A two-part modeling approach is envisioned for GLTP/CA: (1) develop multi-objective optimization models – used for generating a suite alternative reserve configurations and/or management strategies; and (2) develop multi-criteria decision models (MCDM's) – used for evaluating the alternatives in terms of the preferences and values of stakeholders and other participants. It is expected that GLTP/CA participants would be actively involved in helping to formulate the models. Results from implementing the models would characterize the range of tradeoffs among the objectives, and would provide new and relevant information for planning and decision making. An effort will be made to demonstrate the relevance of this modeling approach to existing planning frameworks that may be applied to GLTP/CA, for example: community-based resource management; special development Initiatives; eco-regional planning; and biosphere reserves.

Aquaculture-based management. Translating research into practice, we are participating in developing an adaptive management plan for salmon aquaculture in Canada, growing out of the risk-management framework that we developed in previous years. Salmon aquaculture has grown

at a tremendous rate in countries with appropriate locations, and is a major force of environmental change in coastal areas. It is an example of an industry that involves global movement of capital, knowledge, technology, and products whose consequences are manifest in remote locations and small communities. The potential consequences of this rapid development are highly controversial and poorly understood. With supplementary support from a major Canadian research program, we have been working with a broad range of stakeholders to develop an adaptive management plan for salmon aquaculture, to foster learning over time. We hope to generalize this experience to other participatory planning processes. In associated descriptive research projects, we are looking at salmon aquaculture as an example of a global change process with multiple scales, multiple levels of regulatory decisions, and multiple actors.

Water-based management. The Okanagan region of British Columbia is dry and enjoys warm summers. It has long been a productive agricultural region and has become a haven for new retirement communities. It suffers from severe water supply constraints that climate change is expected to exacerbate. A number of urban and rural initiatives have been taken in the past two decades to assure adequacy of water supply. We are looking at four of these initiatives for a comparative case study, using interviews and archival material to discover the decision-making processes and outcomes of these initiatives. The findings suggest weak networks of learning even among decision-makers located in a small region facing the same or very similar challenges. Such observations of lost opportunities to learn through comparative policy analysis are discouraging of our ability to effectively implement adaptive management strategies in the current institutional decision-making milieu.

Arctic Development. Major projects in northern Canada often hope to attract follow-on development. For example, roads to remote mineral properties can attract mines, support services and communities. Although welcome, the ensuing economic benefits can produce other environmental and social effects. External influences (e.g. climate change, global mercury deposition) complicate the assessment of these impacts. Concurrently, Arctic communities are experiencing rapid change on other fronts. Climate change is shifting seasons and fundamentally altering ecosystems. Technology and sea ice melt are creating new opportunities for the extraction and transport of minerals. Trans-boundary pollution poses a health risk. New institutions and models of self-governance are on trial, while efforts to address persistent social and economic challenges continue.

Our project is creating a set of integrating tools, for estimating the overall impacts of projects, with the ultimate goal of assisting communities in devising adaptation strategies suited to sustainable development. It will: (a) Conduct an integrated assessment of the magnitude, rate and likelihood of expected changes (environmental, economic, social, institutional and technological) and their effects on development in Arctic communities. (b) Determine the extent to which historical lessons can inform decisions about future options. (c) Synthesize and apply the results of the above by working in partnership with two communities in Nunavut to devise an adaptive management plan. The participation of the community is critical, in expressing their concerns and information needs, in conveying their knowledge of local impacts and in defining options and thresholds for future development.

Institutions for learning. Complex global change issues pose a challenge to the scientific community. In case studies using methods from science and technology studies, we are examining the adaptive learning processes of the emerging climate change science, as it is institutionalized in diverse national cultures of scientific research and policymaking, each with diverse social actors (scientists, policymakers, stakeholders). These national experiences are viewed in the context of international scientific processes, such as the Intergovernmental Panel on Climate Change (IPCC). We selected Brazil as a site to provide a developing country perspective on Northern-generated “international” scientific and environmental projects. One component of the project focuses on national and comparative policymaking, including the delineation of

national environmental research strategies, as a source of information about the framing of climate change as a topic for research and policy. Another component of the research aims to characterize in depth the national-level consequences of international scientific research and assessment. A final component of the research examines ideas of precaution as they are being developed, articulated and taken up in the European Union (see below).

Within the United States, we are evaluating the experience of the National Assessment of local and regional impacts of climate change, itself an attempt to change the institutional and political character of climate change research and application. It draws on a framework that we have developed for examining the social processes involved in scientific assessments. At a workshop in Washington in late April 2004, we convened many of the major actors in the assessment, as well as distinguished observers of their work. At it, we reported responses to a detailed survey, from 160 “players” in this process and observers of its work.

#### *Understanding and valuing non-marginal change*

Community transformations. We are concluding three studies conducted for Metis settlements in Alberta, as part of their efforts to win compensation for energy developments on their lands. An amendment to the Alberta constitution calls for compensation for all manner of cultural, spiritual and traditional use impacts, but standard market-based approaches to compensation are not appropriate for addressing these kinds of losses – which introduced a fundamental, non-marginal change in the lives of these people, forced to radically change how they lived. We developed a multi-attribute approach and applied in community-based workshops involving settlement residents to addressing these difficult questions. One paper growing out of this work is noted below. We also expect to develop a general framework outlining what is needed in conceptual and practical terms for addressing compensation for losses in other situations of non-marginal and non-substitutable impacts.

Another form of non-marginal change is found in resource-dependent communities, whose traditional base has shrunk, either because the resource has been exhausted or because conservation concerns have reduced the extraction rate. In these locales, avoiding such change requires ensuring the long-term sustainability of the natural systems. That, in turn, depends on the capacity of social institutions to set and regulate harvest levels, monitor anthropogenic impacts and limit the negative or unintended consequences of human activity. Forestry requires such institutional regime, involving industry, government and the working population, and its institutional representative (labor movements, NGOs). We have been studying the particular instantiations found in British Columbia forestry communities. They differ from those in many developing countries in being protected by a wider welfare safety net, but still share key structural characteristics that tend to lock the regime into environmentally unsustainable levels of resource extraction. Hence they have been called ‘addictive’ rather than dependent communities, with often bitter resistance to adaptation. Our study includes the sensitivity of these processes to fluctuations in lumber prices, themselves often embedded in trade disputes and other byproducts of globalization. These exogenous events provide a sort of natural experiment, revealing properties of the communities and offering opportunities for non-marginal changes. Ultimately, one of the most challenging questions in this study is whether these exogenous events induce a process of strategic social learning that reduces vulnerability of the communities or increases their capacity to respond more effectively in the future. There are two dimensions to this question. The first is to consider the conditions under which some form of social learning might take place, the second is to consider social learning at the level of communities.

A newer project, conducted within the ARIDNet framework, is developing a model linking the combined effects of drought and overgrazing on the C4 semiarid grass communities of the Jornada Basin in New Mexico, which has switched from a grass- to a shrub-dominated system after 100 years of desertification. To explain why grass decline here has been so fast and difficult to revert, the model considers the functional diversity of C4 perennial grasses (slow- vs. fast-

growing) and the differential effects of drought and cattle. We are testing three hypotheses: (i) potentially fast-growing grasses are more affected by drought than potentially slow-growing grasses; (ii) large grazing herbivores base their feeding preferences on the realized growth rate of plants not standing biomass; and (iii) herbivore preference for a given species is not fixed, but varies with soil-water (drought) conditions. Testing the model will require reconstructing the historical processes by which types of cattle and management practices were introduced.

Technology-driven changes: Genomics. The proponents of new technologies often promise benefits that will make life fundamentally different, if they are adopted (e.g., bringing radically new possibilities, or bringing old capabilities within the means of a wide new audience). Opponents often fear threats that will make fundamental differences of their own (e.g., violate moral codes, upset the balance of nature). With biologically active technologies, local decisions can quickly have global dimensions, as new practices and diseases spread. We have begun two projects looking at the human dimensions of the global changes associated with genomics, one concerned with its deeply uncertain risks, the other with the ethical dimensions that such risk analyses reveal. Each involves a diverse group of consulting experts, as well as supplementary funding that should allow them to reach their conclusions, after the Center finishes its life.

Any analytical scheme is challenged by phenomena surrounded by deep uncertainty. Often, scenario planning is used to capture some of the attendant complexity. However, there is a disconnect between these qualitative procedures and the quantitative ones often needed for systematic management, with consistent implementation. We have been examining the incorporation of scenario planning in integrated assessment. That has involved developing a general approach, and applying it to the deeply uncertain risks and benefits of advanced genomics research, with subject matter expertise provided by the HybridVigor Institute. As a focal topic, we have taken xenotransplantation, the creation of animals designed to produce organs for humans, with minimal rejection risk. Although technological success will solve the painful organ shortage, there are theoretical possibilities (of unknown probability) of novel diseases spreading in human populations. The process began with an expert consultation, moderated with elements of conventional scenario planning. It was followed by a formalization of their results in an integrated assessment guided by a working group with two molecular biologists. Scenarios are being used to test the model and to prepare explanatory materials to render it comprehensible to users. The results will be reviewed by a second meeting of the expert panel this Fall. The ensuing revisions are intended to refine both the analysis of the specific topic and the general methodology – like many of the Center’s project.

Whatever the theoretical risks, genomic and biotechnological research is expanding rapidly and is producing a range of commercially viable technologies. Experience in Europe suggests that public concern about biotechnology often emerges independent of demonstrable scientific evidence of safety concerns; controversy has a moral rather than a scientific foundation. A Center study in Canada is applying three forms of ethical analysis to the support the development of public policy related to biotechnology. They are embedded in a series of public consultation exercises funded by Genome Canada and Genome BC. <http://gels.ethics.ubc.ca>.

Analytical methods. One of our most fully developed studies of non-marginal change considers the suitability of cost-benefit approaches for evaluating the cascading long-term uncertainty that pervades our understanding of the climate. Currently, we are investigating a risk-averting approach that builds on the “tolerable windows” and “safe landing” constructions of the 1990s. Risk analysis seems far more appropriate than cost-benefit analysis because it copes with uncertainty explicitly. In our framing, it asks questions like, Should we respond to the risks of climate change given that we don’t really know very much about what might happen? How much “insurance” we should “buy” against the risks associated with climate change? How much should we invest in early mitigation, in significant research into energy conservation, and in

building adaptive capacity around the world? Not because we can produce estimates of immediate or future benefits, but because uncertainty, itself, is *the reason* for doing something.

We continue to examine a COSMIC-based range of “not-implausible” scenarios for flooding along the Ganges and Brahmaputra Rivers. The recently released Adaptation Policy Framework of the UNDP uses vulnerability indices developed in earlier work, in order to accommodate the wide range of uncertainty associated with adaptation options. We are tracing the implications of achieving specific mitigation (concentration) targets on the transient distributions of flooding events. A related project considers how a contingent climate insurance program might help developing countries cope with increased climate risk in ways that are compatible with their development plans. Another considers the roles that adaptation plays in sustainable development and UNFCCC contexts.

Scenarios are a popular intellectual technology for addressing planning problems with great complexity and uncertainty. The claims made for scenarios often focus on somewhat intangible impacts, such as “stretching minds” and “gaining insight.” In addition to testimonials, support for these claims often invokes stylized psychological results, such as: (a) Stories takes advantage people’s enhanced ability to process complex evidence that is integrated in concrete, causally coherent narratives. (2) Group interactions, like those associated with scenario planning, increase people’s feelings of confidence, competence, and willingness to act. Skeptics often counter with their own stylized facts, such as: (1) Narratives evoke conjunction fallacies, exaggerating the apparent likelihood of focal scenarios (notwithstanding disclaimers, against assigning probabilities). (2) Scenarios’ ambiguity can create an illusion of consensus, undermining decision-making processes. We offer a graph-based approach to scenario planning, designed to formalize these concerns, in a way that should clarify their situation-specific validity. Used proactively, it should facilitate planning processes that “capture the magic” often attributed to scenarios, while conforming to the strengths and weaknesses of the cognitive processes of those who seek to rely on them.

Once changes have been understood, as best they can, they must be evaluated. We have continued to develop the basic science for how people perform such evaluation. To that end, we have used a combination of laboratory experiments and studies of natural experiments, looking at individuals whose lives have dealt them non-marginal changes. Its over-riding result is that people tend to under-appreciate their powers of adaptation, for even significant negative events. We are exploring the policy implications of these results. Although it may be consoling, in the short run, to accommodate to changes, recognizing one’s ability to do could undermine the determination needed to defend a valued status quo. While individuals are sometimes sovereign to set the evaluations for their own lives, often others have that right (e.g., policy makers, manufacturers). Self-other differences have been observed in many areas of psychology. In earlier Center-supported work, we identified two common effects, interfering with these valuation processes. *Affective contamination* refers to the tendency to believe that other people share one's emotional states to a greater extent than they actually do. *Affective ignorance* refers to the tendency to underestimate the impact of visceral influences on one's own and on others' behavior. We have documented these effects for a wide range of visceral sensations, including hunger, thirst, and physical discomfort. In the past year, we have completed a project understanding the “identifiable victim effect”: the tendency to care more about, and allocate greater resources to, identifiable than to statistical victims. Understanding these processes facilitates identifying situations in which they are unwittingly in play. That, in turn, frames the philosophical question of which perspective is sought.

### *Representing equity and its implication*

Our investigators are encouraged to consider distributional effects of the policies and technologies that they investigate. Their success can be seen in projects like the studies of

conservation in South Africa, land-use practices in southern Yucatan, and consumer energy use relative to income level. In earlier work, we focused on developing metrics for equity, suited to use in integrated assessment. In more recent work, we have sought to give expression to individuals whose concerns are likely to be neglected. (This concern is also central to the projects described in the next section, designed to empower citizens to assert their own rights and wishes, by having information about their circumstances.)

One aspect of intertemporal distributional effects concerns transfers across generations. Our policies reflect what adults choose to create for future generations, perhaps informed by what they think that those in the future want. Young people are rarely consulted, perhaps out of disinterest in the views, perhaps out of skepticism regarding their ability to provide meaningful guidance. However, current research into adolescent psychology suggests that, by their mid-teens, young people have most of the adult repertoire of relevant cognitive skills. It also suggests that they lack the special feeling of invulnerability often attributed to them, while harboring deep pessimism about some existential aspects of their world, including the environment. We have replicated these basic results in several surveys. Using cross-sectional analyses, we have found suggestive evidence of three factors: (a) specific fears, often exaggerated (when compared with statistical evidence); (b) existential anxiety, regarding the possibility of a future (threatened by some, unstated threats); and (c) developmental limitation, on teens' ability to think about the future. Questions regarding the future of the natural world showed such negative expectations that there was little opportunity to use responses as covariates.

Over the past two years, we have conducted 72 in-depth interviews with a diverse sample of teens in the Pittsburgh area, regarding their view of the natural world, and their desires for it, in policy relevant terms. Our analyses reveal considerable variation in the extent of teens' previous thought about environmental issues and their importance. The transcribed interviews were analyzed qualitatively, using ethnographic perspectives, and quantitatively, using systematic coding drawn from mental models procedures. Many of the most articulate students expressed awareness of many of the major global problems of our time and some personal concern about them, yet also expressed the view that there was essentially nothing that they could do about them. When asked to explain changes or propose solutions most do not place primary responsibility on institutions (government, corporations). Rather, they consider responsibility to be widely diffused, using terms like 'everybody,' 'just people,' and 'all of us. Anger and sadness, frequently in combination, were most commonly reported emotions. These fit the deep pessimism about the future of the natural world seen in concurrent structured surveys. The most commonly proposed mitigation strategy was coded as 'increased public awareness.' The results will, we hope, provide guidance for parents, educators, and policy makers, concerned with both the cognitive and the emotional bases for environmental values.

Procedures for incorporating equity concerns. In a project that continues our earlier focus on the professional (or analytical) treatment of equity, we have examined the articulation and institutional uptake of the idea of *precaution* in the European Union (EU) in relation to the issue of climate change. The effectuation of the precautionary principle concerns a number of tangled issues of transnational or multi-level governance, expertise, legitimacy and sovereignty. Indeed, even at the European Commission, it occurs at the convergence - or divergence - of the stakes and aspirations that pull it in a number of directions. These complications belie the dichotomous simplifications posited in the debate between *science-based* (or *sound science*) and *precautionary* approaches, or even between action and inaction («*To act or not to act*», «*If in doubt don't do it*»). The stakes involved include the (governance of) international trade –and climate change– negotiations and disputes, as *external* dimensions; the *internal* intra-European policy coordination or harmonisation; the singularity, demarcation, and integration of the environment and other policy domains; the taking into account of public participation, of 'other legitimate factors' in risk assessment and decision-making, etc. Conversely, the precautionary principle can be understood as a complex set-up, intended to address or resolve those predicaments.

The CMU risk ranking method, a systematic group process for eliciting lay peoples' concerns about risks to health, safety, and environment, is a potentially valuable tool for Chinese government officials to use in setting environmental management priorities. However, little is known about whether the CMU technique, with its heavy emphasis on group deliberation, will work in a non-western cultural setting. Cultural dimensions that might affect the relative success of the CMU risk ranking process in the US and China include egalitarianism-authoritarianism, individualism-collectivism, short vs. long decision horizons, and risk aversion. We have begun to develop a set of risk-ranking experiments with Chinese lay subjects with the eventual goal of collecting data with students in Beijing, with the possibility of an eventual field application in Wuhan.

*Rendering IA approaches and findings from its application accessible*

Many of our efforts in achieving this goal are summarized in the section on Outreach (Section IV). However, we also have several projects underway, with the explicit goal of evaluating the feasibility of integrated assessment as an environmental management approach. Our analysis suggests that integrated assessment can meet the psychological and social requirements of planning processes while remaining true to the relevant natural and social science. Evaluating these impressions requires systematically designed and empirically documented case studies. The adaptive learning studies (described above) are one expression of this commitment. Several of the consultations described there are based on the joint creation and consumption of integrated assessments. These initiatives reflect the common observations that public participants in environmental management processes feel that important issues are neglected or that their input is ignored. Conversely, technical specialists often feel that uncertainty is poorly depicted or that the integrity of scientific logic is compromised due to a stakeholder-based consultation process. The theoretical and applied research challenge is to maintain scientific rigor while including public values as part of decision-making processes. Some of the previously mentioned projects have inherently participatory elements. For example, the Yucatan project has involved participatory vulnerability modeling, using multi-agent GIS approaches. The new TBPARI projects are essentially intertwined with the concerns and participation of local communities. Here, we describe several sections where participation is the focus of the research.

Participatory processes in integrated assessment. Recent years have shown a global shift from top-down agency planning to community level participatory decision-making in a wide variety of environmental programs. This shift to sustainable community-based participation requires communication, feedback, and consensus building among development planners, environmental policy-makers, and local populations. Yet, there has been little attention to the processes of information exchange that facilitates these dialogues. One Center dissertation focuses on bridging the gap between planners' environmental and development agendas and peoples' priorities for their own "backyards" by 1) evaluating an expert perspective of development planning and decision-making for the case of electric transmission line siting in the United States, 2) characterizing a local perspective of neighborhood priorities and public decision-making for the case of three different Pittsburgh communities, 3) developing a method for information exchange using a unique combination of participatory mapping and Geographic Information Systems (GIS) technology, 4) and finally integrating the methods and tools developed in the first three chapters of this dissertation in a real-world natural resource management case study.

A project in Thailand is set in the context of economic and social development marked by two contrasting and simultaneous trends. One is an increasing recognition of the special environmental and social values associated with the unique Thai culture. The other is modernization and industrialization, as Thailand joins the global marketplace and becomes a leader in south-Asia economic growth. The rapid industrialization of Thailand has opened the door to both domestic and foreign industries interested in the production and exportation of forest and agricultural products, electronics, textiles, and chemicals. An active entrepreneurial class and

a generally pro-business state (personified in the current Prime Minister) have contributed to this growth. By conventional measures, rates of growth have been surprising and exceptional. For the decade beginning in 1987, the Thai economy was arguably the fastest growing in the world. This growth has resulted in a greatly increased role for foreign and multinational companies as well as, some critics argue, a willingness to overlook environmental and social costs. This pro-business emphasis has been tempered by a growing recognition of the importance of the Thai environment and related culture. With agriculture as the largest employer and with much of the population still living in rural areas, the country has benefited from a stable government at a time when much of South-east Asia has suffered terribly from colonial and civil wars. Tourists have prompted a rising interest in ecotourism, and the government (as personified by the King) has retained a strong interest in protecting indigenous plants and animals and their habitats. The past twenty years have seen improvements in health care and environmental protection (led by agencies such as the Pollution Control Directorate); parallel social changes include substantial decreases in infant mortality, increases in female participation in the workforce, and a significant rise in school enrollments. There also have been marked increases, both internally and externally, for support of academic research on environmental and health protection. The focus of the current project is to improve the ability of community residents to participate effectively in environmental management and to engage meaningfully in efforts to reduce both environmental and health risks. GSEI (the Institute for Good Governance for Social Development and the Environment), based in Bangkok, has taken the lead on several projects designed to further this objective and has received assistance from groups such as the Thailand Research Foundation, the Canadian International Development Agency (CIDA), and Resources for the Future (RFF).

The Georgia Basin Futures Project attempts to facilitate citizen participation in the designing 40-year scenarios for the region surrounding Vancouver and Victoria in British Columbia. The UBC-based team has developed a decision tool known as "Georgia Basin Quest" that is a hybrid between traditional integrated assessment models and qualitative scenario-building exercises. The tool was inspired by the popularity of the 'Sim City' family of computer games. However, it is based on expert models of social and environmental systems, grounded in the research literature. The interface to the tool was designed to resonate with issues in the public realm and the underlying models create a possibility space within which users can explore the trade-offs of a range of development pathways. Our research with it focuses on models of consultation, the challenges of creating dialogue around computer-based tools, the role of such scenario tools in the policy process and the challenges of operating on the divide between lay and expert cultures. The team has developed a suite of web-based tools to support policy and decision-making at a range of individual and institutional scales. <http://www.basinfutures.net/>

As part of the Transboundary Protected Areas Research Initiative, we have conducted exploratory ethnographic research on agroforestry practices in the Limpopo National Park June 16 to August 7, 2003. The Limpopo National Park (LNP) is the Mozambican side of the proposed Great Limpopo Transfrontier Park (GLTP), which, in addition to Mozambique, spans significant sections of land in South Africa and Zimbabwe. Ethnographic agroforestry research in Mozambique's Limpopo National Park began to (1) increase the visibility of residents and resident land use, (2) reveal the role of humans in tree distribution, (3) legitimize resident land use practices as intrinsically conservationist, and (4) provide insight into the history of this landscape. Additionally the research provided preliminary data concerning Shangaan cultural sites, insight into a changing international landscape, and the necessary foundation for ongoing ethnographic research. Interviews were conducted primarily in the Shangaan language. This form of social "ground truthing" is a partial answer to the lack of high-resolution, on-the-ground, social science research in the LNP. As a result, little is known about the people who are most directly affected by the recent change in management regime. Additionally, representations of the LNP landscape do not reveal the realities of park residents and contribute to decreasing the visibility of local people in this region. Ongoing research in the Great Limpopo Transfrontier Park aims to

increase the visibility of resident realities in the LNP by considering ways in which historical ethnographic data may be incorporated on spatial representations of the land.

Communicating integrated assessment results. The mental models method to risk communication is designed as a complement to integrated assessment, helping to shape analyses to users' needs, while making their results available in focused, coherent, and comprehensible form. We are pursuing this strategy in a complement to the genomics research mentioned earlier. Specifically, we are conducting an experiment exploring different methods of disseminating complex scientific information to the citizens of British Columbia (BC), regarding the risks and benefits of using genetically engineered canola to feed farmed salmon in BC. Soon, it may be possible to feed farmed carnivorous salmon on an essentially vegetarian diet by substituting wild fish meal from South America with genetically engineered canola as the main protein component in fish feed. Doing so should enable salmon farmers to lower their overhead costs, while avoiding the overfishing pressures from using wild fish as feed. Yet, the industry may be reluctant to adopt this technology before being assured of its public acceptability. The work to date has included creating an integrated assessment looking at economic, social, and economic impacts. That was followed by mental models interviews revealing common misconceptions regarding salmon aquaculture and genetic engineering technologies. The risk communication experiment involves an *in person* survey in three sections: (a) a series of multiple choice questions that tested the prevalence of mental models results in the larger sample; (b) three different methods of communicating the expert information within the flow charts; and (c) re-testing on the questions from the first section one. Dependent measures include intended purchase decisions and social acceptability.

The study of the acceptability of carbon sequestration (described earlier) is built on the same basic research base.

### **III. CENTER MEMBERS AND ACTIVITIES**

Appendix A lists Center Members (drawing financial resources from it) and Affiliated Researchers (participating in its activities without support). Appendix B presents Center members' brief descriptions of their research programs, followed by descriptions of research by graduate students supported, at least in part, by the Center. Appendix C shows Center members' collaborators on Center-supported research projects. We are proud of the network that we, collectively, have created among productive researchers. We are especially proud of our contribution to creating the next generation of researchers, for whom this sort of interdisciplinary collaboration will be the norm. Appendix J lists the publications reported by Center members.

Center members have also been very active in national and international activities related to human dimensions of global change. In addition to professional activities, such as editorial board service (not summarized here), they have played roles in the US National Assessment, UNESCO World Water Assessment, UNU/RVM Global Change Initiative, BIOCAP Canada, Tyndall Centre for Climate Change, Millennium Assessment, IPCC, National Council on Radiation Protection and Measurement, Thailand Good Governance for Social Development and Environmental Institute, IOM Roundtable on Environmental Health Science and Research, National Academy of Sciences Communications Advisory Committee, NAS Committee on Novel Approaches to the Management of Greenhouse Gases, National Research Council Board on Earth and Environmental Sciences, Kings College Centre for Risk Analysis, National Research Council Committee on Human Dimensions of Global Change, Global Carbon Project, International Geosphere-Biosphere Programme, International Long Term Ecological Research, IUCN/CEESP Collaborative Management Working Group, Lucc Focus 1 Workshop on Latin America, International Human Dimensions Programme, NRC Board on Earth Science and Resources, NRC Board on Agriculture and Natural Resources, NRC Committee on Geography, UNDP Adaptation

Policy Framework, Inter-American Institute for Global Change Research, Indian Climate Change Capacity Building Program, EPRI Advisory Committee, World Parks Congress, North American Commission for Environmental Cooperation, Society for Judgment and Decision Making, Eighth Conference of Parties (COP-8), Environmental Protection Agency Scientific Advisory Board, and Department of Homeland Security Science and Advisory Panel.

Appendix H lists these activities more fully. In addition to being a matter of pride to the Center, they both improve our science (by testing it against the rigors of these difficult problems and the opinions of other participants) and ensure that it makes a difference. Appendix D lists presentations of Center-related research. Appendix E lists workshops, within which there has been an opportunity to advance the research, by applying the perspective to challenging problems. Appendix G reports research support leveraged from Center activities, further demonstration of recognition of the usefulness of the general approach.

Over the past year our funded professional ranks grew by the addition of five PhD-level investigators:

Wandi Bruine de Bruin, Carnegie Mellon

Felix Dayo, Triple-E Systems, Lagos

Julie Downs, Carnegie Mellon

Max Henrion, Lumina System4

Justin Williams, Johns Hopkins University

In addition, our Transboundary Protected Areas project has involved a network of students and scientists at different levels of their careers.

There are currently 27 graduate students wholly or partially supported by the Center.

Many undergraduates have been at least partially supported by the Center.

We did not convene a meeting of our Advisory Board this year, as our projects were sufficiently set in their work plans that it did not seem like a good use of their time. Center principles have ongoing contact with most members. We will share our summary report, as one way of showing what we have accomplished with their support.

#### **IV. OUTREACH**

Center investigators have a remarkable level of activity, in getting the word out about their research, through the traditional means of publication (Appendix J) and presentations (Appendices D, E, F, I, and J). There are the primary means of promoting the visibility of our research to peers and policy makers. A quick reading of those lists will show the diversity and visibility of the research presentations, and the opportunities to extract their implications to policy makers, in this country and elsewhere, in government, industry, and NGOs. It is particularly satisfying to see the level of exposure for graduate students and scientists in the earlier stages of their career.

With the tragic events of September 11<sup>th</sup> and its aftermath, some Center members have been called upon, by the news media and national bodies, to provide help in interpreting the events and charting the future course. In an unprecedented way, these events have called for the integration of diverse forms of expertise, as well as the coordination of analysis and communication. Our ability to respond relies on the research foundation created by the Center funding and related support over the years. Where possible, it has been gratefully acknowledged. In public presentations, we have maintained that our methodologies (and even some of our results) provide a systematic approach to a very different class of problems, hence constitute an unanticipated societal return on its investment in NSF. Some of these activities are described in the appendices.

We have continued with efforts reported in earlier years to extend our reach to a broader range of ethnic backgrounds and age groups. Our successes have been primarily in recruitment at the graduate and undergraduate level, while there has been relatively little turnover at the faculty level. Our set of projects in Western and Southern Africa has, in part, in the hopes of having activities of greater interest to African Americans. It provides us a bona fide collaboration in an ethnically diverse setting. Although it has taken considerable effort to launch this project, and the recruitment is still in process, we believe that this initiative is serving community-building goals, in addition to its inherent scientific and policy interest. Our projects in the Arctic, Thailand, and Mexico are similarly designed to develop means for participation by indigenous populations in technical decisions involving their welfare. Thus, they set the groundwork for leveling the playing field more generally – in addition to having diverse populations participating in field exercises designed to empower them. Our work with adolescents (described below) has the similar mission of bringing science to citizens, in a responsible, authoritative, respectful way.

### *Bringing global change issues to the K-12 community*

We are completing a major research project looking at adolescents' understanding of environmental issues. In addition to its scientific interest, the project provides a foundation for more effective education, by using young people's time well – telling them things that they need to know, avoiding peripheral details or ones that go without saying. It provides educators with access to some of adolescents' deepest concerns, fears, and hope regarding the environment. In pursuing these issues, we secured an NSF Research Experience for Undergraduates grant, allowing us to train students in both the substantive issues and research approaches. With proper training, they have provided age-appropriate interviewers, learning from the adolescents, as well as from the research. The undergraduates have participated in all phases of the research; compiling surveys, obtaining the necessary releases and signatures, conducting interviews, coding the surveys, summary review of the findings. They were involved in identifying and creating the fullest possible role for high school students in making choices about their lives – and their environment.

During the past year, we were approached by leadership of the China-US Center for Sustainable Development, regarding the possibility of developing a module for teaching life-cycle analysis for Chinese eighth graders (in the last year of free, compulsory education). This project would take advantage of our expertise in engineering, communication, environmental education, adolescent psychology, curriculum design, and China's environment and technological situation. We have developed a research and development proposal that is currently under consideration by a major private foundation, with the encouragement of the Center's leadership. It would begin with developmental work with adolescents in the United States (and in English).

### *University teaching*

Many investigators have responded to invitations by colleagues to teach about global change as guest lecturers. Many have also prepared material suitable for university students on global change issues in general and their own areas of special interest and research.

In terms of Center-specific courses, one developed by a Center member (Keith Florig), *Technocracy, Democracy, and Technology* has guided students in answering questions like: What are the beneficial and detrimental effects of technology? Who decides what technologies are best? How can and should we as citizens influence the ways in which technology is used? Using a variety of disciplinary perspectives, the course explores cases from bioengineered food to mp3 players. Special attention is devoted to the role of the technical elite in sculpting our technological destiny. Another Center member (Hadi Dowlatabadi) has developed ethics based seminars on complex systems, corporate social responsibility, and climate policy.

We have completed a REU (Research Experiences for Undergraduate) grant for the project on adolescents' views of environmental change. It enabled us to train a large, diverse group of undergraduates in the full suite of research methods involved in qualitative research. With that training, they provided particularly relevant interviewers for our adolescent research participants. The experience provided an additional kind of academic rigor to the environmental interests that many of the undergraduates brought to the project.

Carnegie Mellon University has created the first (to the best of our knowledge) interdisciplinary major in Decision Sciences, headed by a Center Member (Baruch Fischhoff). The first dozen graduates, from its first two years, have gone on to positions in top graduate schools (psychology-Princeton), professional schools (MBA-Harvard, medicine-Cornell), government and industry. Many have been research assistants on HDGC projects. Although only indirectly the result of the Center, their success is a sign of the viability of the sort of research and educational philosophy that we have attempted to achieve.

#### *Building a professional community*

Center members are recognized for their accomplishments. They have many opportunities to speak and present the approaches developed here. These individual efforts, supported by Center research, taking advantage of personal professional networks, are perhaps the most effective means for dissemination. They are sustainable, as a result of being extensions of what people do naturally, building on their professional credentials for changing their own communities.

International Association for Integrated Assessment: A professional association was launched by the Center to further the aims of capacity building and outreach by the IA community.

The Journal of Integrated Assessment: Jan Rotmans and Hadi Dowlatabadi continue to serve as chief editors of this journal, now in its second year of publication. Complex negotiations with Cambridge University Press and Sage Publishing finally succeeded in transferring the publishing rights from Kluwer, which did not allow for pricing strategies that ensured access to a wide community (including the developing world).

ESIAM: The Electronic Series in Integrated Assessment Modeling is a CD Series publication whereby computer models and their associated documentation are being distributed as widely as possible, through an agreement with Baltzer Science Publications. Our role has been to collect, review, and guide the development of suitable user interfaces for their Integrated Assessment Models. So far, two CD-ROMs were published (TARGETS, MIASMA), before we have decided to end publication of this series, given improved broadband capability, allowing direct access to working models.

ICAM: The model and associated software environment can be downloaded from the web by both Mac and PC users. We continue to enjoy thousands of first-time visitors to the home page of our site every year. An unknown number of visits are made to other pages (which could have been book-marked by repeat users). Our web pages are organized to collect information about the community downloading papers and the ICAM model, so that we can alert them to new publications and new models once they are available for distribution. Please visit our web pages at: <http://hdgc.epp.cmu.edu>.

Interdisciplinary networking: A critical test of interdisciplinary research is whether it can be replicated outside the context of dedicated funding. As will be seen in the members' reports, many have initiated related efforts within their "disciplines of origin" or home institutions. For example, at IIT-Bombay, a working group has been created with colleagues from the Departments of Humanities and Social Sciences (D Parthasarathy, sociologist; K Narayanan, economist), Center for Studies in Resources Engineering (A Inamdar, remote sensing), Center for Environmental Science & Engineering (S R Asolekar, water quality) and Civil Engineering

(Kapil Gupta, water resources). The Transboundary Protected Area project follows such a model, with the Center's perspective providing a catalyst for individuals ready to work with one another, but needing a context.

Center faculty serve on the editorial boards of many journals, representing both disciplinary and interdisciplinary fields.

We have contributed to the creation and activity of Ohio State University's Adaptive Research and Governance in Climate Change (ARGCC), which serves as an organizing committee for directing research into the human dimensions of global climate change. It coordinates research and grant writing in the area of human dimensions, organizes workshops to develop social science and policy-oriented programs, develops international conferences on social, political, and economic elements of the climate question, designs courses on the human/climate interface, and hosts conferences.

Internet

The Center's web pages provide information to visitors in an easy-to-navigate format and continues to be developed. The front page lists the weekly seminar schedule with a brief title and abstract. The calendar link has historical records of the seminars presented since 1998. The people link is a useful tool for information about the researchers, faculty and students involved with the center. Each listing provides a brief description of the collaborators research, affiliation and how to contact details.

A link on the website has been created for this Transboundary Protected Areas Research Initiative (TBARI) - <http://hdgc.epp.cmu.edu/misc/TBPA.htm>. The TPARI website serves as a 1-stop information site about the GLTP. It also allows researchers to register their research areas. TPARI is currently assessing how one might develop the website further so as to allow researchers to place their primary data in a controlled access area. The idea here is to reduce repetitive research in the GLTP and research fatigue on the part of local communities and government officials. Ultimately this initiative will be superseded by the digital history and GIS projects. The listserv is used to notify members of the TPARI network of teleseminars and new information on the website.

At Carnegie Mellon, we created a website for our work on risk perception and communication: <http://www.hss.cmu.edu/departments/sds/risk/>.

Our weekly seminar (described below) has pioneered the use of low bandwidth methods to secure broad participation. For example, over 100 people phoned in, from locations around the world, to a presentation by a South African philosopher regarding ethical issues regarding the "management" of interactions between elephants and human populations. It is hard to imagine any other way of arranging for respectful interactions among so diverse and dispersed a group.

Weekly Seminar

The Center continues an active weekly seminar series at Carnegie Mellon. Over the past year, we have continued our distance teleconference series incorporating bulletin board dialogue with multiple line telephone dial-in capabilities for both US and international participants. Before each distance seminar, the presenter's paper and slides are posted to the bulletin board for review and as a reference during the teleconference. This site may also be used for ongoing dialogue/comments/questions regarding the paper and is available for everyone to read and participate. The site is: <http://www.hdgc.epp.cmu.edu/maillinglists/hdgcctml/mail/>. This method has helped us to keep members connected and informed, as well as facilitating communication and collaboration, over the specific issues. The initial series has been organized around a unifying theme of indicators of change, stress, impacts and vulnerability, but other themes and perhaps even parallel series might emerge over time. Invitations to the series currently go to

faculty, researchers, and students in Center-affiliated institutions as well as other scientists and policy makers. All seminars are advertised to the full Center membership.

Seminars presented FY 2003 – 2004:

**September 3, 2003**-Benoit Morel, Senior Lecturer, CMU/EPP-"How option theory can be used for technological risk management and decision under high uncertainty."

**September 10, 2003**-George Loewenstein, Professor, CMU/SDS and Daylian Cain, PhD Student, GSIA.-The Dirt on Coming Clean: Perverse Effects of Disclosing Conflicts of Interest"

**September 17, 2003** -Spyros Pandis, Prof, CMU – CHEME/EPP-"Atmospheric Particulate Matter: From the Source to the Receptor"

**September 24, 2003** -Rahul Tongia, System Scientist, ISRI-"Information Technology and Power Distribution/Consumption"

**October 1, 2003** -David Huges, Asst Prof, Rutgers-"When Tourists Cross Boundaries and Peasants Don't: Scale-Making and Exclusion in the Great Limpopo"

**October 8, 2003** -Robert Nichols, Flood Research Center, Middlesex University  
-"Some global impacts of sea-level rise: A case study of flooding"

**October 15, 2003** -Nick Shorr, Post-Doc Fellow, EPP:HDGC-"WHAT GOOD IS FEELING BAD? Negative emotions and environmental concern among Pittsburgh teenagers"

**October 22, 2003** -Lester Lave, CMU Professor, GSIA/EPP-"Should the Corporate Average Fuel Economy (CAFE) Standards Be Raised?"

**October 29, 2003** -David Grossman, Ecologist/Consultant-"Overview of the natural and human dimensions of the GLCA: Current status and key issues."

**November 5, 2003** -Peter Adams, Asst. Professor, CMU:ECE-"Ultrafine particles and climate change"

**November 12, 2003** -Francisco Veloso, Professor, CMU:EPP-"Process Management Practices and Performance: Early results from an investigation of ISO 9000 adoption in the automotive components sector"

**November 19, 2003** -Michael Grubb, Imperial College, Environmental Science and Technology-"Technology's the answer - but what was the question? - analytic and transatlantic divides in responding to climate change."

**December 3, 2003** -W. Neil Adger, Tyndall Centre for Climate Change, University of East Anglia-"Justice in Adaptation to Climate Change"

**December 5, 2003** -Felix Dayo, Triple-E-Systems and Max Henrion, Lumina-"Integrated Assessment of Global Change in West Africa: Towards a model of climate, water, and agriculture."

**December 10, 2003** -Richard Moss, Director Climate Change Science Program Office-"Making Climate Science Relevant to Decisionmaking"

**January 14, 2004** -Hadi Dowlatabadi, Professor UBC-"Explorations in regime change: B-Thalassaemia, and the interplay of technological change and social norms."

**January 29, 2004** -Benoit Morel, Senior Lecturer, CMU:EPP-"Making the electric powergrid more reliable"

**February 4, 2004** -Mahesh Patankar & Anand Patwardhan, IIT -"Environmental policies and resulting outcomes - an analysis of transport sector case studies in India"

**February 13, 2004** -Robert Lempert, Senior Scientist, RAND-"Robust Decisionmaking"

**February 18, 2004** -James Reynolds, Professor, Duke University-"The interactive role of human and environmental dimensions in the desertification debate"

**February 25, 2004** -Nick Shorr, Post-Doc Fellow, EPP:HDGC-"In Search of Civic environmentalism: some clues from adolescent environmental concerns and understandings"

**March 3, 2004** -Gary Yohe, Professor, Wesleyan University-"AR4 - Help Wanted"

**March 18, 2004** -Hennie Lotter, Professor, Rand University-"Should Elephants be culled?"

**March 24, 2004** -Upasna Sharma & Anand Patwardhan, IIT-"Assessing impacts as changes in economic output"

**March 31, 2004** -Tim McDaniels, Professor, UBC-"Steps towards policy analysis for global change issues: a synthesis from the CISHDGC values, learning and decision processes project."

**April 7, 2004** -Billie Turner, Professor and R. Gilmore Pontius, Asst. Professor Clark University-"Classification for Integrated Land-Change Science"

**April 16, 2004** -Joseph Arvai, School of Natural Resources, Ohio University-"Trick or treatment? Evaluating the quality of structured risk management decisions"

**April 21, 2004** -James Tansey, Research Associate, SDRI:UBC-"Living in groups, dying alone: A population health perspective on resilience"

**May 3, 2004** -Sheila Jasanoff, Professor, Harvard-"Constitutional Implications of Global Environmental Change"

**May 5, 2004** -H. Keith Florig, Sr. Research Engineer, CMU:EPP - "Public Involvement in Risk Management ? A Retrospective and Assessment"

**May 12, 2004** – HDGC:TBPARI Bates College Student Presentation, Peter J. Rogers, Advisor Abigail Harris - Border Life: A clash between wildlife conservation and rural poverty  
Kathryn Mannle - Nurturing Seeds of Association: Encouraging Democracy and Conservation through Civil Society at Masoala National Park, Madagascar  
Elizabeth Morrill - Carrying the Burden: Understanding the Influences on Women's Fuel-wood Collection Practices in Northeastern Tanzania

**May 19, 2004** – Barry Lynn, Research Scientist, Hebrew University - "The relationship between the characteristics of precipitation and extreme climate (change)variability."

### ***Summary Reports***

We have undertaken two dedicated efforts to bring together the Center's accomplishments in a unified, accessible form.

One is a summary report on the Center's full life. It is being drafted by Diana Rhoten, of the Social Science Research Council, in collaboration with the Center's director. Diana is in a unique position to undertake this initiative, as a student of interdisciplinary research, who studied our Center, among others, as part of an NSF-funded research project. As part of that project, she conducted in-depth interviews with many Center investigators, as well as securing their participation in a structured survey, illuminating the formal and informal networks among investigators. Although the summary will celebrate the Center's many accomplishments, it will also reflect on the lessons that we have learned (and are still seeking to learn) regarding the challenges of interdisciplinary research. A draft will be available at this year's annual meeting, and the subject of a dedicated discussion. We hope to have an attractively designed version available over the summer.

The second summary is a book-length treatment of our approach to sharing information among scientists and between them and their publics. Under contract to Cambridge University Press, it is tentatively titled Understanding Risk Decisions. In effect, it brings together our work on integrated assessment and risk communication, using the "mental models" effort (initially supported by NSF, some 15 years ago). The mental models approach translated early integrated assessment research into terms that facilitated the participation of the behavioral sciences, as well as formulating assessment in terms that met the information needs of stakeholders (and not just those of scientists seeking ways to work together). A full prospectus is available upon request. It builds on Morgan et al.'s Risk Communications: The Mental Models Approach (2001), also supported by Center (and NSF) funding. However, rather than focusing on the development of communications, it focuses on the creation of behaviorally realistic risk assessments – which could be used for communication purposes, but also for predicting the performance and improving the design of complex systems. It also seeks to restore the integration of normative, descriptive, and prescriptive research, which was essential to the formative stages of behavioral decision research, but which has been somewhat diminished as researchers have specialized.

The book will present (a) the basic approach, (b) present a fully worked example (on sexually transmitted diseases), and (c) a diverse set of case studies (supported by a variety of public and private sources, in addition to NSF), intended to demonstrate the generality of the approach and facilitate its application. Theoretically, the methodology brings together research from cognitive psychology, decision science, risk analysis, public health, and systems analysis. Each application involves further theoretical work, as it integrates diverse strands of research regarding the processes creating and controlling risks. As a result, the approach embodies a paradigm for interdisciplinary science. It has been pursued in domains as diverse as sexually transmitted diseases, sexual assault, climate change, radon, childhood immunization, breast implants, mammography, domestic chemical, terrorism, and infectious diseases. . The case study chapters were chosen from our several dozen case studies according to the following criteria: (a) theoretical contribution of the integrated assessment, in terms of the research that it brings together; (b) descriptive contribution of the empirical studies, to understanding specific beliefs and general cognitive processes; (c) prescriptive contribution of the applications, to improving decision making; (d) generality of the solution, in whole or in part; and (e) inherent interest of the subject matter. Concluding chapters consider (a) how to apply the approach to new problems, building on the pieces presented there; (b) what the research shows, regarding lay people's decision-making competence; and (c) implications for the organization of an interdisciplinary research program.

## **V. OTHER FUNDS**

Over the past year, we have continued to attract additional funding, extending projects begun at the Center (see Section F). The cumulative list of these funding sources over the life of the Center includes:

W. Alton Jones Foundation: Biofuels; Nuclear Power in China: The Social Dimensions of Energy Choice  
 Aquanet NCE program  
 American Petroleum Institute: General research funds.  
 American Psychological Society: Research on terror risk perceptions  
 Babcock & Wilcox; carbon sequestration  
 Canada National Centres for Excellence  
 Canadian Climate Change Action Fund  
 Canadian Foundation for Innovation  
 Canadian Social Science Humanities Research Center, Georgia Basis Futures Project  
 Carnegie Mellon University, seed funds for geochemical sequestration  
 Centers for Disease Control: Integrated study of vaccine risks and communication.  
 Conde Nast Traveler Magazine, in kind contribution for survey research  
 Electric Power Research Institute (EPRI): Institutional factors affecting energy use regimes; transition to sustainable energy systems; managing Egyptian water resources; carbon sequestration.  
 Environmental Protection Agency: research on emissions trading; Consortium for Atlantic Regional Assessment (CARA)  
 ExxonMobil Corporation: General funds for environmental health research.  
 Food and Drug Administration, communication of technical information  
 Fulbright Hays  
 India Ministry of Environment and Forests  
 International Center for Research in Agroforestry, graduate support  
 IUCN-South Africa, TBPARI  
 MacArthur Foundation: Intertemporal choice; risk management; international security; renewable energy  
 Mellon Foundation; carbon sequestration; underground deposition of pollutants.  
 National Science Foundation: Workshop on desertification (Dahlem Conference); science policy in Brazil; assessment of National Assessment; deeply uncertain risks of genomics, extreme events and infrastructure. ARIDNet  
 NATO, climate change and tourism  
 NOAA, Sustainability systems  
 Office of Naval Research, on decentralized resources and decision making in electric power.  
 Russell Sage Foundation: Role of emotions in choice.  
 Sloan Foundation: Transition to stable energy systems, multi-pollutant control.  
 South African National Research Foundation, TBPARI  
 Teresa Heinz Scholars for Environmental Research (Anand Rao)  
 The Charles A. and Anne Morrow Lindbergh Foundation (Shalini Vajjhala)  
 UKESRC, risk communication on environmental health  
 USAID: Indian vulnerability to climate change.  
 USDOE: Integrated modeling of carbon management technologies.  
 University of British Columbia, Bridge Program, linking public policy, health sciences, and engineering; bioethics and genomics  
 University of West Virginia, digital history training  
 University of Witwatersrand: Transboundary protected areas.  
 World Health Organization: Air pollution in China.

The joint funding from EPRI and the Sloan Foundation has allowed us to create a spin-off center for research on emerging electricity issues, focused on aspects of one of the Center's focal domains. Carnegie Mellon University's Center for the Study and Improvement of Regulation also arose, in part, from CIS-HDGC. The Carnegie Mellon Center for Risk Perception and Communication has funds from various sources (e.g., CDC, FDA, NIAID) for work building on the integrated assessment-mental models approach developed under NSF auspices. In addition to the examples of leverage presented above, various Center investigators have raised substantial

funds in support of their work directly. We have not reflected their successes here, even though many attribute some of this success to the projects begun with the Center and its environment, helping them to consider human dimensions issues more effectively.

The Canadian government has recognized our achievements by honoring two Center investigators with endowed professorships, Hadi Dowlatabadi (British Columbia) and David Keith (Calgary). Institutionalizing its commitment, the University of British Columbia, with other government and corporate supporters, is in the process of creating a Centre for Interactive Research on Sustainability (CIRS) to build and evaluate one of the most advanced green buildings in the world and house a facility that will support 'sustainability experimentation' in the region designed to lead to the development of commercially viable and politically acceptable strategies and interventions, consistent with the goals of sustainable development.