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Assessing Climate Change: Co-evolution of Knowledge, Communities, and Methodologies

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Abstract

This paper explores climate change impact assessment, an area of increasing importance in regard to climate change science and policy-making. Through an historical overview of impact assessment and through case studies of sea-level rise and health impact sectors we document some of the major trends and debates that have characterized the impacts field. Our findings reveal ways in which the definition and analysis of impacts reflect aggregation of scientific, political, and societal issues. We also suggest that impact assessments can be thought of as "trading zones" in which negotiations take place between many actors over data, research priorities, participation, and methodological issues. These negotiations, in turn, have important implications for knowledge and power. For example, impacts and assessments of impacts are closely tied to organization within the scientific community, dominance of various research methodologies, boundaries that differentiate science and policy, and the viability of certain climate change policy responses.

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The Global Environmental Assessment (GEA) project is a collaborative team study of global environmental assessment as a link between science and policy. The Team is based at Harvard University, but includes substantial contributions from the International Institute for Applied Systems Analysis (IIASA) in Austria, Cornell University, Duke University and the Center for Integrated Study of the Human Dimensions of Global Change at Carnegie Mellon University. The project has two principal objectives. The first is to develop a more realistic and synoptic model of the actual relationships among science, assessment, and management in social responses to global change, and to use that model to understand, critique, and improve current practice of assessment as a bridge between science and policy making. The second is to elucidate a strategy of adaptive assessment and policy for global environmental problems, along with the methods and institutions to implement such a strategy in the real world.

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Publication abstracts of the GEA Project can be found on the GEA Web Page at http://www.ksg.harvard.edu/bcsia/enrp/gea. Further information on the Global Environmental Assessment project can be obtained from the Project Associate Director**,** Nancy Dickson, Belfer Center for Science and International Affairs, Kennedy School of Government, Harvard University, 79 JFK Street, Cambridge, MA 02138, telephone (617) 496-9469, telefax (617) 495-8963, Email nancy_dickson@harvard.edu.

Acronym List

AAAS	American Association for the Advancement of Science
ACF	Advocacy Coalition Framework
AOSIS	Alliance of Small Island States
CIAP	Climate Impact Assessment Program
CZM	Coastal Zone Management
CZMS	Coastal Zone Management Subgroup
DOE	United States Department of Energy
DOT	United States Department of Transportation
EIA	Environmental Impact Assessment
EPA	United States Environmental Protection Agency
FCCC	Framework Convention on Climate Change
GCM	General Circulation Model
ICSU	International Council of Scientific Unions
IIASA	International Institute for Applied Systems Analysis
IPCC	Intergovernmental Panel on Climate Change
NAS	National Academy of Sciences
NDU	National Defense University
NEPA	National Environmental Protection Act
NGO	Non-governmental Organization
NRC	National Research Council
SMIC	Study of Man's Impact on Climate
SCOPE	Scientific Committee on Problems of the Environment
SPREP	South Pacific Regional Environment Programme
UNEP	United Nations Environment Programme
WAIS	West Antarctic Ice Sheet
WCC	World Climate Conference
WHO	World Health Organization

WMO World Meteorological Organization

WWF World Wildlife Federation

Assessing Climate Change Impacts: Co-evolution of Knowledge, Communities, and Methodologies

Marybeth Long and Alastair Iles

Introduction[i]

Societies tend to perceive and respond to global environmental change in terms of its manifestations in social and ecological systems. European acid rain is linked with forest die-backs, the ozone hole is associated with dramatic increases in skin cancer, and climate change is often viewed as causing droughts, inundated coastal areas, and the spread of tropical diseases. The current prominence of these effects in climate change research and policy-making suggests that climate change impacts are based on well-defined sets of knowledge, experts, and methodologies. However, assessments[ii] of impacts appear to reflect a highly fluid and changeable domain in which impact categories, research communities, and methodologies vary considerably across time and across assessment activities.

Currently, impacts research and assessment is less stable than, for example, atmospheric science research. Analyses of how greenhouse gas emissions might influence biogeochemical cycles have remained fairly consistent in scientific studies throughout the 1980s and 1990s (e.g., NRC 1983; DOE 1985; IPCC 1990a; and IPCC 1995a). Typically climate change assessments examining the "chemistry" of global warming and its more immediate effects focus on greenhouse gas emissions, and their influence on oceans, the atmosphere, and the general circulation. Similar assumptions and methodologies generally characterize all such analyses and the scientific debate now largely focuses on how to interpret results. By contrast, impact assessments have been far less consistent over time and across studies. As evidenced by the notably different treatment of impacts by the Intergovernmental Panel on Climate Change (IPCC) in 1990 and 1995 (IPCC, 1990b; 1995b), discussions among scientists, policy-makers, and assessors are currently underway regarding such fundamental issues as what constitutes an impact and how impacts should be investigated.

Although the practice of impact assessment has evolved considerably since the first studies of the 1970s, controversy still pervades many aspects of the field. Milestones in development of agricultural impact methodologies include: simple, statistical relationships between temperature, precipitation, and rainfall, with technological change treated exogenously (NDU, 1980), incorporation of different types of adaptation in models of agricultural production (Parry et al., 1988); linking of crop and economic models (EPA, 1989); inclusion of inter-regional economic connections with adjustments and adaptations (Rosenberg, 1993); and integrated global assessments of agricultural impacts (Rosenzweig and Parry, 1994). Despite this overall, progression, however, important debates continue regarding the most appropriate spatial scales for analysis (Easterling, 1997) and the treatment of adaptation (EPA, 1989; Smit et al., 1996). Similarly, sea-level rise experts and coastal zone managers disagree about the nature and goals of vulnerability and adaptation studies (EPA, 1989; IPCC, 1992b; SPREP, 1993; IPCC 1995b).

As seen in climate change impact assessments from the 1970s onward, "impacts" can be identified, defined, and interpreted by scientists, policy-makers, and assessors in many different ways. Most assessments analyze impacts from a developed country perspective[iii] (see Harvey, 1993) and categorize them according to market sectors. However, the impact sectors that are identified can vary significantly. While some studies have examined the impacts of climate change on a small set of impact areas such as agriculture, water supply, and sea-level rise (NRC, 1983), others have analyzed up to twenty-five impact sectors including forests, fisheries, energy use, and urban infrastructure (EPA, 1989; IPCC 1995b).

In this paper we document some of the major trends and changes that have characterized the evolution of impact categories and impact assessments over time. We then interpret these dynamics from a social studies of science perspective. Our observations are based largely on written and verbal accounts of impact assessment processes. Because impacts concern complex relationships between climate change phenomena and natural and social systems, an assessment of impacts is an aggregation of scientific, political, and societal issues. Consequently, such an assessment can be thought of as a "trading zone" where questions over data, research priorities, participation, and methodological approaches are negotiated among scientists, assessors, policy-makers, and other assessment users. These negotiations contribute to "co-production"[iv] of knowledge, which in turn, gives rise to particular impact interpretations and framings.[v]

Our study presents a broad history of impact assessments (Section 2) and two case studies (Sections 4 through 6). One of the case studies concerns assessment of sea-level rise, while the other focuses on assessment of health impacts.[vi] In our historical overview we address questions such as: What is an impact and when do different types of impacts emerge? Who defines an impact? And how are impacts studied? In our case studies we focus on three more specific questions, namely, 1) How are impacts defined and redefined over time? 2) How do communities co-evolve with impact definitions and assessments of impacts, and 3) How do research methodologies co-evolve with impact definitions and assessments of impacts?

In addressing these questions we draw upon perspectives which have yet to be applied to the climate change impacts area, but which have proven useful in understanding interactions between science and policy in other arenas. In particular, we borrow ideas from political science; policy studies; and science, technology, and society fields, with the aim of illuminating the dynamics we observe in impacts research and their broader consequences (see Section 3). Our findings reveal important relationships between the ways in which impacts are defined and redefined over time, the organization of communities around impact sectors, and the evolution of assessment methodologies. Further, our analysis indicates that negotiations (or boundary work) take place among scientists, policy-makers, and assessors regarding what is an impact and who is affected, what counts as science and what counts as policy, the degree to which certain populations are seen as susceptible to climate change, and the viability of certain climate change policy responses.

Impact assessments and "impacts"

Climate change impact assessments are usually conducted with the aim of providing information that can be used by policy-makers and scientists to identify where the key effects of climate change are likely to occur, what character these effects have, and what research is needed to improve understanding of these effects. Thus, in 1978, the National Academy of Sciences' (NAS') International Workshop on Climate Change concluded that climate impact studies should "determine the effects of climate on the various sectors of the natural world and on human economic and social life, such as hydrology, agriculture, and energy." According to NRC (1978), these studies should also help "determine the kind of climatological information needed to serve short and medium-range decision-making intended either to decrease adverse effects of unfavorable climate or to take advantage of favorable conditions with reference to a given natural or human system."

Impact assessments, however, are not merely tools for identifying what climate change may do to human activities and the environment. They are also tools of communication and aggregation. Even in early assessments, impacts were viewed as a means of communicating climate change phenomena to policy-makers and the broader public. Impacts can make climate change politically salient and visible. Hence, impact assessments can also help to catalyze further research and assessment efforts. For example, in 1985, at the Villach Conference, Mostafa Tolba argued that it was time to accept the reality of climate change, and to begin exploring its possible impacts, which might have "enormous social and economic consequences." To facilitate the policy debate over what should be done, the "person on the street" (in Tolba's words) needs to be informed about climate impacts (UNEP et al., 1985).

As the threat of climate change has increased over the last twenty-five years so has the demand for information about global warming and its consequences. The resultant proliferation of climate change assessments has paralleled marked developments in the concepts of "climate impact" and "impact assessment." In the early 1970s, efforts such

as the Study of Man's Impact on Climate (SMIC, 1970) gave way to investigations of how human-induced climate variations might influence social and ecological systems (Rockefeller, 1976; NDU, 1978; NDU, 1980). These early analyses often examined, for example, how changes in temperature and precipitation would influence crop yields. However, these studies generally assumed a direct cause-and-effect relationship, focused on a limited spatial scale, and did not account for impacts of non-climate variables, nor the multiple feedback effects that operate in coupled natural and social systems. More recent reflections on the nature of climate/society interactions have been instrumental in calling attention to the inherent complexity of these interactions and the need to account for this complexity in analysis of impacts (Kates et al., 1985; Parry et al., 1988). Subsequent impact assessments have increasingly accounted for intervening factors, feedbacks associated with human response, and a range of spatial and temporal scales (examples from the agriculture sector include Parry et al., 1988; Rosenberg; 1993; Smith and Tirpak, 1989; and Rosenzweig and Parry, 1994).

Despite the increasing sophistication of impact assessments and their underlying models of climate/society interactions, few, if any, accounts of climate change impact studies have directly questioned the definition of "impact" and how this definition shapes and is shaped by forces in science, policy, and public arenas. Climate change impacts could have been conceived of in an indefinite number of ways. Yet, these impacts have largely been categorized according to market sectors and in terms of the various modes outlined in Table 1. Recognizing that accepted definitions of impacts are not automatically dictated by natural phenomena, prompts questions that take a step back from the progressive and helpful reflections of Kates et al. (1985) and Parry et al. (1988). Such questions include:

- What is an impact and when do various notions of impacts emerge?
- How are impacts identified and who judges which impacts are most relevant and important to societies?
- How do certain definitions of impacts give rise to specific modes of impact assessment and what consequences arise from various types of assessment?
- How do impacts and assessments of impacts serve to delineate the respective domains of science and policy?
- To what extent do certain impact conceptions enable scientists to make their work policy-relevant and enable policy-makers to make strategic declarations or decisions about climate change?

In the historical overview and case studies below we aim to address some of these questions. In doing so we attempt to demonstrate the indeterminate nature of the impacts domain. We point out how this indeterminacy has led to the variable, and often highly contested, character of impact assessment. We also explore what consequences these contests and their resolution have for society and its responses to climate change.

Boundary Work

In interpreting the evolution of the impacts field over time we draw on social science concepts which have proven useful in understanding interactions between science and policy in other contexts. In particular, we find notions of "boundary work" helpful in understanding the development and evolution of impact definitions and assessment practices.

Broadly, boundary work deals with the activities of creating and maintaining "lines" dividing research domains, knowledge, disciplines, expert jurisdictions, and institutional responsibilities. Scholars such as Jasanoff (1990) and Gieryn (1995) have illustrated how when scientists seek or contest the cognitive authority of science, they continually negotiate the borders between science and other fields.[vii] These ideas can be applied to the realm of climate change assessments where boundary work is evident in efforts to facilitate collaboration between scientists and policy-makers while also affirming science's authority. While scientists must ensure that their research communities support the representations of their work, they may also seek this support from the policy communities. For example, scientists may emphasize the heuristics of their work when interacting with other scientists, but highlight the predictive capabilities of their work when dealing with policy-makers. Similarly, policy-makers may draw boundaries, to take more of the natural scientists' jurisdiction into their own domain, or to downplay the importance of natural scientific inputs by highlighting the role of politics.

In this paper we adopt a somewhat broader view of boundary work. We are less concerned with the ways in which science is distinguished from policy, and more interested in how the interactions among scientists, assessors and policy-makers demarcate different aspects of impacts, communities, and methods.[viii] This range of boundary work activities greatly influences the kinds of impacts we consider. While the boundaries between science and policy are crucial in impact assessment, these boundaries seem to be highly porous and malleable, so that an impact assessment can be both "science" and "policy" in a kind of condensation that facilitates the involvement of both scientists and policy-makers. Likewise, both natural and social scientists are increasingly becoming engaged in interactive cooperation rather than merely competition. This suggests that assessment processes serve as both boundary-makers and boundary-crossers to varying degrees. Assessments are also "trading zones" in which different interpretations of climate change and its effects are exchanged and modified, with significant implications for what is eventually channeled into policy-making.

The design and practice of impact assessment potentially includes many instances of boundary negotiation. For example, by locating an impact within human instead of natural systems, an assessment process might define this impact as a social science rather than a natural science problem. Assessors might separate some impacts from other impacts, or may describe them in particular ways that make them seem more, or less, significant for policy-makers. Assessments may also distinguish "impacts of climate change" from the effects of naturally occurring climatic variability. Further, researchers and assessors may seek to downplay the validity of key assumptions or models by

questioning their scope, credibility, and implications. Scientists may favor certain methods as more technically useful and valid than others as evidenced by application of models which endogenize adaptation or use of transient scenarios instead of equilibrium scenarios of climate change. Finally, boundary work may occur as uncertainty is interpreted by different actors in accordance with their various agendas.

Historical Evolution of Impact Assessments

Boundary work is evident in the history of impact assessment. Below we provide an overview of the impacts field by tracing chronologically the development of several key themes in the evolution of impacts and impact assessment processes. The overview illustrates how generally accepted models of impacts have changed over time, highlights instances of boundary work, and provides a broad context for our case studies.

The 1970s

The 1970s marked initial developments in the impacts field. Climate change impact assessments emerged alongside ongoing climate variability research and environmental impact assessments. The first signs of a sectoral organization of impacts appeared and some assessments began to distinguish between first and higher-order impacts (see Table 1).

The "impact" concept rose to prominence in the early 1970s. However, most studies concerned human impact on the environment or the effects of weather variability on agriculture. In 1969 the U.S. Congress enacted the National Environmental Protection Act (NEPA), which required federal government agencies to assess the ecological effects of significant projects. This focus on human influences on the environment was also evident in some of the first major climate assessments. The Study of Man's Impact on Climate (SMIC, 1970), for example, addressed impacts in exploring how tropospheric and stratospheric modification and changes in land use patterns affected the earth's surface. Studies during this period which did examine impacts of climate variation on human systems generally emphasized the effects of short-term climate variability on water resources and agriculture production, as evidenced in the NRC study entitled *Climate and Food* (NRC, 1976).[ix]

A significant event in the evolution of impact assessments and impact categories was the Climate Impact Assessment Program (CIAP) study ending in 1975. In response to a request by the U.S. Congress, the federal Department of Transportation (DOT) sponsored a five year research project into climate changes potentially flowing from stratospheric flight by supersonic aircraft. Although this study set out to determine the range of impacts on the climate caused by human activities, it also examined how resulting climate changes might affect ecological, social, and economic conditions (CIAP, 1975a).

Furthermore, two of the monographs produced by CIAP were among the first assessments to frame climate change impacts according to sectors and in terms of direct cause-and-effect relationships, flowing from environmental change to society.

Monograph 5 reported on a series of commissioned biological studies to assess the effects of changes in temperature, precipitation, winds, and (ultraviolet) UV radiation on the agricultural sector (CIAP, 1975b). It emphasized agricultural productivity as measured by crop and forest yields, therefore helping set the tenor of future agricultural impact assessments. Monograph 6, lead-authored by Ralph d'Arge and prepared by a small group of economists, was the first assessment to focus on social and economic measures of climate change (CIAP, 1975c). This group sought to investigate the question: "What would be the magnitude of societal impact, both in economic and non-economic terms, of substantial alterations in climate?" Their research focused on urban, health, and natural resources (divided into agricultural, fisheries, and forests) impacts. It helped generate a view of climate as an economic resource, in which "impacts" of climate change had direct and indirect economic values for societies.

Another key event in the emergence of "impacts" as a constructed category of analysis was the NAS workshop held at the Institute for Applied Systems Analysis (IIASA) in 1978. This was the first major gathering of scientists and social scientists to specifically target impacts as a discrete aspect of climate change. The workshop identified the climate impact study as a relatively new form of research and outlined general impact study objectives. According to these objectives, impact studies "should attempt to determine the direct effects of climate variability on physical and biological systems; the indirect effects, as they are modulated by socio-economic structures; and, on the basis of this understanding, the information and methods needed to support decision-making and long-range planning" (NRC, 1978). This assumes that, climate change can be divided into a range of direct (socially unmediated) and indirect (socially mediated) effects on natural and social systems.

During the late 1970s, impacts were increasingly addressed in assessments carried out, largely by U.S. government agencies and scientific research institutions, such as the Central Intelligence Agency (CIA, 1974a; CIA, 1974b), and the National Research Council (NRC, 1977; NRC, 1978; NRC, 1979) . These assessments collectively began to build a frame of impacts as being divided into "first-order" physical and climatic effects on temperature, precipitation, and oceans. In turn, there was a number of "higher-order" effects caused directly or indirectly by these first-order effects, such as sea-level rise resulting from ocean thermal expansion, or changes in agricultural crop yields (see Table 1).

At this stage, the higher-order impacts were largely undifferentiated from one another and generally concerned effects on ecological systems, agricultural productivity, and property loss. However, assessments did begin to reflect boundaries between different kinds of "impacts," as well as the allocation of research tasks among different disciplines according to these boundaries. For example, in 1979, the NRC Climate Research Board examined climate change effects on temperature, precipitation, evaporation, and soil moisture. However, the Board refrained from considering socio-economic impacts because it did not think itself qualified to do so (preface, NRC 1979). Instead, the Board deferred these tasks to the Scientific Committee on Problems of the Environment

(SCOPE, organized under the auspices of the International Council of Scientific Unions (ICSU)), which was comprised largely of geographers and biologists.

The National Defense University (NDU) studies of climate change and agriculture, carried out in the late 1970s, reflect additional forms of boundary-drawing regarding impacts. In particular, the NDU study reveals how researchers, assessors, and policy-makers tend to "carve out" a small number of impact manifestations from phenomenological space in order to facilitate research and evaluation. Originally, the NDU assessment was intended to investigate the implications of climate change for US national security generally. When this task proved too expansive the US government "settled" for a case study of the agricultural sector, specifically crop yields. This choice was particularly relevant in light of recent food security crises.[x] Further, officials and assessors believed that a study of agriculture could provide a reproducible "template" for future study of other areas (NDU, 1980).[xi]

Another critical event in the evolution of impact assessment was the Workshop on Environmental and Societal Consequences of Climatic Change, hosted in 1979 by the U.S. Department of Energy (DOE) and the American Association for the Advancement of Science (AAAS). The workshop emphasized some "higher-order" impacts, particularly the effects of increased carbon dioxide in fertilizing crop and forest growth, changes in regional hydrological cycles, property losses caused by sea-level rise, and the biological modifications of ecosystems. These "impact" categories were similar to those in other early assessments, as much less attention was given to "human effects" (health and nutrition) and to "sociopolitical impacts." The workshop, however, did discuss the economic effects flowing from agricultural productivity (such as farm income and property loss), but without attention to intervening human activity. While the focus was on negative impacts, the beginnings of what can be called a "net impact" approach are visible here. Under this approach to constructing impacts, both beneficial and adverse effects are considered, and the net outcome of climate change is aggregated for policy-making purposes (see DOE, 1980).

Impacts were also assessed as part of the first World Climate Conference (WCC) in 1979, one of the first international climate change assessments of its kind. This assessment reflects a relatively narrow conceptualization of impact categories. Its proceedings largely focused on the agricultural sector, and did not address other impact areas such as sea-level rise, which was then beginning to emerge as a sector in its own right. The agricultural impacts analyses addressed agriculture as a climatic resource and examined global aspects of food production. In addition, relationships between climatic variability and agriculture were assessed for temperate, tropical moist and semi-arid tropical regions (WCC, 1979).

While the first World Climate Conference was the first major conference to address human health, its treatment of health/climate change interactions focused on basic relationships between climate and health, and did not investigate how global climate change might induce changes in the character of diseases (WCC, 1979).

The Period: 1980-1984

During the early 1980s, much discussion ensued regarding impact assessment methodologies and the need for interdisciplinary research. Furthermore, adaptation was more systematically incorporated into impact assessment, and boundaries between certain sectors became more firmly delineated.

The beginnings of the 1980s marked a crucial transition phase, both for climate science and for assessment of impacts. At this time a debate crystallized over the methodological bases of climate science research. The debate included the following elements:

- The limitations of case studies, historical analog approaches, and present-day observations were discussed exhaustively at conferences and in the literature. In particular, the rate and extent of climate change were claimed to be unprecedented, therefore limiting the utility of extrapolations from historical data and present-day observations.
- The equilibrium-based (general circulation model) GCM methods of generating mathematical representations of climate effects and projecting future climate trends were promoted as a means of making research methods more rigorous and less biased toward present-day conditions. Impact research was to be entrained in the GCM framework, with impact modeling relying on climate data generated by GCMs.
- A range of non-modeling-based methods were also proposed for assessments of impacts. These included analogy methods (Glantz, 1988) and correlation analysis (Kates, et al., 1985).
- There were also calls for interdisciplinary research and communication (Chen, 1981; Warrick and Riebsame, 1981). These critiques explored how fragmented frames of "impacts" hindered a more synthesized and interrelated perspective, and how existing disciplinary communities and methods discouraged cross-disciplinary work. Schneider and Chen's attempt in 1980 to estimate some of the economic costs flowing from sea-level rise for the United States was an attempt to broaden the terms of impact assessments and spur "integrated assessments" (Schneider and Chen, 1980).
- Noticeably, there was little reference in climate impact circles to concurrent developments in Environmental Impact Assessment (EIA), which was seemingly set apart from the technical work of climate impact researchers. The "climate" character of impact assessments was used to distinguish these assessments from other environmental assessments.

Impact assessment during the 1980s reflects a growing dominance of GCM-based methodologies. The alternative methods noted above might have given rise to different research strategies. However, researchers, based mainly in the U.S., Britain, and Australia (the primary sites for impact assessment) opted for GCM techniques. This reflects a type of boundary drawing exercise whereby the physical science disciplines (GCM modellers) have expanded their circle of influence into the natural and social science domain of impact studies. Furthermore, the dominance of GCM analysis has

implications in regard to other types of boundary-crossing and boundary-making. Firstly, GCM's and other modeling tools can facilitate interaction between different disciplines through the linking of different models. Integrated agricultural impact studies, for example, might combine GCM outputs, plant physiology models, and global trade models (Rosenzweig and Parry, 1994). On the other hand, GCM methodologies might prevent cross-disciplinary interaction by shutting out disciplines in which preferred techniques are not amenable to GCM approaches. As discussed below, this type of barrier may have played a role in the treatment of health impacts during the 1980s (Martens, 1997). The specific context in which GCM methods are linked with other impact research activities is, therefore, crucial.

The idea that human societies can adapt to the impacts of climate change began to appear more frequently during the early 1980s. The EPA assessment of 1983, while failing to consider impacts to any substantive extent, foresaw "the possibility that some negative effects will be mitigated, depending on the success and speed of efforts to adapt economic activity to altered climatic conditions." At this time, however, assessments did not incorporate a view of adaptation as endogenous to every climate change impact. Rather, adaptation was considered separately from impacts and generally viewed as a policy response. This tendency is reflected in the early work of the IPCC during the late 1980s, which allocated assessment of adaptation options to Working Group III (responses) instead of to Working Group II (impacts).

During the early 1980s, as well, sectoral categorization of impacts became more prominent. Previously, "impacts" had often been described and represented as relatively undifferentiated climate change effects. During the early 1980s, however, assessors began defining, evaluating, and reporting on a set of specific sectors of environmental and social importance. Nonetheless, sector categorizations were not "settled," in the 1980s. Different assessments presented divergent views of sectoral categories for impacts (although they all reflected the underlying assumption that impacts could be "sectorized"). An interesting contrast can be made between the NRC assessment in 1983 which included analysis of three sectors: agriculture, water resources, and health; and the EPA study in 1989 which included analysis of nine sectors (including agriculture, energy use, and forests) and four regional areas. What may be more important is that impact sectors have tended to remain relatively "intact" over time, even if they may be divided further into more discrete sectors (as with the fission of forests from agriculture, and health from miscellaneous human impacts).

Sectors pertaining to impacts roughly parallel those which delineate government planning processes and economic activities. Consequently, the organization of impacts into sectors is convenient for policy-makers who have to make decisions regarding how climate change might affect the interests of constituencies. Furthermore, sectors provide domains in which scientists can make their work policy relevant by framing their research results in terms of delimited cognitive fields (see Schon and Rein, 1994).

Other assessments by U.S. government agencies presented a different map of impact sectors, and even placed impacts at different points along the causal chain. For example,

the EPA study in 1983 focused on whether policies controlling the consumption of fossil fuels might help delay temperature increases. The report from this study only refers to impacts such as "dramatic changes in precipitation and storm patterns, and a rise in global average sea levels" which illustrate the need for emissions reductions. This reveals another assumption underlying the assessment of impacts: that researchers and policy-makers know what impacts are relevant and can judge which impacts deserve the greatest attention and research. Yet studies such as EPA (1983), NRC (1983), and EPA (1989) suggest that impact categories are judged to be of importance only if policies and/or adaptive strategies can be developed around them. Significantly, none of the above assessments mentions the ways in which ecosystem and socio-economic effects cross impact sectors or link together as part of an overall impact frame.

The Period: 1985-1990

During the late 1980s, assessments began to account for the interactive nature of climate/society relationships and sectoral categories proliferated.

The Villach Conference of 1985 was a major point in the construction of impact categories. While the conference was intended to review climate change data, and produce an authoritative statement of the scientific facts and the need for policy action, it was also intended to encourage a shift in researcher and policy-maker focus to "social and economic impacts" (UNEP et al., 1985). Working Group V of the conference (the panel on social and economic effects) noted that, even though most methods of impact assessment were underdeveloped, it was more critical to acknowledge and work with the limited reliability of these methods rather than continue to refine methods before applying them.

While the Villach working group did not engage in detailed scrutiny of impact assessment, it took a more synoptic perspective of how impacts could be understood. For example, priority was given to the need to identify ecological, social, and economic systems with special vulnerabilities to climate change, and to understand their critical, interactions. Priority was also given to the net effects of policies across the spectrum of environmental problems. This may have been one of the first efforts to "bundle" many multiple impacts. In other words, this assessment was not merely examining impacts in terms of fragmented and relatively discrete sectors, but was also aggregating impacts and considering linkages among them (UNEP et al., 1985)

The SCOPE 27 project was another critical assessment promoting an "interactive" view of impacts. Drawing on the existing geography scholarship regarding human responses to natural disasters, Kates et al. (1985) argued that the capacity of societies to absorb environmental impacts was not a simple and one-dimensional linear function, but arose from complex, interactive relationships between social and natural systems. Thus, impact research should try to identify vulnerable peoples, regions, and activities. The SCOPE 27 study essentially introduced vulnerability as a new impact category (see Table 1) that cut across existing categories by directing attention at the relative capabilities of different societies and local populations to cope with climate change. The SCOPE 27 assessment

also challenged assessors and researchers to think about the scales and relevance of their various research and assessment activities.

The continued development of impact analysis is evident in a major study on agricultural impacts conducted at IIASA (Parry et al., 1988). Although this study was limited to the agricultural sector, it proposed a more holistic model of impact assessment and applied it to a number of case studies in both developed and developing countries. In one of the few thoughtful reviews of impact theories, Parry et al. (1988) pointed out that early impact studies such as the CIAP and NDU assessments, tended to overlook important intervening variables and feedback processes by assuming a simple one-way, cause-and-effect relationship between climate change phenomena and impacts.

In contrast, Parry et al. (1988) introduced a "new" generation of impact studies which explicitly recognized that climate is only one of many variables affecting a population or an ecosystem. They applied a hierarchical "cascading" model where data on temperature and precipitation changes were fed into other models of agricultural processes to estimate how the social and economic characteristics of farmers might be affected. Parry et al. (1988) also downplayed the predictive capabilities of agricultural models by stressing that impact assessments were intended to suggest potential consequences of climate change events, and consider a range of impacts and adaptations. Their research findings were influential in helping define the range of impact variables eventually considered by the IPCC (1990b, 1995b). For example, Parry et al. (1988) targeted both the first-order effects directly resulting from temperature and precipitation changes, and the higher-order effects regarding farm productivity, regional production costs, regional farm income, household incomes, employment rates, and macro-economic behavior.

The IIASA (1988) study was also the first to fully integrate adaptation into analysis of agricultural impacts. Although adaptation had been considered in many earlier studies, Parry et al. (1988) were the first to incorporate it systematically. Interestingly, their reliance on empirical experience to specify the scope and character of adaptation for use with GCMs meant that the concept of impacts widened to include actual, localized perceptions of climate change and social behavior. These approaches have continued to influence the character of assessments in the 1990s, as evidenced by studies such as Rosenzweig and Parry (1994) and Smit et al. (1996).

The EPA assessment of 1989 illustrates the trend toward the increasingly specific and "comprehensive" impact sector reviews, which characterize the IPCC (1990b), WCC (1990), and IPCC (1995b) assessments. EPA assessors addressed impacts on forests, agriculture, sea-level rise, biodiversity, water resources, electricity demand, air quality, health, and urban infrastructure, as well as a number of regionally-based analyses. This study, too, marks the first extensive appearance of an economic analysis of impacts. Analyses regarding sea-level rise were based on a number of regional studies around the United States and explored the economic costs of protecting coastlines from inundation,. These studies emphasized the costs of losing property and presented various methods of coastline protection, with the aim of proposing the most cost-effective strategies for dealing with sea-level rise.

Furthermore, EPA (1989) was groundbreaking in that it marked the first attempt to directly model adaptation of agricultural production to climate change. The analysis centered on four regional case studies. GCM climate scenarios were used in conjunction with crop simulation models and, in some cases assumptions regarding agronomic adjustments.

Developments since 1990 are best explored in our specific discussion of sea-level rise, and health since these impact sectors are central to impact assessment generally. In conclusion, the evolution of impact sectors and impacts, more broadly, suggests that impacts are not static in their conceptualization, nor separate from changing research agendas, communities, and methodologies. As explored further in the case studies, the projected magnitude of many impacts (such as sea-level rise or agricultural productivity changes) have diminished over time. In addition, multiple and overlapping meanings of impact have emerged, so that no single comprehensive conceptualization of impact exists, and close attention needs to be given to the particular context in which an impact is assessed and researched.

Theoretical Framings for Case Study Analysis

The history of impact assessments illustrates that assessments are a vehicle through which scientists, assessors, policy-makers and other facets of society develop knowledge about impacts. Consequently, assessments serve as both indicators and agents of change. They reflect the different perceptions, expertise, and methodologies that surround certain impact definitions, while they can also serve to alter how impacts are viewed, researched, and factored (or not) into decisionmaking. To date, there has been little reflective scholarship directed toward understanding these intriguing aspects of impact assessment. In general, theoretical frames for investigating science and policy associated with global environmental change are generally underdeveloped, and many relevant ideas are based on studies of policy-making at the domestic level. Hence, a priority for our research is to begin collecting a set of theoretical insights that can help us interpret the co-produced nature of climate change impacts by researchers, assessors and policy-makers, and the possible implications this poses for society's response to global environmental issues.

In this section we consider the potential usefulness of theoretical frames from the "causal" and "interpretive" social science fields. Distinctions separating these two approaches are unclear and often permeable. For example, an element of interpretation underlies the most explicitly causal social science because of the ways in which causal pathways and dependent/independent variables are delineated. In a general sense, however, we use "causal" to refer to the fields of political science, economics, and sociology which employ scientific-style methods in seeking out cause-and-effect relationships between clearly defined dependent and independent variables. Exemplary ideas from this approach include those regarding agenda-setting (Kingdon et al., 1995), epistemic communities (Haas, 1992) and advocacy coalitions (Sabatier and Jenkins-Smith, 1993). In referring to "interpretive" social science fields we mean disciplines such as anthropology and science studies in which themes and organizing concepts are both

extracted from and used to illuminate observations of society. From the interpretive perspective we draw on ideas of boundary work (Jasanoff, 1990; Gieryn, 1995) (discussed in Section 2.1).

Agenda-Setting

The salience and nature of different types of impacts differ over time and across and within sectors. For example, agriculture, sea-level rise and health sectors seem to have attracted the most attention. However, they rose to prominence at different times with agriculture leading the way in the 1970s and health attracting significant attention in the 1990s. In addition, certain focal points and impact "manifestations" within each area have evolved over time. For example, attention to sea-level rise and agriculture have become increasingly concerned with adaptation (IPCC 1995b) and health impacts are beginning to be viewed in terms of costs to society (Epstein 1997).

These observations suggest that agenda-setting might be helpful in understanding the changing shape and salience of impacts as reflected in assessments of impacts. Kingdon (1995) looks at how a set of problems comes to attract the serious attention of government officials. He suggests that agenda-setting results from interactions between the three "streams" of problems, politics and policy-related, visible participants. According to Kingdon (1995), government officials become aware of problems through indicators, focusing events and feedback. Indicators are used to assess the condition and magnitude of certain problems (e.g., the incidence of disease, the costs of flood damage). Focusing events include disasters, crises, and powerful symbols.[xii] Informal or formal types of feedback can also attract attention by way of monitoring results and complaints from program observers. The political stream contributes to agenda-setting through perceived swings in national mood, elections and interest groups. Visible participants influence the agenda via the press and public attention they attract.

Although Kingdon's (1995) emphasis on dynamics, spontaneity, chaos and technical information are applicable to the impact assessment landscape, there are many aspects of this theory that are of limited usefulness in understanding impacts and assessment of impacts. The dynamical aspects of Kingdon's approach can be applied in examining assessments of impacts. For example, Kingdon recognizes that multiple processes, focusing events and feedbacks work simultaneously to contribute to the shape and salience of various issues. These dynamics are evident as assessment processes respond, embody and contribute to the multiple, interacting forces which accompany impact framings. Furthermore, assessments often signal a response to a focusing event or contain information about what Kingdon calls indicators.

However, other assumptions underlying agenda-setting theory are problematic when viewed against observations of impact assessments. In particular, the case studies in the following sections reveal that Kingdon's identification of distinct streams of policy, politics and problems is artificial. For example, it is impossible to locate assessment processes in any one of Kingdon's three streams. Although assessments might highlight focusing events or provide evaluative functions for government officials, assessments and

the impact framings they reflect are the product of interactions among scientists, assessors, policy-makers and others. Thus, assessments cannot be categorized according to just one of the policy, politics or problem categories that Kingdon identifies.

In light of these problems, our case study treatment of impacts does not attempt to directly apply Kingdon's agenda-setting ideas to the impacts field. Instead, we use a mix of ideas from agenda-setting, community-building and boundary work to interpret the definition of certain impacts over time. This approach better enables us to explore the many contests, negotiations, and consensus-building activities that comprise assessments and framings of impacts.

Community-Building

As evidenced in the case studies, the impacts domain seems to include several loose and overlapping networks of actors which have coalesced around various climate change impact areas. In many instances these networks consist largely of an interdisciplinary set of experts who bring their specialized knowledge to the study of the complex effects expected from climate change. This is evident in the area of agriculture, for example, where different collections of agrometeorologists, climatologists, economists, policy-makers and others have collectively and individually addressed issues such as carbon dioxide fertilization, crop yields, agricultural economics and adaptive farming practices. However, such "communities" need not be limited to experts. Communities surrounding health impacts issues consist of a diverse set of public health specialists, medical experts and representatives from non-governmental organizations. Similarly, coastal zone managers, vulnerable populations and experts have come together around sea-level rise issues.

Given the appearance of these loose networks, the notion of "community" seems helpful in investigating the common interests and interactions that arise in regard to various climate change impacts. Many recent studies address "epistemic communities," "policy subsystems" and "advocacy coalitions". The concept of epistemic communities, as advanced by Peter Haas, describes networks of professionals with "recognized expertise and competence" who hold an authoritative claim to policy relevant knowledge and who share basic values, causal frameworks, forms of knowledge verification and a common policy enterprise (Haas, 1992). According to Haas, epistemic communities develop as demand for information arises and as strong actors at national and international levels delegate power to them (Haas, 1992).

In contrast, Sabatier and Jenkins-Smith (1993) provide a broader notion of community in their ideas about policy subsystems and advocacy coalitions. Subsystems include participants who regard themselves as part of a semi-autonomous community, share a domain of expertise on the policy issue; and seek to influence policy within the domain over a time period of at least 7 to 10 years.[xiii] [xiv] A subsystem is small enough such that members can communicate and pay attention to the relevant issues (Lee, 1993). Within the subsystem are various coalitions. A coalition is comprised of individuals from all levels of government and from different positions (e.g., interest groups, researchers,

officials) who share a set of beliefs. Coalition members interact over periods of a decade or more to affect formulation and implementation of public policy within a policy subsystem (Sabatier and Jenkins-Smith, 1993).[xv]

Epistemic communities and advocacy coalition ideas are valuable in that they call attention to the existence of actor networks and the interactions that characterize them. In addition, the Advocacy Coalition Framework (ACF) presented by Sabatier and Jenkins-Smith (1993) captures important dynamic characteristics of coalition membership and policy change and learning over time. However, certain membership criteria and failure to address emergence of ideas and networks, limit the usefulness of these concepts when examining the impacts arena. Shared sets of beliefs, experiences and normative convictions about how the world operates or should operate are a necessary condition for the existence of epistemic communities and advocacy coalitions. However, as our case studies reveal, these types of shared beliefs do not necessarily characterize impacts communities. Furthermore, established notions of community fail to consider how the beliefs and ideas that bind communities develop and how communities themselves emerge (Jasanoff, 1996). Our work aims to extend beyond these views of community in exploring catalysts and inhibitors related to impacts community development. Further, we are particularly interested in the role that assessments play in these dynamics.

Brief Synthesis

While many of the above theoretical frames of agenda-setting, advocacy coalitions and boundary work (discussed in Section 2.1) have been applied in domestic arenas, few have been used to illuminate the complex, multi-level issue of climate change. Nonetheless, the activities highlighted in each of our case study sectors shed light on these theoretical framings and enable preliminary analysis of an arena that has received little attention by social scientists. Through the case studies we illustrate how analysis of impact assessments challenges theoretical frames such as Kingdon's (1995) agenda-setting and Haas' (1992) epistemic communities. We also demonstrate how ideas regarding boundary work hold more promise for interpreting dynamics surrounding climate change impact assessment and other global environmental issues.

Introduction to Case Studies

In Section 2, we set out to introduce the general concept of "impact" and broadly trace its evolution over time. In the following sections we explore, in detail, two particular impact sectors: sea-level rise and health. We take an interpretive approach to examining these cases. That is, we do not attempt to explain our observations via specific causal pathways or by quasi-experimental processes. We have discovered, instead, that boundaries between dependent and independent variables necessary for such explanations are permeable, shifting and sometimes difficult to delineate with confidence. Consequently, we attempt to interpret our case study examples using analytical tools such as boundary work.

Sea-level rise and health enable interesting comparisons and contrasts. For example, these impact sectors are generally agreed to be two of the most salient of all the impact areas. Furthermore, these impact sectors have different histories, have increased and decreased in prominence at different times, and reflect diverse community and methodological features. Sea-level rise originally evolved out of glaciology research and now embraces the ideas of coastal zone management. Sea-level rise also exhibits strong tensions between adaptation and vulnerability forms of analysis. Health is the most newly prominent of the impact sectors. It comprises a small, but active community of researchers, non-governmental groups and medical expert and a growing set of methodological approaches.

Each of the case studies contains narratives of some of what we found to be the most interesting issues, debates and evolutions within the sea-level rise and health areas. We do not attempt to portray a complete and exhaustive account of each area, but highlight specific observations in each. In telling these stories we focus on three aspects of each issue: 1) changes in the definition of impact; 2) the organization of communities around impact ideas; and 3) the evolution of research methodologies. Our findings illuminate the utility and shortcomings of various theoretical frames presented in Section 3, and also suggest how awareness of boundary work, in particular, might inform the practice of impact assessment in the future.

Sea-Level Rise, Small Islands, and Coastal Zones

Relationships between global warming and sea-level rise first began to attract attention during the mid-1970s. Impact research in this area grew out of geology and glaciology studies of Antarctica and other ice-covered regions. These studies focused on historical interactions between temperature and sea-level changes during the past 125,000 years, and behavior of ice sheets during inter-glacial periods.[xvi] Unlike the agricultural sector with its long history of agriculture/weather assessments, there was only a limited number of sea-level/climate research activities occurring prior to the identification of climate change risks. In addition, there were few entrenched methodologies, disciplinary networks, and institutional frameworks in place to support this type of analysis. This has had significant implications for the evolution of sea-level rise impact assessment, as is explored throughout this section.

Impact Definition

This sub-section focuses on three key historical trends which have characterized the co-production of knowledge regarding sea-level rise impacts: changing emphasis on causal mechanisms such as West Antarctic Ice Sheet (WAIS) melting and thermal expansion, linkages between impacts work and populations affected by impacts, and treatment of adaptation and vulnerability.

Causal Mechanisms

Projected sea-level rise impacts have varied considerably over time. Much of this variation reflects changing ideas regarding temperature increases associated with global warming and the behavior of the West Antarctic Ice Sheet (WAIS). The question of which causal mechanisms are emphasized in sea-level rise impact assessments has important implications for the boundaries that define sea-level rise impacts. In particular, the relative importance of WAIS disintegration, alpine glacier melting, and thermal expansion dictates the extent to which adaptation to sea-level rise is feasible.

During the 1970s, shifting concerns regarding the behavior of the WAIS had considerable influence over projections of climate-induced sea-level rise. In the early 1970s sea-level rise analyses downplayed the likelihood that the WAIS would disintegrate and result in higher sea level. Schneider and Dickenson (1974), as well as Bolin (1975), asserted that the WAIS would react very slowly to climate warming. Others noted that climate change might increase snowfall in Antarctica, intensify stresses on the ice caps, and lead to sea-level surges in three centuries. However, they cautioned that projections of global warming's effects on sea-level at the time, were too speculative to warrant a sea-level rise forecast (NRC, 1977). By contrast, in 1978, Mercer challenged the views of these researchers by claiming that even moderate warming would likely cause catastrophic WAIS disintegration. He projected that, based on then-current fossil fuel consumption, "a rapid five meter rise in sea level caused by deglaciation of West Antartica may be imminent or in progress after atmospheric carbon dioxide concentrations have only doubled" (Mercer, 1978). Mercer's (1978) article directed a great deal of attention to the possibility of WAIS disintegration and subsequent sea-level rise (Oerlemans, 1989). As a result, sea-level rise assessments during the late 1970s (e.g., the DOE/AAAS workshop (DOE 1980) and Schneider and Chen (1980)) referred to and utilized Mercer's estimates.

In the 1980s, however, there was growing consensus among American and Dutch researchers that the risks of WAIS melting were much less than originally projected. A series of individual scientific studies and assessment processes emphasized the effects of thermal expansion and alpine glacier melting on ocean levels, while WAIS melting came to be characterized as a low probability, high consequence impact that only constituted a "speculative concern" (NRC, 1983). WAIS has generally been excluded from, or downplayed in impact assessments from the late 1980s onwards.[xvii]

Over time, as researchers have emphasized different causes of sea-level rise and accounted for changes in temperature estimates and other factors, projections of sea-level rise by the year 2100 have steadily decreased. This decline arises from the combination of greater knowledge about atmosphere-ocean interactions and ocean behavior, greater computer modeling capability, changes in the projected rate of global warming, and the availability of more models and projections to aggregate and test estimates. Below are examples of changes in sea-level rise projections:

- tens of meters -- Study of Critical Environmental Problems (SCEP), 1970
- 5 meters -- Mercer, 1978

- 5 meters -- (Schneider and Chen (1980) did not develop this projection, but performed an impact assessment based on this projection.)

- 0.48 to 3.8 meters -- EPA, 1983
- 0.2 to 3 meters -- NRC, 1983
- 0.5 to 1 meters -- IPCC, 1990a
- 0.38 to 0.55 meters -- IPCC, 1995a[xviii]

These changing sea-level rise values are particularly important because they are linked to a boundary drawing exercise, concerning the feasibility of adaptation as a response to climate change. In the early 1980s, many assessments that projected relatively high sea-level values suggested (implicitly or explicitly) that human adaptation to sea-level rise would not be possible. For example, the Department of Energy (DOE) assessors concluded that sea-level rise was one of the areas where human intervention was unlikely to be effective (DOE, 1980). Consequently, this type of finding implied that reduction in carbon dioxide emissions was the best way to address the potential effects of sea-level rise. However, as understanding of sea-level rise mechanisms changed and estimates of sea-level rise decreased, adaptation became viewed as viable and the boundary determining whether or not adaptation could be included with sea-level rise impacts shifted.

Linkages to Affected Populations

Linkages between treatment of extreme events (such as the increased frequency and intensity of cyclones) and the recognition of island states in assessments provide additional examples of boundary work in the sea-level rise impacts domain. Initially, the majority of sea-level rise assessments were carried out by a small group of countries, namely the United States, the Netherlands, and Australia. Consequently, assessments generally focused on how rising seas might affect these territories in particular, and coastal states in general. Assessment findings reflected extensive research into the conditions that these states are likely to encounter now and in the future. Until the early 1990s, for example, assessments of sea-level rise typically focused on impacts such as: inundation of low-lying coastal areas, greater risk of flooding and storm surges, and contamination of freshwater lenses by salinity. In contrast, extreme events received only cursory treatment in most assessments. Although extreme events are important for coastal zone states, they tend to affect island states disproportionately in terms of economic, ecological, and social damage due to their small territories, societies, and economies.

However, in the early 1990s, treatment of extreme events in assessments changed as many South Pacific island states experienced cyclones, some repeatedly (such as Vanatau which had four cyclones in early 1992 alone). Storm surges also occurred often, flooding

agricultural and urban areas on the islands. As a result, impact assessments undertaken by the South Pacific Regional Environment Programme (SPREP) began to highlight extreme events as equally important as inundation, whereas they had previously downplayed the role of such events.[xix] Consequently, the IPCC (1995b) and the United Nations Environment Progamme (UNEP) Regional Seas Programme, began to draw upon the SPREP assessments and emphasize the effects of extreme events as well. Similarly, in the Caribbean, several islands experienced hurricanes during the 1990s and assessments of extreme events and sea-level rise impacts in this region have also increased.

Changes regarding treatment of extreme events parallel changes in the way assessments have addressed populations affected by sea-level rise. The IPCC (1990b) report and the Common Methodology Report (IPCC, 1992) refer to island states as if they were effectively subsumed into the category of coastal states. However, following the extensive assessment work carried out by the SPREP, and the political lobbying efforts of the Association of Small Island States (AOSIS), "island states" emerged as a category of their own in the late 1980s. This new category is noticeable in the title of the IPCC's (1995b) chapter on sea-level rise: "Coastal Zones and Island States." In this chapter, the particular needs and characteristics of the small island states are acknowledged by assessors, (though these are not always reflected in international decision-making regarding responses to climate change.)[xx]

These examples illustrates how both "focusing events" and boundary work play into the co-production of impact categories. When coastal zone states dominated impacts work on sea-level rise, the definition of sea-level rise impacts and the treatment of these impacts through assessment processes reflected the views of these states. However, as crises arising from actual extreme events focused attention on island states and led to certain assessment activities in these areas, the definition of sea-level rise expanded as the boundaries delineating both assessment participants and impact meanings broadened.

Adaptation and Vulnerability

The third story pertains to concepts of adaptation and vulnerability as addressed through sea-level rise research and assessment. As defined by the IPCC (1995b), adaptability reflects the degree to which it is possible to adjust to changes in climate through the practices, processes, and structures of systems. Vulnerability indicates the extent to which climate change may harm or damage a system. Vulnerability depends on a system's sensitivity to climate change as well as its adaptability: as adaptive capacity decreases, vulnerability increases (IPCC, 1995b). The treatment of adaptation and vulnerability in impact assessment can hold important implications regarding boundaries that delineate which responses to climate change are feasible and which are not.

Initially, as noted above, adaptation to WAIS melting was not viewed by researchers as practicable. However, as focus shifted to more benign causal factors such as thermal expansion and alpine glacier melting, feasibility of adaptation increased. Since then, ideas regarding adaptation have remained fairly constant over time. Approaches outlined

by Dutch and American assessors in 1983, emphasized the major categories of adaptation still considered today: retreat (leaving areas that will be inundated), accommodation (building piers and filling in beaches), and protection (building dikes) (NRC, 1983). Analyses that address these forms of adaptation generally provide information about human and ecosystem responses to climate change, their costs, and relevant policies and incentive structures. Hence, adaptation tends to focus attention on how human and natural systems will react to climate change, rather than how society will prevent or minimize climate change.

On the other hand, vulnerability assessments in the sea-level rise area have more varied implications. Results of vulnerability assessment can encourage preemptory adaptive actions, certain types of research, and preventative policy action. In one sense, information regarding vulnerability can alert populations to their sensitivity to climate change. From the perspective of many scientists and assessors, for example, vulnerability is a useful rubric to encourage countries, especially developing ones, to take action to address the potential impacts of sea-level rise now. This is a view that pervaded past IPCC assessments of coastal area impacts (IPCC, 1990b; 1995b) and the common methodology (IPCC, 1992).

Similarly, affected populations (such as the small island states) and others can use the findings from vulnerability assessments to press for research and policy regarding climate change. For example, vulnerability assessments can make the risks of climate change more tangible to policy-makers, thereby providing a platform for those (such as AOSIS) who favor rigorous emission limits. The concept of vulnerability can also help to define what constitutes important research and appropriate research methodologies. Small island states have argued that their greater vulnerability to sea-level rise impacts warrants increased funding for regional research programs aimed at their particular needs and experiences. Following the emergence of AOSIS, for example, assessors began to conduct a large and rapidly growing set of case studies specifically targeting small island states and the sea-level rise problems they face (IPCC, 1992).

Communities

As with the agricultural and health sectors, the sea-level rise sector is characterized by multiple, loosely connected, and overlapping “communities” of researchers, assessors, and policy-makers who have both common and divergent beliefs. The evolution of various communities around sea-level rise illustrates how different disciplines and countries have become involved in the sea-level rise sector and have shaped the way sea-level rise impacts have been defined and interpreted. Analysis of sea-level rise impacts communities also illustrates how assessment activities and the participants in these activities have contributed to development of coastal zone management and vulnerability concepts central to sea-level rise impacts.

The discussion below also indicates that communities in the sea-level rise sector do not closely resemble any of the theoretical framings of “community” currently offered by policy studies and political science. Some communities (especially the oceanographers

and geologists) seem to cohere around the goal of building knowledge about sea-level rise processes and impacts, whereas other groups are more interested in how sea-level rise can be made less deleterious through coastal zone management. Still other groups (notably island states and some researchers) share normative beliefs about the need to treat sea-level rise impacts in terms of international equity. These communities, however, are not mutually exclusive, and participants appear to shift between (or to be engaged across) communities depending on their involvement with sea-level rise at a particular time.

Country and Disciplinary Representation in Sea-level Rise Communities

The evolution of knowledge regarding sea-level rise impacts largely reflects how the communities of researchers and assessors concerned with sea-level rise developed. Originally, the sea-level rise "community" comprised a very small group of oceanographers, who operated a network of tide-gauge sites, monitoring sea-level fluctuations in parts of the world. For example, the Permanent Service for Mean Sea Level (under the auspices of the International Council of Scientific Unions (ICSU)) is operated by the British, whose Proudfoot Oceanographic Laboratory has directed the world-wide survey of sea-level changes since 1933. There has been a secular sea-level rise occurring for the past century, at rates of 1-2 mm a year, and the network aims to track this trend. As well, in the 1960s and 1970s, geologists and paleoclimatologists (experts studying climate conditions during past epochs of warming and cooling) based largely in Britain and the United States also participated in the sea-level rise sector. This network of scientists interested in measuring the rate and nature of sea-level rise is still part of the contemporary "community," but plays a far less prominent role in impact research and assessment, with possibly 10-20 full-time experts world-wide (according to our interviews).

By the beginning of the 1980s, the sea-level rise community had already become a fairly loosely connected and multi-disciplinary network. During the late 1970s, for example, climatologists began to take greater interest in sea-level rise. This was partly due to Mercer's (1978) *Nature* article, highlighting the possibility that global warming could result in WAIS disintegration. One sign of the growing influence of climatologists is the important attempt by Schneider and Chen in 1980 to project the economic impacts of sea-level rise on the United States. During the early 1980s, as focus shifted to thermal expansion, the estimates of sea-level rise started to be revised downwards, and adaptation appeared feasible, the sea-level rise sector began to include experts who worked to project sea-level rise and its various impacts on physical and ecological systems. The sector also began to include geographers, ecologists, and other experts (largely American) capable of investigating and reporting on these "first-order" impacts. As a result, more and different types of assessors began to explore the physical and environmental consequences of inundation, freshwater contamination, flooding, and other phenomena associated with sea-level rise.

During this period, the community also began to broaden its geographical scope. In particular, the Netherlands began to exert influence over the evolution of sea-level rise impact assessments. The Netherlands has a long history of coastal zone management to confront the risks of flooding posed by the encroaching North Sea. Consequently, the Dutch have a highly entrenched and developed range of expertise, knowledge, research and management institutions, and management strategies in place domestically.[xxi]

Since the early 1980s the US and the Netherlands have been joined by Australia and more recently, by Japan and South Pacific islands in their efforts to shape, participate in, and utilize sea-level rise assessments. In particular, the Japanese have joined the Australians in carrying out many studies of small islands in the Pacific. Like the Dutch, the Japanese have a long history of coastal zone management because Japan is situated in a volcanically active region and is, therefore, highly exposed to tsunamis. Perhaps for political desires to increase policy influence over the region, or raise their nation's profile in the technical science of global environmental change, the Japanese have sponsored (through the Environment Agency of Japan, the Foreign Affairs Department, university centers, and the Asian Development Bank) research into climate change impacts in the Asia/Pacific region.

This trend toward greater participation of Asian and Pacific-based researchers shows up in the membership of the subgroup responsible for the IPCC (1995b) chapter, "Coastal Zone and Island States." While the Dutch and the Americans still have strong representation in the IPCC, they now interact with experts from a much broader geographical area than before. Furthermore, the Dutch are now much less concerned about the potential effects of sea-level rise on their nation, largely because their domestic assessments have demonstrated that current and projected coastal zone infrastructure is adequate to withstand projected sea-level rise impacts. Thus, the Dutch appear to have shifted their attention to "exporting" research skills and knowledge, both in sea-level rise assessment and in coastal zone management, to the international level and to other nations.[xxii]

As the geographic scope of the community widened it also began to include coastal engineers, coastal zone managers, and social scientists (especially economists). These experts were largely based in the Netherlands and in the United States, where most assessments of sea-level rise impacts were carried out during the 1980s.

Increased participation by economists is especially noteworthy during the last decade. While Schneider and Chen (1980) were the first assessors to attempt to apply economic analysis to sea-level rise impacts, economic methods were not extensively applied in this sector until the late 1980s. Here, the EPA study of 1989, led by Smith and Tirpak, was highly influential in catalyzing greater involvement of economists as part of the impact research and assessment "community." Most of the expertise in applying economic methods to this sector is found in the United States, partly because the use of economic analysis is a far more pervasive part of policy and research culture in the United States than in most other nations, and partly because most of the assessment processes employing economic methods are American.

Coastal Zone Management

Activities associated with the IPCC and its Coastal Zone Management Subgroup illustrate the important role that assessments can play in building communities around impact sectors and in co-producing knowledge regarding impacts.

In 1988, the IPCC was formed to produce an assessment of climate change implications. The IPCC was divided into three working groups, those for: science, impacts, and responses. The IPCC Working Group III created a Coastal Zone Management Subgroup (CZMS) to deal with responses to sea-level rise. Over the next five years, the CZMS was dominated by the Dutch (five representatives plus the co-chair, Pier Vellinga) and the Americans (eight representatives) (IPCC, 1992). In addition, several Australians participated as assessors. Relatively few researchers from developing countries and the Pacific islands participated directly in the CZMS, although they were sporadically engaged in workshops held by the CZMS each year between 1988 and 1993.

The interesting observation from our perspective is that the CZMS played a highly active, entrepreneurial role in shaping and directing the development of vulnerability assessment and integrated coastal zone management. This is unlike most other IPCC subgroups, which focus on reviews of existing research, rather than efforts to catalyze research and policy-making efforts. The CZMS repeatedly emphasized, in its various publications and conferences, that adaptive strategies were urgently required now since a long lead time is required for addressing sea-level rise impacts. The CZMS has, therefore, played a critical role in influencing what type of knowledge regarding sea-level rise impacts is important and how this knowledge should be developed.[xxiii]

The IPCC also sponsored the World Coast Conference of 1993, which was an extremely significant event in promoting coastal zone management as part of the sea-level rise sector, and in developing a community of researchers, assessors, and policy-makers to support it. This conference was held at Nordwijk in the Netherlands and was largely supported by the Dutch government. The conference brought together a diverse range of actors to constitute a "new" coastal zone management community. These actors included not only coastal engineers and coastal zone managers, but also government policy-makers at all levels and NGOs. Significantly, there was a relative absence of social scientists other than economists.[xxiv] However, the World Coast Conference produced a "broad consensus" statement expressing urgent need for "integrated" coastal zone management plans.[xxv] Here again, assessment processes, spearheaded by the IPCC, were instrumental in bringing people together and outlining research and management priorities (World Coast Conference, 1993).

To some degree, the CZMS and those who support it represent a type of advocacy coalition since the group was based around a seemingly shared set of beliefs and goals, namely the promotion of adaptation and coastal zone management. However, it is difficult to delineate the boundaries that circumscribe this community and it is, therefore, difficult, if not impossible, to locate this coalition within the Sabatier and Jenkins-Smith (1993) definition. Development of a CZMS "network," for example, illustrates the characteristic "unboundedness" of such impacts communities. In 1990 the CZMS sought

to build a "CZMS network"[xxvi] to disseminate data, research, assessment, and policies relating to coastal zone management among countries world-wide. Managed by the Dutch, this network continues to exist (albeit in a different form and no longer supported by the IPCC). However, the co-existence of this looser and fragmented network linked with the CZMS, challenges the standard model of advocacy coalitions and highlights some of the problems associated with mapping established theoretical ideas onto the impacts landscape.

Vulnerability

The changing meanings of "vulnerability" are also linked to community dynamics. As seen above, "vulnerability" can be interpreted in different ways by different groups. Here, we examine how participation by actors from the South Pacific region have shaped perceptions of vulnerability.

The role of the SPREP and the AOSIS in the historical evolution of the sea-level rise sector may be the clearest example of the advocacy coalitions that Sabatier and Jenkins-Smith (1993) identify. While it was originally conceived as a regional legal regime to communicate and exchange data on environmental issues, the SPREP has developed into a highly vocal, technically expert, and visibly political-scientific network. Its work is not confined to climate change issues, but encompasses a broad variety of environmental and sustainable development concerns, as seen in its statement to the United Nations Conference on Environment and Development (SPREP, 1991). It was, however, the first regional seas environment program to build a climate change research and response process.

A series of workshops, conferences, and assessments from 1988 onward appears to have entrained a number of researchers from the Asia/Pacific region within the SPREP process. In 1987, the United Nations Environment Programme (UNEP) began to build ties with the SPREP, which then began to take an interest in climate change. Here, formation of the IPCC appears to have provided a "focusing event."[xxvii] The SPREP refers frequently in its publications and meetings to the IPCC's findings in 1990 and 1995, indicating that the SPREP monitors closely what occurs in the IPCC. The SPREP also works with the IPCC on increasing the involvement of small island states in the IPCC, and sent government representatives to negotiations of the Framework Convention on Climate Change. From its inception, the SPREP climate change research program has emphasized impacts and the assessment of impacts, and has come to concentrate on mitigation measures as well.

The SPREP has played a pivotal and changing role in the evolution of "vulnerability." Initially, the SPREP was one of the first groups to support development of vulnerability assessments for potentially susceptible nations, and the SPREP carried out many of the early experimental assessments in the late 1980s and early 1990s. By 1992, at least six detailed case studies had been done of Pacific islands (the Federated States of Micronesia, the Cook Islands, Kiribati, the Marshall Islands, Tokelau, and Western Samoa), with a number of other more cursory studies done elsewhere in the region. These

studies were first sponsored by the UNEP, and later by the IPCC and the CZMS, as well (IPCC, 1992).[xxviii]

The AOSIS has also been a key actor in the sea-level rise sector. The SPREP had sought assistance from the London-based Center for International Environmental Law to advise island governments in the FCCC negotiations. This resulted in the formation of the AOSIS at the Second World Climate Conference in 1990. Since then, the AOSIS has participated in numerous international conferences and processes, and has consistently called for "vulnerability" to be at the heart of impact assessments and climate change policy. For example, at the Margarita Island workshop (which gave rise to the IPCC Common Methodology) the AOSIS urged that many more vulnerability case studies be carried out for small island states (IPCC, 1992).[xxix]

The AOSIS also called attention to the vulnerability of small island states at the United Nations Conference on Environment and Development. This was especially important because it encouraged creation of communication channels among island states, enabling development of a common position (SPREP, 1992). Later, the AOSIS helped organize the Global Conference on the Sustainable Development of Small Island Developing States. This conference stated in its declaration that "small island developing states are particularly vulnerable to natural as well as environmental disasters..." and that they require special assistance under the FCCC because of their "peculiar vulnerabilities and characteristics." The conference argued that "all States should reduce and eliminate unsustainable patterns of production and consumption." These statements reveal the moral and equity issues underlying the concept of vulnerability and vulnerability assessment. They also illustrate how the vulnerability notion has pervaded both the research and politics of sea-level rise impacts, and climate change more generally.

Issues regarding vulnerability are just one example of how community dynamics interact with knowledge regarding impacts. Specifically, the SPREP and AOSIS illustrate how advocacy-type groups can participate in impacts communities, and influence the ways in which impacts are analyzed and interpreted. Coalitions of actors from small island regions, were successful in promoting vulnerability studies. This approach facilitated impact assessment in areas where GCM-based and other types of analysis would have been more difficult to implement given available resources and expertise. In addition, emphasis on vulnerability studies have helped to raise awareness of potential climate change effects among relevant populations. Thus, small island and South Pacific coalitions were instrumental in shaping research methods, research priorities, and political agendas.

Methodologies

Methodologies employed in studying sea-level rise have co-evolved with impacts communities and knowledge regarding impacts. While GCMs have become dominant in the sector as a source of data and a method of inquiry, there has recently been a renewed interest in the "older" methods of observation and historical analogs, as well as in new methods (such as vulnerability assessment) that rely extensively on the social sciences

and geography. The sea-level rise sector also exhibits signs of a continuing tension between endeavors by some actors (notably the IPCC and CZMS) to standardize research and assessment methods worldwide, and the efforts by other actors (especially the SPREP, AOSIS, and UNEP) to push for greater research and assessment specifically tailored to regional and local scales.

The sections below highlight these trends through discussions of global versus regional-scale analysis and the common methodology developed for vulnerability assessment.

Global versus Regional-scale Analysis

Originally, research in the sea-level rise sector focused on the use of observational and historical data. Researchers studying sea-level trends around the world used (and continue to use) a network of tidal and sea-level gauges as well as observations of climate/ocean interactions. In addition, geologists and paleoclimatologists used geological surveys, samples extracted from Antarctic ice sheets and vegetation to determine the temperatures and atmospheric content in the past. Generally, these observations were used to determine how oceans would respond to various climate forcings at a global scale. Focus on global averages became even more prominent with the introduction of GCMs to sea-level rise analysis in the 1980s. At that time, climatologists began to enter the sea-level rise "community," and most research activity was aimed at model-building and at improving knowledge about atmosphere and ocean processes for use in the models.

The projections of sea-level rise produced by science assessments during the 1980s and the 1990s tended to reflect a doubled-CO2 equilibrium scenario applied worldwide. This scenario assumes that sea-level rise will be spatially uniform and constant over time and across all regions. Projections of sea-level rise are made globally, and not regionally or locally, even though the local differences may be important in certain areas. Such a methodological approach reflects the dominance of GCM methods in the sea-level rise sector. It also reflects the role of climatologists (rather than, say, geographers and coastal experts) in defining the characteristics of sea-level rise per se.

More recently, the IPCC (1995b) noted the problems associated with assessing sea-level rise impacts based on global sea-level rise estimates. In particular, "one cannot assume that changes in sea-level at regional and local levels will necessarily be the same as the global-change average" (IPCC, 1995b). That is, sea-level can only be measured relative to the surrounding geomorphology and landscape, as land can shift upwards or downwards due to various geological, human, and environmental processes. Also, there are dynamic effects associated with ocean circulation and wind patterns which cause variations in the sea surface. Thus, it is no longer possible to define effects "simply in terms of inundation of the sea upon the land, nor by just shifting the land-sea contour by an amount corresponding to the projected vertical increase in global sea-level" (IPCC, 1995b). In other words, the "fractal" nature of coastlines makes it very difficult to apply global projections locally.

In light of the limitations of GCM-based, global approaches to sea-level rise, assessments have shifted to alternative methods to supplement GCM results. These methods include studies which reconstruct past geomorphological responses to sea-level rise and studies of sea-level rise trends during the past few decades. Greater emphasis on regional-scale impact analyses has implications for the communities engaged in and relevant to impact assessments. In particular, regional approaches may mean that more local experts become involved in the community and more attention is paid to concerns of local populations.

The Common Methodology

The Common Methodology developed under the IPCC, reflects trends toward more regional-scale assessment. This methodology has played an important role in the evolution of the sea-level rise impact sector. The Common Methodology contains seven steps for assessing the ability of nations to cope with the consequences of sea-level rise. It examines, through case studies, the susceptibility of coastal zones to physical changes, the impacts of these physical changes on socio-economic and ecological systems, and the degree of risk that populations, social systems, and property face. The Common Methodology recognizes that there can be multiple vulnerabilities (physical, ecological, and socio-economic), and encourages much greater desegregation of data and assessment than previously practiced. It encourages highly site-specific assessment that is sensitive to prevailing local conditions.[xxx] Further, the Common Methodology requires a combination of many disciplinary areas, especially social science and policy management, and can be used to cross the boundaries between science, policy, and politics by generating specific recommendations regarding infrastructure and other response strategies.

Conversely, the Common Methodology has been used as a vehicle by the CZMS to standardize vulnerability assessments across the world. In 1992, the CZMS suggested that the Common Methodology could be used by researchers to develop "world-wide assessments" which could then be aggregated into a global vulnerability index. Interestingly, the CZMS also stated in 1992 that one of its goals was to enable international development and financial institutions to make decisions regarding the allocation of funds to research and response efforts (IPCC, 1992). Indeed, this strategy seems to have begun to succeed, since the World Bank-directed Global Environment Fund (GEF) has recently sponsored a Caribbean Islands research project.

However, these efforts at standardization of vulnerability assessments have been resisted by the SPREP and other small island actors from the mid-1990s onwards. In particular, the Common Methodology Report of 1992 discusses the limitations of vulnerability assessment as hitherto practiced, but these limitations are all economic in nature, ranging from a failure to incorporate the depreciation of economic values, to ignorance of the economic implications of population growth. In addition, recent studies have been conducted in Fiji and other Pacific islands by a collaborating team of Japanese, Australian, and Pacific researchers (SPREP, 1994). These studies produced a "Sustainable Capacity Index" based on the sum of ratings of vulnerability and resilience

for a range of categories of cultural, social, agricultural, and industrial impacts (Yamada et al., 1995). Findings suggest that prevailing methods probably underestimate impacts of sea-level rise on high-lying islands.

Significantly, the IPCC is currently preparing a Technical Report on Regional Impacts of Climate Change, partly because of the repeated requests by the AOSIS that the IPCC increase its production of assessments aimed more precisely at the particular needs of regional policy-making bodies, notably in the South Pacific.

Debates regarding the Common Methodology and approaches to regional assessment indicate the close relationships between communities and methodologies and the importance of methods in shaping definitions, perceptions, and interpretations of impacts. Moreover, the sea-level rise sector exhibits tensions regarding scale and standardization that pervade impacts assessment more generally. Underlying these issues are questions regarding the intended uses of impact assessment. For example: Who are impact assessments meant to inform? To what extent should impact assessments inform local resource managers versus international negotiators – further, are there real trade-offs between addressing these different scales? If impact assessments are most useful to resource managers, then efforts to standardize could be problematic if they force assessors to overlook important localized aspects of climate change. Conversely, standardization could be advantageous if assessments are used at the international scale to compare sea-level rise impacts across regions. As diverse actors such as the IPCC, the US, and small island states increasingly undertake impact assessments of sea-level rise they are likely to develop very different answers to the above questions. However, with the limited resources available for assessment activities, it appears beneficial to reconcile some of the tensions such that groups can pursue complementary endeavors.

Health

The health sector first began to emerge in the late 1980s, and most of its evolutionary development has occurred during the past four years. Consequently, the health sector reveals much about the processes of constructing impact categories and developing impact communities because most researchers and assessors now working on health impacts began this work in the early 1990s, and their activities have increased markedly in recent years. The discussion (see below) of impact definitions in the health sector reveals that assessors in this area tend to emphasize a small number of health impacts, such as heat waves or vector-borne diseases. They also draw boundaries around these impacts, setting them apart from other health effects on the basis that they constitute particularly problematic consequences. Moreover, over time, assessors and others have sought to delineate “health” as an impact sector in its own right and to split it off from the human settlements and air pollution sectors in which it was previously included. This case study further highlights how these developments parallel community dynamics and the evolution of health impact research methodologies.

Impact definition

Relationships between human health and climate have long been an important research topic for physicians and public health experts. During this century, and especially following World War II, extensive research has been carried out on how meteorological conditions influence human health. This research emerged concurrently with the growth of epidemiology as a science. For example, epidemiologists examined correlations between climate and population statistics, and thereby explored how the homiothermic function of human bodies varied with temperature changes.

Health impacts were first considered in global environmental change assessments during the mid-1970s, in connection with SST and ozone issues. Carried out under the sponsorship of the U.S. Department of Transportation at the request of Congress, the CIAP study considered health effects, but concentrated mainly on the impact of ultraviolet-B radiation on skin cancer rates (CIAP, 1975a). Further, CIAP did not differentiate between the health effects of climate change and those arising from climate variability.

Throughout the 1980s climate variability and ozone depletion attracted more health impact research and assessment than did climate change. For example, the first World Climate Conference, the first major international assessment of climate change to address health impacts, considered how short-term rather than long-term climate variations would affect human health. The conference included a discussion of human health/climate relationships by Wolf Weihe (a World Health Organization (WHO) expert who was for a long time one of a very few assessors working on climate change/health issues). The discussion focused mainly on health effects arising from climate variability and summarized many basic facts about the physiological ways in which climatic conditions impact health. Weihe outlined, for example, how climate influences the outbreak and intensity of infectious diseases. He also explained how climate can affect human nutrition needs by increasing or decreasing calorie needs; and how humidity can change heat exchanges between a body and its environment. However, Weihe said little about how long-term climate change, per se, might influence health (Weihe, 1979).

This emphasis on the links between short-term climate events, and human health effects also dominated the Leningrad conference on climate and health held in 1986.[xxxi] Hosted by the Russian government (which did not play a significant role in the later emergence of the health sector), the conference was organized by the WHO, UNEP, and the World Meteorological Organization (WMO), which came together for the first time to begin promoting the health impacts of climate change as an important topic for research and assessment. The purposes of this conference were to evaluate the "effects of meteorological elements on health," examine "meteorological forecasting for medical purposes," classify "climate with respect to healthy and diseased man," and determine the "social and economic value of climatological information for preventive medicine." Most of the conference addressed how meteorologists could work with health experts to facilitate research and prediction of health problems generated by unusual climatic variability and events (WMO, 1987).

Several high-level assessments during the mid-1980s also examined biological consequences of stratospheric ozone depletion. For example, an EPA/UNEP conference in 1986 and EPA risk assessments explored the possibility of skin cancer, cataracts, and suppressed immune system effects arising from increased exposure to ultraviolet-B radiation (Benedick, 1991). Similar studies continued in the 1990s with assessments by UNEP, in particular (UNEP, 1991; 1994).

In contrast, the report of the United Nations World Commission on Environment and Development (WCED), *Our Common Future* (1987) and the IPCC assessment in 1990 focused much less attention on environment/health relationships. The WCED did not directly address the health implications of environment and development issues. Similarly, the IPCC (1990b) only briefly noted the health impacts of climate change and lumped these impacts together with air pollution and various ecosystem effects.

However, during the 1990s concern for climate change/health interactions began to take hold. In the late 1980s the WHO convened an expert panel to examine health impacts that could arise from heat stress, enhanced air pollution, malnutrition due to decreased food productivity, changing patterns of vector-borne diseases, and coastal flooding. This group published a report entitled *Potential Health Effects of Climate Change* (WHO, 1990b).[xxxii] Also during this period, several developed country governments commissioned climate change/health studies. The EPA (1989), the Netherlands government (WHO, 1990a), the Australian National Health and Medical Research Council (NHMRC, 1991), the Canadian Global Change Research Program (GGCP, 1995) and the UK government's Climate Change Impacts Review Group (CCIRG, 1996) all reported on climate change and health.

The momentum surrounding these studies accompanied two particularly noteworthy assessments in the mid-1990s. The IPCC (1995b) assessment and the subsequent WHO et al. (1996) study succeeded in organizing technically diverse and geographically broad groups of experts to examine the adverse effects of climate change on human health and welfare in the context of the Framework Convention on Climate Change. In fact, some suggest that the IPCC (1995b) effort in particular, "raised markedly the profile of population health impact as a criterion for policy-making relating to climate change" (WHO et al., 1996). The WHO et al. (1996) study that followed the IPCC 1995 assessment engaged many authors of the IPCC (1995b) health chapter and served to update this chapter.

The sections below further detail the emergence and nature of the health sector and the communities and methodologies that continue to evolve in this impacts area.

Emergence of the Health Sector

One example of boundary work concerns the continuing efforts of a number of health experts during the 1990s to frame health impacts as an autonomous sector instead of including it in other existing impact sectors. Until the 1990s, health impacts were largely considered the domain of environmental health experts and part of ecological or human settlement sectors. Thus, the IPCC (1990b) process (and its summary review in the WCC

1990 report) treated health impacts with other miscellaneous effects such as urban air pollution, the well-being of plants and animals, and ultraviolet-B radiation. These effects were viewed only in terms of increasing temperatures, and health impacts stemming from other manifestations of climate change such as sea-level rise were generally not considered.

Interestingly, the research tasks suggested by the IPCC (1990b) were divided into a set of highly specific health impacts with assumed causal pathways and problems. They mostly addressed the measurement of human health responses to changes in seasonal weather or temperature. The adaptability of human populations to heat stress and the spread of vector-borne diseases were perceived to be the two most important impact manifestations and proved to be prominent topics in later assessments (e.g., IPCC, 1995b).

In the 1990s, health impact assessors began to differentiate health concerns from other impacts on ecosystems and human systems. They did so by encouraging many new streams of health impacts research such that more data and methods would be available to underpin assessments. In a series of journal articles, newspaper articles, and government reports (particularly in Britain, the Netherlands, and the United States), researchers argued that there were many ways in which climate change might be responsible for current health problems. These included the cholera outbreaks in Latin America, the spread of malaria to ordinarily unaffected areas in Africa because of unseasonable heat, and the emergence of hantaviruses in North America (Epstein et al., 1997). Essentially, these occurrences served as Kingdon-style "focusing events" as researchers highlighted how climate change (rather than other causes such as air pollution, or ecosystem degradation) might lead to these effects. This distinguished the health effects of climate change from other environmental health issues. The more recent emphasis on climate change/health relationships is clear in the differences between the WHO (1992) assessment on environmental health (which provided only cursory attention to climate change) and the WHO et al. (1996) assessment (which focused solely on climate change and human health issues).

As mentioned above, assessment processes at the national level also helped to establish health as a climate change issue. These activities assisted in promoting a still-evolving issue of health impacts into a more widely recognized public health concern (this is somewhat analogous to what has happened in the sea-level rise sector with the emergence of coastal zone management, but on a much smaller scale). However, the majority of boundary work giving rise to health as a "sector" appears to have occurred at the international level, where many large-scale health impact assessments have been conducted. This may be partly because the key actors promoting the health sector are international organizations, because the assessors work simultaneously for different international organizations (e.g., the WHO assessors are also the IPCC assessors), and because the assessors themselves perceive that they may have a greater impact on agenda-setting by trying to influence the policy debate at the international level.

One indication of and possible contribution to the relatively abrupt appearance of health impacts on international and domestic agendas is the growing media attention given to

these impacts. In 1990 there were virtually no newspaper articles on health impacts and most newspaper accounts of climate change impacts emphasized agriculture and sea-level rise effects. However, in 1992 several articles on health impacts appeared during the lead up to the United Nations Conference on Environment and Development. By 1995 and 1996, there were at least 30 to 35 newspaper articles per year that specifically cited health impacts. To a great extent, these articles were associated with publicity activities surrounding release of the IPCC (1995b) and WHO et al. (1996) reports.

Emergence of the health impact sector has paralleled growing recognition of health as a climate change issue. As researchers, assessors and others have sought to delineate the boundaries that circumscribe health as an impact sector in its own right, scientists, policy-makers, and the public appear to be increasingly cognizant of health/climate change relationships. Now that a health impacts sector has been established, a new boundary-setting process is taking place to determine what combination of natural science, medicine, and policy will characterize the health impacts sector. Assessments have clearly played a role in facilitating and shaping these dynamics.

Health Effects

Another set of interesting boundary work practices concerns the way in which specific health impacts and causal pathways have been emphasized by assessors. In particular, focus on certain types of diseases and treatment of direct and indirect health effects have differed over time and across assessments.

A small number of prominent effects has always been considered in assessments of health impacts since 1979. These effects include heat stress, vector-borne diseases like malaria and arboviruses, and water-related diseases such as cholera or meningitis. Other kinds of health impacts have been noted, but they are usually given peripheral significance. For example, attention to psychological responses to climate change has fluctuated widely in assessments over time. At the Second World Climate Conference in 1990, Weihe and Mertens (1990) gave great priority to psychological distress even though they acknowledged that it was a moderately significant potential impact. By contrast, the IPCC (1995b) assessors undertook virtually no discussion of psychological effects. These differences reflect boundary work by assessors and others as they shape research and policy priorities regarding climate change impacts. For example, assessment processes can involve important negotiations regarding what is important and what is not in regard to climate change impacts. The outcome of such boundary drawing activities has implications for how climate change/health relationships are perceived and addressed.

Treatment of direct and indirect health impacts has also varied across assessments. Prior to 1990, health impacts were generally presented as a largely disaggregated set of effects with no distinctions made between which health impacts arose directly from climate change and which occurred as a result of some mediating factor. In 1990, however, assessors at the Second World Climate Conference began to distinguish between these

types of effects but noted that the differences between direct and indirect are often blurred because of the ways in which environmental factors interact with climate change.

In contrast, the IPCC (1995b) assessment draws precise lines between different causal pathways in terms of whether they occur through the direct impact of a climate variable (temperature, or weather variability) on humans, or whether they are mediated by changes in biological and geochemical systems. In turn, the health sector is "summarized" in terms of a small diagram which aims to show the range of health outcomes flowing (with uni-directional causal arrows) from climate change, classify these impacts into direct and indirect effects, and show the "mediating process" responsible for each health outcome (IPCC 1995b). This may be one of the most finely wrought and specific descriptions of causal pathways in impact assessment.[xxxiii]

The significance of specifying these direct and indirect causal pathways is that they not only reduce a complex sector to a set of specific mechanisms around which policy responses can be planned, they also encompass a number of other impact sectors because the indirect causal pathways necessarily involve looking at ecological, sea-level rise, and air pollution mechanisms; food supply systems; and many other factors. While this reflects a movement toward recognizing the complex and interrelated character of health impacts, it also appears to reflect boundary work aimed at making the health sector and health assessment "legitimate" by linking it to more "traditional" impact sectors.

Some manifestations of direct and indirect health impacts have always been accentuated more than others. This is partly due to the pre-existing history of research and assessment efforts concentrated in a few developed nations, notably the United States, Britain, and the Netherlands. It is also partly attributable to views held by assessors as to how to make health impacts more salient to policy-makers, politicians, and the broader public in different parts of the world.

Direct effects have usually been pictured as the links between temperature and mortality rates. Heat waves and other effects related to heat-stress are usually a prominent focus of assessment processes, and are always explored in great detail. A significant number of studies investigating heat effects have been carried out, but they principally concern developed, non-tropical countries - especially countries in North America and Europe (and increasingly Asia), rather than those of Africa and Latin America.

Vector-borne diseases are generally the most prominently featured indirect impacts. In particular, significant research is being carried out into the possible effects of climate change on malaria, with both modeling efforts and ecological studies proliferating at present. In part, this is because malaria is widely regarded by the WHO, many governments, and public health experts as the gravest health threat in the world today, especially given the trend toward growing immunity of malaria pathogens to drug treatments. A vast number of people are affected, with some 300 to 500 million new or persisting cases each year. Both the IPCC (1995b) and the WHO et al. (1996) studies emphasize that malaria-carrying vectors could spread into higher latitude regions with changes in their temperature-dependent habitat range. These studies also give great attention to arboviruses, such as dengue fever, and their potential spread to Latin America

and North America. By contrast, African-based diseases such as onchocerciasis or African trypanosomiasis are given less attention.

All the vector-borne diseases are principally developing country diseases, but the IPCC (1995b) and WHO et al. (1996) studies tend to portray the diseases as particularly dangerous because they could spread into developed countries. Dowlatabadi (1997), however, points out that there are two problems with this perspective. First, most of the significant changes in the distribution ranges of vector-borne diseases are likely to occur within developing countries. Second, international assessments tend to downplay health risks, such as cholera, arising from inadequate sanitation. Climate change, for example, can decrease water supplies and make it more difficult to maintain hygiene. Thus, countries with poorer access to water supplies and sanitation are likely to suffer the most from the health impacts of climate change (Dowlatabadi, 1997). Yet the IPCC (1995b) and WHO et al. (1996) assessors tend to focus attention on movement of vector-borne diseases from developing to developed countries and overlook hygiene-based causal pathways by which health impacts can develop.

Another important aspect of boundary work defining the health impacts sector concerns the way in which the sector has been expanded to encompass disturbances of ecosystems. Recently, a number of researchers have emphasized the interactions between health and ecosystems. Changes in ecosystems due to both human activities and climate change may mean that, for example, predators on a vector species diminish in population numbers or geographical range, leading to a proliferation of vector organisms. For instance, in the assessment of potential changes in malaria distribution, it is important to look at models accounting for local ecological conditions such as food availability, vegetation types, micro-climates, and water availability.

The causal pathways examined in health impact analyses appear to reflect important features of the "negotiations" that occur via assessment activities and the implications they hold for the portrayal, perception, and response to health impacts. As mentioned above, the organization of health impacts into specific direct and mediated effects reflects a boundary-drawing exercise aimed at delineating policy-relevant health impact categories and their relationships to more long-standing impact sectors and ecosystem features. Furthermore, assessments of both direct and indirect effects of climate change frequently reflect the developed country perspective shared by most health assessors. While the majority of health assessments are developed country endeavors, there has been a tendency to focus on health issues most relevant to these regions.

Adaptation and Vulnerability

Unlike in the sea-level rise assessments, there is relatively little mention of adaptation and vulnerability in the health assessments of the 1990s. Where there is discussion of these topics, vulnerability is generally a more salient issue than adaptation. During the first World Climate Conference (1979), Weihe emphasized the ways in which human organisms can adapt naturally to climatic conditions (such as through homeostasis or vasodilatation of blood vessels in the skin surface). However, more recently assessors

have paid much less attention to this "natural" form of adaptation. IPCC (1990b) briefly notes links between socio-economic factors and adaptive capacity (e.g., air conditioning can be used to react to heat waves). However, the concept of vulnerability receives more attention. For example, the IPCC (1990b) assessors argued that health impacts should increasingly be framed in terms of sensitivity to health risks, such as according to population density, degree of interpersonal contact, and health care infrastructure. These assessors also emphasized that the most vulnerable populations and communities are likely to be those living in poverty with malnutrition, chronic exposure to infectious diseases, and inadequate access to social and physical infrastructure (IPCC, 1990b).

Overall, assessors in the health sector appear to be more interested in identifying and communicating the risks of health impacts per se, rather than in trying to focus the policy debate around the axes of vulnerability and adaptation. This may reflect the sector's relatively new status and its need to establish itself through demonstrating the risks of health impacts. Additionally, limited concern with adaptation in health impact assessment may simply reflect that humans cannot easily adapt to most of the indirect impacts (such as vector-borne diseases and water-related diseases).

Thus, assessors may be arguing implicitly that it is necessary to take stringent policy responses (such as mitigation) to address climate change. However, there are signs that segments of the health sector may follow parts of the sea-level rise and agricultural sectors in picking up on adaptation issues as a counter to the concept of vulnerability. For example, some researchers, such as Kalkstein, have suggested that adaptation is likely to be possible with regard to many health impacts (notably heat-related effects) because of the possibility of technological and social mechanisms of adaptation (Kalkstein, 1995). The boundary drawing that occurs around adaptation and vulnerability is something to observe in the future as the health sector "matures."

Given the importance of health impacts regarding the ozone depletion issue, such boundary negotiations could have considerable bearing on how societies perceive and ultimately respond to climate change. If, for example, health impacts come to be seen as critical effects of climate change, not amenable to adaptation, mitigation measures might gain more widespread acceptance. Alternatively, if adaptation is viewed as a viable approach to health impacts, this could potentially limit support for other response strategies.

Communities

A prominent feature of the health impacts sector concerns the recently formed and rapidly developing community of health experts. Health experts did not begin to coalesce around climate change/health impacts issues until the late 1980s. In fact, throughout much of the 1980s, climate change impacts were not differentiated from other environmental health impacts and were seen as arising mainly from short-term climatic events. At the 1986 Leningrad Conference on climate and health, for example, the vast majority of participants were meteorologists and not climatologists nor medical experts (WMO, 1987). In contrast, the health impacts community today, is a relatively small, but

strong and expanding group of public health experts, physicians, and natural scientists. The community is also beginning to attract some economists. This section explores how various assessment processes have promoted development of this community.

Entrepreneurs and institutions have been particularly important in bringing health impacts onto science and policy agendas, both domestically and internationally.[xxxiv] For example, within the U.S., a relatively small group of scientists, physicians, and public health experts has been largely responsible for raising awareness among researchers and the broader public regarding potential impacts of climate change on human health. In 1993, Dr. Paul Epstein organized a suite of Lancet articles (Epstein and Sharp, 1993) which proved instrumental in directing the attention of medical professionals to climate change/health relationships. Paul Epstein and Eric Chivian have also undertaken more publicly-oriented outreach initiatives by joining forces with non-governmental organizations (NGOs) such as the World Wildlife Federation (WWF) and Greenpeace to produce literature and web pages that address climate change/health issues. These types of activities seem to reflect the fact that public health experts are more attuned than perhaps glaciologists or agricultural experts to communicating with the public.

At the national level, scientific research institutions, particularly in the U.S. and in Europe, have begun to invest significant resources in health impacts research. Work at Johns Hopkins University, Harvard Medical School, and government agencies has helped to shape methodologies and set research agendas. Harvard's School of Public health is now offering courses which focus on climate change/health relationships and the National Oceanic and Atmospheric Association's (NOAA's) and the National Aeronautics and Space Administration's (NASA's) climate impacts research programs are helping to promote greater ecological-climatic modeling and econometric analysis.

Major international institutions have also been instrumental in promoting concern for and study of health impacts. Since 1986 WHO, WMO, and UNEP have helped to bring together climate, environment, and public health experts Their efforts recently culminated in a report entitled *Climate Change and Human Health* (1996). This assessment was particularly important in broadening the geographic scope of the health impacts community to include members from Kenya, Argentina, and Japan, as well as participants from the US, the UK and Germany. The IPCC has also been a prominent force in enabling the formation and strengthening of a health impacts community. In particular, creation of a sub-group to evaluate health impacts, indicates that this sector has been officially "canonized." The surge in the number of health impacts research projects undertaken between 1990 and 1995 indicate the rapidly growing productivity of experts concerned with this sector.

The nature of above-mentioned indirect health impacts also requires that the health impacts community encompass experts in technically diverse areas such as sea-level rise, agriculture, and extreme events. The diversity of the team that participated in the WHO et al. (1996) assessment, for example, reflects the importance of linking health experts

with researchers who understand the causal pathways via which climate can indirectly influence health.

Issues of boundary work concern both the relative "dormancy" of the health impacts community during the 1980s and its emergence in the 1990s. One might ask how assessment processes erected barriers that "kept out" health professionals in the 1980s, and how assessments more amenable to boundary-crossing promoted community development in the 1990s. While collaborative research projects, conferences, interaction with NGOs, and major assessment activities were instrumental community-building efforts during the 1990s, several factors seem to have contributed to an absence of a health impacts network in earlier years.

People we spoke with indicated that methodological barriers, institutional turf battles, and lack of communication channels, are some of the factors responsible for a previously weak health impacts community. In particular, GCM analysis was not amenable to health research methods, and only now are researchers beginning to merge previously divergent research tools. In addition, throughout most of the 1980s, health issues were considered the domain of health institutions such as WHO, and not the appropriate "territory" for the climate change community at large. Therefore, examination of climate change/health relationships was previously "reserved" for the attention of established public health institutions, rather than for the climate change community.

In general, epistemic community and advocacy coalition ideas are not particularly helpful in understanding the health impacts community. There is a small group of health experts who actively advocate adherence to the precautionary principle and believe diffusing information about health impacts is key to mobilizing the public and policy-makers to take preventative action in the face of possible climate change. However, on the whole, it is not possible to identify the health impacts community with a single policy position or a set of shared beliefs.

Consequently, the health sector illustrates that there are important networks that form around the study and interpretation of climate change impacts. The cohesiveness, geographic extent, disciplinary links, and institutional affiliations of the members in these communities can have an important bearing on how societies view climate change/health interactions and the climate change issue in general. As illustrated above, lack of a cohesive health impacts community and preferred epidemiological research methodologies may have contributed to the relative "dormancy" of health issues during the 1980s. Similarly, the prominence of health assessors from developed countries may account for certain framings of health impacts. There are clearly important linkages between who comprises health impacts communities, and how health impacts are defined and interpreted. However, epistemic community and advocacy coalition ideas do not capture these relationships. Observations regarding climate change impacts communities suggest that new perspectives on science/policy communities is warranted.

Methodologies

Health impact assessment encompasses a diverse set of methodologies. The relatively young and mainly observational science of epidemiology is confronting many challenges in understanding health in the context of global environmental change. Empirically-based observational work still tends to dominate the research, while mathematical modeling is only beginning to develop. However, as in the sea-level rise sector, the health sector has become increasingly complex, nuanced, and non-deterministic in its approach, probably more so than most impact sectors. Moreover, methodologies employed in analysis of health impacts have changed more rapidly than in the sea-level rise sector. This has happened, in part, because the health impacts community has rapidly incorporated members from many different disciplinary backgrounds.

Global environmental change poses many challenges to the field of epidemiology. Environmental epidemiology aims to identify and quantify relationships between environmental factors such as radiation and chemical pollutants and exposure to disease. Dose-response relationships provide a critical tool for carrying out these analyses. This tool has been important in setting environmental quality standards in countries such as the US. However, epidemiology has few research methods to enable understanding of interactions between climate change and health. The scale, time horizons, complexities, and uncertainties regarding climate change processes and projections compound the existing limitations of epidemiological methods (WHO et al., 1996).

However, a history of interdisciplinary activity and innovation in the epidemiological field suggest that the health sector will continue to grow rapidly in the climate change arena. Traditionally the public health domain has been populated by various types of scientists, public health experts, medical professionals, and even economists. Interdisciplinary cooperation has been integral for understanding causal processes underlying problems of cholera and water supply, mosquitoes and malaria, and smoking and lung cancer. Recent advances in examining climate variations associated with El Nino indicate the types of innovations that have occurred in the epidemiological field and are likely to enable this field to develop methodologies to address climate change (WHO et al., 1996). Thus the health impacts community might naturally be more amenable to widening the boundaries that surround it such that they encompass a diverse group of experts who bring readily accepted techniques and perspectives to the study of health impacts.

Assessment activities have been particularly instrumental in bringing together experts from multiple disciplines and integrating their respective modes of analyses. Use of future exposure profiles, predictions of indirect health impacts, and integrated modeling are mixing with more traditional methodologies in the health impacts sector. Health experts routinely predict future trends in population health based on current exposures -- for example, future rates of lung cancer are based on data regarding current smoking habits. However, study of climate change impacts on health requires a new type of analysis in which predictions are based on some future profile of exposure (e.g., smoking habits in the year 2020) (IPCC, 1995b).

Integrated models and extrapolations from historical analogies are being used to forecast health effects of unprecedented, climate-induced changes in the environment. While traditional epidemiological does-response analyses can be used to examine the direct climate change effects arising from increased heatwaves, these methods are less useful in estimating the health effects of shifting ecological zones. While experts continue to develop models to better include complex nonlinear relationships and feedback processes, difficulties in predicting regional effects continue to persist. Lack of local detail is apparent in the "targeted populations" studied via health impact assessment. Whereas past studies linking climate variability to health focused on individual responses; the use of GCM analyses to consider long-term climate change has resulted in a focus on "populations" and "communities."

The use of future climate change scenarios also reflects the introduction of new methodologies into the health field. As evidenced by a new study directed by Paul Epstein and funded by NOAA,[xxxv] it appears that economics may become increasingly significant in health impacts research. The NOAA study examines the links between human health and the economic dimensions of climate change, targeting how climate-induced changes in marine ecosystems can result in disease events affecting both marine organisms and humans. The study will attempt to quantify the economic costs of disease events, as well as to integrate complex ecological and environmental interactions through models.

The rapidly expanding domain of health impact methodologies suggests that newer sectors may be more open to transformation than older, more established sectors such as agriculture. It also indicates that a field such as health which is interdisciplinary to begin with, might be more apt than an area in which traditional approaches and methods are more entrenched, to extend its boundaries to incorporate newer ideas and methodologies.

Conclusions

In this analysis we set out to provide some initial insights into the co-produced nature of climate change impacts. Our research presents a new, reflexive account of impacts work different than any presently found in the literature. In viewing impact assessments as indicators of change, we trace the framing and reframing of impacts, the relative salience of different types and approaches to impacts, and the evolution of research methodologies. In viewing assessment processes as both social processes and agents of change, we examine the "trading zone" that characterizes the impacts domain. In this zone, and through various interactions, scientists, assessors, policy-makers and others negotiate questions of research priorities, data, participation, and analytical techniques. These interactions respond and give rise to particular impact framings and interpretations.

Our historical account of impacts over the past twenty-five years illustrates the dynamic and malleable nature of the impacts field and the ideas about climate change/society interactions that have arisen from this field. Over time, the very definition of impact changed as focus shifted from concern with society's effects on climate to concern regarding how human-altered climate might affect society. The evolution of impacts

work also evidences the sectoral, "marketization" of impacts, increasing attention to adaptation, and awareness of non-climatic factors and intervening effects which characterize the complex relationships regarding society and climate change.

Notions of boundaries and boundary work have been particularly useful in understanding the broad evolution of impact categories over time. The physical science focus of the 1979 NRC Climate Study and the working group structures of the more recent IPCC assessments, clearly show how categories of impacts and non-impacts, as well as categories within the impacts domain largely align with boundaries marking traditional disciplinary cultures. Boundary work also occurs as different orders of impacts (e.g., lower and higher) are carved out of phenomenological space for investigation, as preferred methodologies serve to erect or cross boundaries, and as assessors and decisionmakers negotiate the boundaries of science and policy. Overall, boundary work is helpful in understanding the definition and redefinition of impacts and the resultant implications for how society views the climate change issue.

Via case studies we explore the above-mentioned dynamics in more depth by focusing on specific impact sectors and we examine the utility of various well-known theoretical ideas in understanding the complex, multi-level, and multi-dimensional issue of climate change. Our discussion of sea-level rise and health reveals that agenda-setting is somewhat useful in understanding how "focusing events" help to attract interest in certain research sectors. However, Kingdon's (1995) rather static notion of agenda, his assumption that the "government agenda" is separable from other agendas, and the distinctions he makes between policy and political streams do not mesh with observations from our impacts work. In particular, we observe multiple, overlapping agendas, which are in constant flux and revision. In addition, the rise of coastal zone management and health on various agendas illustrates that policy and political factors are intertwined and cannot necessarily be viewed as independent variables in explaining the salience of various issues.

Similarly, we find that advocacy coalitions and epistemic communities do not generally reflect the types of networks we see in the impacts domain. While scientists, policy-makers, and assessors do tend to coalesce around impact areas, members of these impacts communities do not necessarily share normative convictions and/or policy enterprises. Further, the above theories do not address the origins of communities and pay little attention to the modes of interaction which give rise and stability to different networks of actors. In contrast, our study describes the co-evolution of impact foci and community membership. We also identify assessments as a critical community-building mechanism. Assessment processes have played an important role in generating, re-forming, and sustaining communities. This is evident in the contributions of regional groups to development of a coastal zone management community concerned with climate change. It is also apparent in the recent emergence of a strong health impacts community.

Overall, both sea-level rise and health sectors illustrate how impact definitions and demaractions, communities, and methodologies co-evolve. Boundary work has proven especially helpful in understanding these interactions - especially, the emphasis and de-

emphasis of particular impacts over time, treatment of adaptation and vulnerability, the inclusion or exclusion of community members, and the role of methodologies in shaping impact framings. The progression from "dormancy" to "salience" regarding health impacts implies a number of boundary drawing exercises regarding dominance of GCM methodologies, the broadening of participation among different disciplines and countries, and the treatment of direct and indirect health impacts. Boundary work concerning sea-level rise is particularly key in regard to tensions between vulnerability and adaptation and in the different national perspectives that have shaped this impact area.

Findings presented here lay groundwork for future research into the impacts domain. The "trading zone" nature of impacts and increasing activity in this area, indicate that "impacts" provide an extremely fruitful subject for investigating the interactions between science, policy, and society and how these interactions relate to the production of knowledge. Furthermore, understanding these dynamics is increasingly important for policy endeavors as impacts may move to center stage of the climate change policy debate. Some climate change experts, for example, believe that political contests over climate change policy will soon focus on questions about what impacts will occur and with what certainty impact analyses can project the timing and nature of these impacts.[xxxvi] Improved understanding of the impacts domain, its evolution, communities, and methodologies may provide insight into how to meet potential scientific, technical, and political challenges. Understanding of how impact categories have taken shape might provide awareness of critical areas that have been overlooked in the current, largely market-based organization of impact definitions. Similarly, understanding impacts community development may indicate ways to attract the needed expertise or interest of certain groups. Finally, observing the evolution of impact assessment methodologies may suggest means by which development of analytical tools could be enhanced or accelerated to meet growing information demands.

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Tables

TABLE 1: WHAT IMPACTS ARE ADDRESSED IN ASSESSMENTS?

'CAUSAL' ORGANIZATION OF IMPACTS [A CARICATURE]:

⇒ **"first-order" physical-climatical impacts,** such as temperature, precipitation, thermal expansion of oceans, melting of ice, greater humidity, or changing carbon dioxide levels.

⇒ **"higher-order" impacts flowing from first-order impacts**, with different categories of impacts created according to where they are placed on a hierarchical "cascade" of impact levels: lower levels such as the geographical effects of rising sea levels, or the ecological effects of declining precipitation and increasing temperatures, or the biological effects of carbon dioxide fertilization; mid-range levels such as the social and economic consequences of these effects at local and regional scales; and higher levels such as global market operations. These impacts often are interpreted deterministically and linearly, depending on "lower" order impacts and, ultimately, on climate change.

⇒**"interactive" impacts**, where the impacts occurring in a given natural or social system (including many first and higher order effects) interact dynamically over time. Impacts emerge from the intersection and multiple feedbacks of many *climatic* effects. To some extent, this interaction is captured by sectoral and cross-sectoral analyses, and by models of the agricultural sector as a system of impacts where various kinds of impacts are bundled with each other. Different degrees of interactivity can exist in models, in that supposedly "higher-order" impacts may feedback to change the precursors of impacts, or exacerbate "lower-order" impacts, so that impacts can vary because of other impacts. These impacts often do not take account of non-climatic factors.

⇒ **"synergistic" impacts**, where an impact is not viewed as merely flowing from climate change phenomena, but also flows from many other *non-climatic* social and economic phenomena, such as air pollution, or farmer behavior in response to recessions. In a slightly different sense, many impacts may be defined by how climate change phenomena interact with highly local and variable conditions, so that impacts cannot be separated from the local or regional scale. This is seen, for example, in sea-level rise where impacts depend on (highly fractal) coastal features.

OTHER INTERPRETATIONS OF IMPACTS:

⇒ **Impacts as negative effects ("damage" and "loss")**, largely determined by researchers, assessors, and policy-makers according to their standards of damage done to the environment or to society. An example is sea-level rise viewed from a property loss perspective.

⇒ **Impacts as both negative and positive effects**, so that an impact is the net effect, whether global or regional, of climate change on a given sector or system. An example is temperature change in agriculture, which may enhance crop productivity in temperate zones, or undermine productivity in warmer latitudes.

⇒ **Impacts with adaptation built in**, or the dynamical interaction between climate change phenomena and human or ecological responses in such a way that people or ecosystems are able to adapt their behavior to the phenomena, and therefore possibly eliminate or modulate the adverse impacts on societies and ecosystems. Alternatively, impacts may vary in their effects over time because of changing rates of adaptation. For example, farmers may introduce new crop varieties and growing techniques in response to climate change over time.

⇒ **Impacts as contrasted to vulnerability**, where populations and regions are analyzed for their prospective susceptibility to first or higher order climate change effects, rather than for the ways in which impacts might affect them. An impact may not be understood as a meaningful impact if the population or region is not analyzed as "vulnerable" (or is viewed as less "vulnerable") to the effects thereof. Sea-level rise may not have a significant impact on a particular population if their coastal zone is relatively impregnable to rising levels.

⇒ **Impacts as the variability of effects**, where an impact is bounded by how people see its variability and respond to that variability. An impact that is highly aggregated or expressed in terms of means often does not seem to vary, so that the impact seems more manageable and eventually predictable. By contrast, an impact that is disaggregated into many variable states seems more complicated, and assessment results become more clearly uncertain and arbitrary.

Endnotes

[i] The authors are grateful for the thoughtful suggestions and guidance provided by Sheila Jasanoff, Bill Clark, Jill Jaeger, and Ted Parson. We are also indebted to numerous impact scientists and assessors who shared with us their experiences and perspectives. Input from William Easterling, Paul Epstein, Hartmut Grassl, Pim Martens, Richard Moss, Lars Olssen, and Stephen Schneider was particularly valuable.

[ii] "Assessments" are defined here as social processes. These processes involve interaction among scientists, assessors, and policy-makers which results in development or identification of policy-relevant knowledge claims, and the communication of these claims to research and policy communities. Assessments can take many forms. These include large-scale interdisciplinary collaborations resulting in reports, scientific research projects, direct communication between experts and decisionmakers, journal publications, workshops, and conferences

[iii] The majority of impact assessments are carried out by scientists representing a relatively small number of countries, namely the United States, Australia, Canada, Britain, the Netherlands, and several other European nations. Consequently, impact assessments often reflect the experiences, needs, and assumptions of industrialized countries, rather than developing countries.

[iv] Co-production refers to the simultaneous generation of both scientific social knowledge and practices (Shackley and Wynne, 1996). Through the process of co-production, knowledge claims, cognitive frames, and political perspectives evolve through a dynamic and contingent interaction among various actors, institutions, and organizations.

[v] "Framing" refers to the way a particular problem is presented or viewed. Frames are shaped by knowledge and underlying visions of the world (Schon and Rein, 1994).

[vi] The data for both the historical overview and case studies are derived primarily from written and verbal accounts of climate change assessment processes in the United States and international arena. These assessments were easiest to examine given resource and time constraints, and they provide insight into how assessments of impacts link or fail to link the domestic and international spheres.

[vii] Boundary work can involve the policing of disciplines and fields of research, dividing them into finer areas, buttressing their independence from each other, and making them no longer available in terms of another discipline or sub-discipline. It may expand existing disciplines through becoming more inclusive of social or natural phenomena. Boundary negotiation may seek to determine who are the experts qualified to speak or carry out research in a field, or to critique that research. Some research, actors, conclusions, techniques, and institutions may be de-legitimated in favor of others. Alternatively, boundary work may contend that some approaches, facts, methods, and findings are credible or authoritative, and therefore beyond dispute. It may locate uncertainty and the problems of "complexity" in the natural world, rather than in the social world (or the interaction between these worlds).

[viii] The former has often predominated

[ix] The NRC (1976) study did acknowledge the effects of both long-term and short-term climate change, but concluded that short-term fluctuations had the most important effects on agriculture and water resources.

[x] During the 1970s droughts in the Sahel and in East Africa led to widespread famine. Drought and winter snow cover in the Soviet Union (USSR) resulted in crop failures and prompted the USSR to buy large amounts of grain from the world's markets, leading to a world grain shortage. In addition, weather-related problems in the U.S., Canada, and Australia during this time, decreased production of wheat, corn, and soybeans just as demand for surpluses in these crops were at a high (Rockefeller, 1976).

[xi] The NDU study (it included three phases concerning climate change (1978), crop yields (1980), and the global grain economy (1983)) is notorious for the methodology it employed. In particular, the study is based on an elicitation strategy. NDU compiled experts opinions regarding climate change scenarios, technological projections, etc., but then averaged these opinions to produce a final result (see Stewart and Glantz, 1985 and Schneider, 1985) for critiques of this study.

[xii] Kingdon points out, however, that a focusing event often has only a transient effect if it is not coupled with an indicator, preconceptions of the problem, or a similar event (Kingdon, 1995).

[xiii] Other subsystem criteria require that subsystems have "organizational residue." That is, specialized subunits of government at all relevant levels should be addressing the issue and interest groups must exist which regard the issue as a major policy topic (Sabatier and Jenkins-Smith, 1997: 23).

[xiv] Note that the ACF was initially developed to reflect domestic policy-making in industrialized countries and assumes that coalitions have the technical resources necessary to engage in policy debate (Sabatier and Jenkins-Smith, 1993). However, some researchers are beginning to apply the ACF to international policy making (e.g. Sewell 1997).

[xv] Schlager (1995) and Schlager and Blomquist (1996) have argued, however, that a shared set of beliefs among coalition members is not a sufficient condition for coordinated action. They point out that transaction costs, distributional conflicts and free-riding temptations can pose important barriers to collective action regardless of aligned belief systems.

[xvi] For example, see (Thomas, 1976) and (Weertman, 1976).

[xvii] However, recent assessment suggests that ideas about causal pathways may be shifting again. For example, researchers such as Titus and Narayan (1996), are suggesting that the small but potentially grave risks of WAIS thawing have largely been ignored and should be reincorporated into sea-level rise assessments.

[xviii] This estimate is based on the range of emission scenarios, IS92a-f using "best estimate" model parameters. The IPCC (1995a) analysis also notes that sea-level rise is projected at approximately 50 cm for the year 2100 with a 20-86 cm range of uncertainty. Further, the extreme range of projections, accounting for both emission scenarios and model uncertainties, is 13-94 cm.

[xix]It is fascinating to compare the series of reports issued by the South Pacific Regional Environmental Programme between 1988 and 1990, with the reports issued in 1992 and later. The later reports read fairly differently from the earlier reports because they devote much space to extreme events.

[xx] AOSIS has been supporting an "AOSIS Protocol" to the Framework Convention on Climate Change (FCCC) since 1995, urging much greater reductions in greenhouse gas emissions than many FCCC members support.

[xxi] Significantly, the NAS sub-contracted much of the research and assessment work in its 1983 report to Dutch experts, perhaps also highlighting what seems to be a continuing ambivalence in the US parts of the "community" about coastal zone management. It seems that the US and the Netherlands have differing visions of ICZM, and that the US is more interested in relatively narrow economic frames of adaptive strategies.

[xxii] For example, Delft Hydraulics carries out a range of assessments on countries such as Egypt.

[xxiii] Significantly, the workshops (especially the Margarita Island workshop of 1992) that eventually produced the IPCC Common Methodology for Vulnerability Assessment were sponsored by the Dutch, American, and Australian governments.

[xxiv] This is particularly interesting because the SPREP tends to give greater prominence to anthropologists, sociologists, and political scientists in its work.

[xxv] Our interviews with participants in the sea-level rise sector have highlighted the World Coast Conference and the Margarita Island workshop as important "moments" in the transformation of the sector.

[xxvi] The Dutch Coastal Zone Management Center has established an internet site named "NetCoast" to provide free access to information about sea-level rise and coastal zone management. This site can "provide global, regional, and national data on the physical, social, and economic characteristics of coastal zones and the conditions constraining their management." In turn, the Center "provides world-wide support for proper coastal zone management planning and services for sustainable development in coastal zones." See http://www.minvenw.nl for details.

[xxvii] An interesting observation may be that the UNEP originally wanted to control the climate change assessment process, but that this process was placed under the supervision of an intergovernmental (not international organizational) body. Hence, the UNEP's continuing involvement in the SPREP may be a sign of its attempts to influence the climate change assessment landscape more indirectly.

[xxviii] In the SPREP, scientists can be both assessors and policy-makers because they work within a specific regional system that gives them great leverage to diffuse their perspectives into the international assessment process. Thus, they have multiple roles. This may have assisted the SPREP in supporting the notion of "vulnerability" on behalf of the small island states.

[xxix] At this workshop, the Dutch had volunteered to aggregate the case studies presented at the Margarita Island workshop and produce a first attempt at a global vulnerability index based on this aggregation. This highlights the continuing tension between different views of "vulnerability" and the dialectic between the Dutch and American coastal zone management "fraction" and the AOSIS/SPREP "fraction."

[xxx] Yet the Common Methodology implicitly assumes that different vulnerabilities can be summed into an overall "profile" of a coastal zone (IPCC, 1992).

[xxxi] This conference produced a book entitled, *Climate and Human Health* (WMO, UNEP, and WHO, 1987).

[xxxii] Around this time WHO's Commission on Health and Environment considered health impacts associated with "transboundary and international problems." However, this study which culminated in the report, *Our Planet, Our Health* (WHO, 1992), focused mainly on localized health impacts related to drinking water contamination, industrial pollution, agricultural activities and urban crowding (also see WHO et al., 1996).

[xxxiii] It also appears in the general policy-maker summary chapter

[xxxiv] Important events that may have contributed to development of a health impacts community include the Gulf War of 1991, a number of cholera and malaria outbreaks in Latin America, and arbovirus problems in the United States. In the Gulf War, many oil wells were set afire by the Iraqi Army, and there was extensive media attention throughout the world to the possibility of local and long-range health hazards from the conflagration. Additionally, during the early 1990s, there were various epidemics of cholera as well as the 1994 plague outbreak at Surat in India. These sorts of "focusing events" as described by Kingdon (1995) appear to have increased overall attention to health/environment relationships generally.

[xxxv] See http://www.noaa.gov/ogp/Epstein,Paul1.html.

[xxxvi] Based on interviews Marybeth Long had with WMO scientists in February 1997.