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Adaptive Governance Needs for Enhancing Governance of Climate Impacts to Biodiversity

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Abstract

Due to the unprecedented rate of human-induced climate change, there is now widespread consensus that biodiversity will not be able to sufficiently adapt to climate change naturally. Trends of climate impacts are already becoming visible, including modification of migration patterns, length of growing seasons, species distributions, and invasive species outbreaks. Even if mitigation strategies were effective in stabilizing emissions, thermal inertia and the lag of impacts will result in significant effects, imposing the need to implement adaptation strategies. Options for adaptation for biodiversity conservation include rigorous monitoring, establishment of corridors and buffer areas, expansion of existing protected areas' core zones, control of invasive species, reduction of non-climate stressors, and acquisition of new reserves.

While conservation biologists and managers have dramatically improved scientific understandings of the problem, the influence of this research in the policy process has been limited. This is problematic because institutional coordination for ecosystem management at all scales will be essential in a changing climate (Lovejoy and Hannah 2005). However, mitigation remains the focus of climate change policy, and advancement of adaptation measures for biodiversity conservation has been slow to take form. Measures could include strengthening effectiveness and compatibility of multilateral environmental agreements; promoting synergies between the climate change and biodiversity regimes; adopting binding targets and timetables; strengthening adaptation funds; and harnessing development aid for adaptation projects. This paper will explore the hurdles inherent in contending with the problem of climate change impacts to biodiversity, such as institutional fragmentation and the need for adaptive governance due to uncertainty and potential future climate "wild cards." In addition, this paper will identify promising institutional innovations for enhancing governance of biodiversity in a changing climate.

Overview of the Problem of Climate Impacts to Biodiversity

Human-induced climate change has been recognized as one of the greatest challenges facing our planet (Prime Minister's Office 2004). It is already rapidly transforming our world, affecting both human-built and natural environments. Overall, the Earth has already warmed 0.8°C in the last century, having increased 0.2°C per decade within the last thirty years. Not only was 2006 the warmest on record for the contiguous United States, as well as tying for the fifth warmest year on record globally (National Climatic Data Center 2006), following 2005, 1998, 2002, and 2003, there is a strong scientific consensus that global temperatures will continue to increase in the future. Recent assessments suggest that business as usual trajectories will result in an additional warming between 1.8°C and 4°C, with an upper range of 6.4°C, by 2100 (Intergovernmental Panel on Climate Change 2007). This warming trend has been attributed to human-induced climate change, resulting from an increase in atmospheric concentrations of greenhouse gases (National Climatic Data Center 2006). Current levels of two key greenhouse gases, methane and carbon dioxide, remain unmatched to any record during the 650,000 years before the Industrial Revolution (Siegenthaler 2005; Spahni 2005).

Moreover, even if we were to stabilize emissions at lower levels, we would still witness significant impacts. For example, Wigley has predicted that even if greenhouse gas levels were stabilized at 2000 levels, atmospheric temperatures would increase by 0.5° C by the end of this century and the amount of sea level rise would increase by 320% by the end of this century (Meehl 2005). And if we were able to halt greenhouse gas emissions altogether, the Earth would still undergo significant increases in both temperatures and sea level rise as a result of the lag effects of greenhouse gases in the atmosphere, as well as thermal inertia. Hence, the science is clear; even if we were to stabilize at lower emissions levels, or eliminate emissions, we would still have already committed to substantial impacts, supporting the need for adaptation policies.

Changes in ecosystems often parallel changes in local climates. As climates are altered, ecosystems can, in turn, be affected. Rising temperatures will have significant implications on precipitation trends and hydrological cycles, as some regions become wetter, while others become drier due to the changes in atmospheric circulation and water-holding capacity of a warmer atmosphere. Changes to biota can be carried out at the micro scale of the cell -- and, scientists are now finding, even the genetic composition of some species is changing (Sarup 2006) -- to the macro level of the biome. Species will vary in their responses to a changing climate, and several indicators have been developed to assess vulnerability to climate change impacts. Some species will have high tolerances to change, while others will quickly become threatened or extinct (Dharmaji 2003), namely those with poor dispersal capabilities, restricted ranges, habitat or niche specialization, low tolerance to climate sensitive variables, and isolated population distributions such as mountaintops or islands (World Conservation Union 2005). And some species will migrate to more tolerable regions. For example, species in high latitude regions are likely to shift tens of kilometers poleward by 2050, whereas temperate and tropical montane species are likely to shift hundreds of meters in altitude by mid-century (Forrest 2003). Species migration will in turn affect ecosystem composition.

Climate change will likely become a leading driver of biodiversity degradation in the 21st century (World Resources Institute 2005). Based on modeling mid-range warming scenarios, scientists have asserted that 15-37% of species will become extinct by 2050 as a result of climate change impacts alone (Thomas 2004). The Intergovernmental Panel on Climate Change (IPCC), an international body created by the United Nations Environment Program and the World Meteorological Organization to provide authoritative assessments on climate science and impacts, has recently suggested that 20% to 30% of species will likely be at a higher risk of extinction with temperature increases greater than 1.5°C to 2.5°C, and risks will increase with additional temperature rise (Intergovernmental Panel on Climate Change 2007). For those species that can adapt, they may dramatically change their ranges (Forrest 2003). As species migrate -- and species will migrate individualistically -- new assemblages of species will be created, which can have adverse impacts to food chain and community dynamics, presenting new challenges to biodiversity management and conservation. Moreover, other human-induced stressors, such as land conversion and fragmentation, habitat destruction, pollution, and overexploitation, leave ecosystems and biodiversity more fragile in a changing climate (Wigley 2005). Thus, non-climate drivers of degradation act synergistically with climate change impacts, a combination of effects that arguably presents the greatest challenge facing conservation today (Lovejoy 2005).

Adaptation strategies for biodiversity conservation

As indicated above, because thermal inertia and the lag of climate change impacts will result in significant effects (Meehl 2005), a two-pronged policy approach that employs both mitigation and adaptation will be required to ameliorate future environmental degradation (McKibbin 2004). While mitigation activities will direct efforts to curb greenhouse gas emissions, adaptation efforts will bolster biodiversity resiliency. Although adaptation strategies will not protect all species from climate change impacts (e.g. there may be physical barriers to migration), adaptation is a critical component of biodiversity conservation in a changing climate.

The notion of adaptation is not novel. Ecologists have long used the concept of adaptation to depict the evolution of organisms in a new environment. Broadening this definition, adaptation in the context of climate change connotes the evolution of humans and ecosystems to new environments caused by climate change (Abramovitz).[1] Indeed, adaptation has been defined similarly by climate change experts. The Intergovernmental Panel on Climate Change (IPCC) defines adaptation as the "adjustment in natural or human systems in response to actual and expected stimuli or their effects, which moderates harm or exploits beneficial opportunities" (Subsidiary Body for Scientific and Technological Advice: UNFCCC 2004).

Adaptation strategies to bolster biodiversity resiliency require assessments of vulnerability and impacts on the local level, primarily through the advent of sophisticated modeling (Abramovitz). There are a number of modeling tools now available for assessing climate change impacts to biodiversity, including regional climate models, dynamic and equilibrium vegetation models, species bioclimatic envelope models, and others (Hansen et al 2003). After vulnerabilities are assessed, adaptation strategies could include: rigorous monitoring and evaluation, control of invasive species, establishment of corridors, reduction of non-climate stressors, and acquisition of new reserves (Ad Hoc Technical Expert Group

[1] However, it should be noted that this change will not occur on an "evolutionary" time frame, as human-induced climate change has ensued at a much faster rate.

2005; Hannah, Midgley et al. 2007). In addition, rehabilitation of previously degraded ecosystems can aid in the maintenance of viable habitat (Dharmaji 2003). Another essential component of adaptation for biodiversity conservation is the reduction on non-climate stressors, such as habitat fragmentation, over-harvesting, pollution, and other factors which augment the impacts of climate change on ecosystems and biodiversity (Ad Hoc Technical Expert Group 2005). Ultimately, the most effective basket of adaptation tools for strengthening biodiversity resiliency will be context-specific and require rigorous assessments by trained experts in conservation biology, managers and other scientific knowledge holders.

Dharmaji et al. categorize adaptation policy responses into four classes: (1) *maintenance of status quo,* which could result in significant risks and costs in the future; (2) *no regret strategies*, which employ only strategies that do not present great costs to communities; (3) *precautionary measures*, which are based on the premise that actions should be taken to contend with predicted impacts; however, precautionary strategies must be cost-effective; and, lastly, (4) *pro-active strategies*, which entail the implementation of far-reaching and aggressive measures in an attempt to mitigate adverse climate impacts (Dharmaji 2003). The majority of adaptation measures remain in the "maintenance of status quo" or "no regret strategies" categories; yet adaptation measures for the enhancement of biodiversity resiliency, given that species loss is irreversible, require both "precautionary measures" and "proactive strategies."

Response to date

A handful of jurisdictions have embraced plans to contend with climate impacts to biodiversity, some of which are briefly described below:

(1) Finland: In 2003, Finland's Parliament commenced work on its National Strategy for Adaptation to Climate Change. The Strategy calls for evaluating existing protected areas networks, reducing non-climate stressors in degraded areas, improving monitoring and planning, and studying thresholds of biodiversity to climate impacts. The document also has a number of short-term, medium-term and long-term measures (Ministry of Agriculture and Forestry of Finland 2005).

(2) Australia: The Australian government has backed widespread monitoring of climate effects in protected areas and, most significantly, adaptation measures for management. The Government has released a "National Biodiversity and Climate Change Action Plan" which is the first national adaptation strategy of its kind (Australian Government Department of the Environment and Heritage 2004). Most significantly, as of late February 2007, state and federal governments, led by the New South Wales government, have decided to build a 2,800 km conservation corridor from Victoria to Queensland, known as the "Alps to Atherton" corridor, to assist species migration in a changing climate. While land will not be acquired by the governments, and, thus, participation remains voluntary, this project is one of the first corridors to be designed to address climate impacts to biodiversity and will be among the longest conservation corridors in the world (Wood 2007).

(3) Canada: Paralleling the Australian government, the Canadian government has been a leader in adaptation efforts for biodiversity management. The Government's report entitled *The State of the National Parks* identifies climate change as a leading factor in ecosystem degradation, and Parks Canada has since launched a project to improve the resiliency of their park network (Scott 2003).

(4) United States: While the US Environmental Protection Agency has developed a pilot "Climate Friendly Parks" project, which calls for voluntary action to address climate change, measures resulting from the project focus on mitigation efforts solely, e.g. energy efficient buildings and facilities (Glacier National Park 2004). However, the United States Climate Change Science Program is in the midst of finalizing a review of "adaptation options for sensitive ecosystems and resources" (US Climate Change Science Program 2006).

In addition, some progress has been made on the international level, but governance of climate impacts to biodiversity remains fragmented with no binding targets or timetables. While policy-makers recognize the need to coordinate, few mechanisms have been put forth to promote synergies except for a centralized searchable database of treaty texts, known as the "Issue Based Modules for Coherent Implementation of Biodiversity Conventions" (Ad Hoc Technical Expert Group 2005). Moreover, the translation of international policies to meaningful action on the national and local levels is a challenge in itself, especially when decision-makers are not those who carry out prescriptions on the ground. In addition to the multiple layers of policymaking, conservation managers are also decision-makers and can be found at all jurisdictional levels.

That said, adaptation measures have increasingly been folded into multilateral environmental agreements and funding mechanisms. With regard to the climate regime, in September of 2005, the General Assembly of the United Nations noted the importance of adaptation, and while not adaptation for biodiversity and ecosystem conservation per se, the Assembly has committed to "continue to assist developing countries, particularly SIDS [small island developing states], LDCs [least developed countries] and countries in Africa in addressing their adaptation needs relating to the adverse effects of climate change"(Ad Hoc Technical Expert Group 2005). Also recognizing the impact of human activities on the atmosphere, and resultant impacts to communities and ecosystems (Intergovernmental Panel on Climate Change 2001), the United Nations Framework Convention on Climate Change (UNFCCC) refers to adaptation in several of its articles. For example, the stated objective in Article 2 is (Subsidiary Body for Scientific and Technological Advice: UNFCCC):

> …to achieve, in accordance with the relevant provisions of the Convention, stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time sufficient to allow *ecosystems* [emphasis added] to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner.

Article 2 makes an explicit reference to adaptation for ecosystems. In addition, Article 4.1(b) references adaptation quite broadly, stating that Parties must "formulate, implement, publish and regularly update…measures to facilitate *adequate* adaptation to climate change" (emphasis added). Similarly, Article 4.1(f) calls for "*appropriate* methods, projects or measures" (emphasis added) for adaptation. However, these articles fail to define "adequate" or "appropriate", and Parties are free to exclude adaptation for conservation if they deem current conservation management strategies satisfactory. For these reasons, some critics denounce the UNFCCC's adaptation measures, as they are referenced in "broad, non-specific" terms (Abramovitz). A number of other adaptation action items are folded into the UNFCCC. One of these articles – Article 4.8 (g) – is perhaps the most relevant to adaptation for biodiversity and ecosystems and states that:

> the Parties shall give full consideration to what actions are necessary under the Convention, especially on…[c]ountries with areas with fragile ecosystems, including mountainous ecosystems.

This article calls for the "consideration" of adaptation activities to conserve ecosystems and biodiversity; however, it should be noted that it does not bind the Parties to execute any such activities.

The Kyoto Protocol builds upon the Framework Convention's stipulations by promoting the implementation of the UNFCCC articles. Most noteworthy, the Protocol's Article 12 calls for a share of proceeds from the Clean Development Mechanism (CDM) -- the mechanism in which Annex I countries (Parties with binding emissions targets) can establish emission reduction/sequestration projects in non-Annex I countries (Parties lacking binding targets) – to be set aside for adaptation costs (Dharmaji 2003). The Adaptation Fund will be financed by a 2% levy on CDM projects, and funding is dependent upon the stream of projects. In addition to the Adaptation Fund under the Kyoto Protocol's CDM, there are three other funds that have been established for adaptation financing: the Least Developed Countries Fund, the Special Climate Change Fund, and the Strategic Priority on Adaptation Global Environment Facility Trust Fund (Spahni). All of these funds, including the Adaptation Fund under the Kyoto Protocol, are supported and managed by the Global Environment Facility (GEF), an independent financial entity that is the largest single source of funding for the environment (2005). The Global Environment Facility is dependent on regular replenishments by the global community, and future replenishments will determine levels of funds.

The Least Developed Countries Fund under the Convention finances the preparation of National Adaptation Programmes of Action, known as NAPAs (United Nations Framework Convention on Climate Change). Drafted during the 7th Conference of the Parties of the UNFCCC, the development of NAPAs requires least developed countries to identify immediate adaptation needs. Rather than relying on costly modeling and sophisticated assessment tools, NAPAs utilize existing information and community identification of priority adaptation activities. Those countries preparing NAPAs are required to include potential projects that could be carried out to ameliorate vulnerability. It should be noted that these plans can include adaptation measures for ecosystem and biodiversity conservation, but there is no requirement that they should be included in countries' NAPAs. Currently, the Least Developed Countries Fund, operational since 2001, contains US $90 million (United Nations Development Program and Global Environment Facility 2006).

Another fund under the Convention, the Special Climate Change Fund (SCCF), was created in 2001 under the Convention and finances four core areas: (1) adaptation projects; (2) technology transfer and capacity building; (3) economic diversification; and (4) management of a number of emitting sectors. According to the Global Environment Facility, adaptation activities under the SCCF are a top priority of the Fund's allocation. Thus far, the Fund, which became operational in October 2005, has acquired US $60 million (United Nations Development Program and Global Environment Facility 2006). The large majority of projects have been dedicated to adaptation for human-built environments; it remains to be seen whether adaptation for biodiversity conservation will be prioritized.

The last fund for adaptation under the Global Environment Facility is known as the Strategic Priority Piloting and Operational Approach to Adaptation under the GEF Trust Fund. Coined the SPA, or the Strategic Priority on Adaptation, the objective of this fund is to reduce vulnerability and increase adaptive capacity. Unlike the other abovementioned adaptation funds, the SPA was not developed under the Marrakech Accords, or the "rule book" for implementation drafted at COP 7 in Marrakech (Abramovitz). Therefore, the SPA is orchestrated by the GEF Trust Fund only. Specifically, the SPA aims to coordinate pilot projects that demonstrate that adaptation can be carried out on the ground and adaptive capacity can be strengthened. A key goal of the SPA is to coordinate activities with the focal areas of the GEF, namely biodiversity, land degradation, and international waters (United Nations Development Program and Global Environment Facility 2006). While US $50 million has been set aside for pilot projects and the Fund has been operational since 2001, the project portfolio contains only coastal, drought, and water resources management projects. According to the project website, "linkages with the focal areas of international waters, land degradation and biodiversity need to be further strengthened" (United Nations Development Program and Global Environment Facility 2006). Thus, it remains to be seen whether adaptation projects for biodiversity resiliency will be prioritized. Moreover, there is uncertainty regarding how the fund will operate after the pilot program phase.

Apart from the UNFCCC and the Kyoto Protocol, climate change impacts to biodiversity and ecosystems have also been addressed by several non-climate multilateral environmental agreements. The Convention on Biological Diversity, which is one of the primary agreements resulting from the 1992 Rio Earth Summit (IGES 2005), contains provisions that could be interpreted as requirements to contend with climate impacts to biodiversity. Parties under the Convention are required to develop national plans for biodiversity conservation, and must (Secretariat of the Convention on Biological Diversity 2003):

> …promote national agreements for emergency responses to activities or events, whether caused naturally or otherwise, which present a grave and imminent danger to biological diversity and encourage international cooperation to supplement such national efforts and, where appropriate and agreed by the States or regional economic integration organizations concerned, to establish joint contingency plans.

However, the language does not make direct mention of climate impacts (Blanco 2004), and, therefore, the decision to contend with climate change remains the purview of the participating party.

The Convention also recognizes that synergies are needed between the climate agreement and its own activities (Convention on Biological Diversity 2004). In 2002 the Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA) and the Conference of the Parties to the Convention on Biological Diversity requested that the Convention explore the impacts of climate change on biodiversity. As a result, an Ad Hoc Technical Expert Group (AHTEG) was created, assessing the linkages between the two conventions. In 2003 the AHTEG completed its first report and the Convention circulated it among Parties, encouraging its use in national planning. Consequently, the AHTEG was charged with providing guidance on how best to promote synergies among adaptation activities on the local, national, regional and internationals levels, as well as under the climate convention and other multilateral environmental agreements (Ad Hoc Technical Expert Group 2005). Upon this request, the AHTEG on Biodiversity and Adaptation to Climate Change convened again in Finland in September of 2005. The Group, comprised of fifteen members from governments, NGOs, indigenous and local communities, and intergovernmental organizations, drafted options for synergy and has circulated the report not only to the Convention on Biological Diversity but also to the UNFCCC. The Group's recommendations are being considered by the Parties currently. During the most recent Conference of the Parties in March 2006, Parties were, among other actions, *encouraged* "to integrate biodiversity considerations into all relevant national policies, programmes and plans in response to climate change" (Convention on Biological Diversity, 2006). However, no binding targets and timetables for adaptation measures have been adopted.

The AHTEG work has also been supported by the Joint Liaison Group of the three conventions developed during the 1992 Rio Earth Summit conference (UNFCCC, CBD, and the UN Convention to Combat Desertification). In January of 2004, the Joint Liaison Group had noted the potential synergies among the conventions and identified the need for adaptation activities. The Group has since outlined adaptation activities under the three conventions and has provided options for enhanced cooperation (Ad Hoc Technical Expert Group 2005; Nesmith 2005). The United Nations Environment Programme has been instrumental in this regard, having created a database entitled, "Issue Based Modules for Coherent Implementation of Biodiversity Conventions." This database contains every article within the three Rio conventions related to adaptation for ecosystems and biodiversity. For example, upon querying adaptation and protected areas, a visitor to the database will see the aforementioned UNFCCC Article 4.1(e), as well as five other articles. The goal of the database is to advance synergies among the conventions, given their disparate activities and fragmentation (Ad Hoc Technical Expert Group 2005).

In addition to the Rio conventions, the Ramsar Convention on Wetlands has also recognized climate change impacts and promotes restoration and adaptation activities. In its Resolution VIII.3 in 2002, the Convention calls upon its Parties to manage wetlands in a manner that increases their resiliency to climate change (The Ramsar Convention on Wetlands 2002). However, it was noted in February 2007 by the Ramsar Standing Committee that there has been little advancement of climate change concerns within Ramsar since the 2002 decisions. The Committee, thus, recommended that the subject be reintroduced in future workshops (Wetlands 2007).

Additionally, another biodiversity-related convention, the United Nations Educational, Scientific and Cultural Organization (UNESCO)'s World Heritage Convention, declared in July 2006 that it would take into account climate change risks to World Heritage sites. The World Heritage List contains 812 sites located in 137 countries. 160 of these sites are recognized for their natural significance instead of their cultural value. The decision to incorporate climate change in protection strategies includes measures to mitigate and adapt to climate change and has initiated a call for pilot projects to establish best conservation practices. A policy document with more detailed responses will be issued in 2007 (Environmental News Service 2006). Most notably, the World Heritage Committee will decide whether any sites affected by climate change warrant listing under the World Heritage in Danger List, which contains sites that require significant assistance under the Convention. Listing of World Heritage sites impacted by climate change could have profound implications, because it requires that the Committee, in conjunction with the concerned Party, take measures to reverse the degradation.

While the above paragraphs may suggest that there is substantial activity on adaptation for ecosystems and biodiversity, binding targets and timetables are needed to slow the rate of biodiversity loss and ecosystem degradation from climate change effects. The majority of aforementioned measures define adaptation broadly and do not stipulate that Parties must carry out adaptation activities for the preservation of species diversity and habitat. In addition, with the exception of the World Heritage Convention's Danger List, these measures fail to establish a methodology for project prioritization, which is necessary given global constraints in capacity (Ad Hoc Technical Expert Group 2005).

Hurdles inherent in enhancing governance of climate impacts to biodiversity

In addition to the fragmented nature of global governance of climate impacts to biodiversity, the problem also lacks simplistic, straightforward planning responses and, thus, confronts simple problem solving techniques (Rittel and Webber 1973). A number of hurdles inherent in addressing climate impacts to biodiversity exist. In the following section, the roles of uncertainty and potential "wild cards" will be explored, two factors that arguably present some of the greatest challenges to governance of climate impacts to biodiversity.

A. Uncertainty

While there is a consensus regarding key attributes of climate impacts to biodiversity, the problem is also riddled with uncertainty. In simple problem solving, uncertainty may not present itself as a challenge. The problem solver would simply resolve critical uncertainties before offering prescriptions. However, uncertainties pertaining to problem drivers, impacts, and effectiveness of solutions are among the greatest impediments facing governance of climate impacts to biodiversity. The implications of uncertainty are significant: it can paralyze decision-makers and/or bias judgment, leading to processing failures and omission in decision-making. Often, we can "get by" and "muddle through" uncertainty with simple problems, but if uncertainty has significant ramifications, it can lead to irreversible harm (Morgan and Henrion 1990).

While the next section will focus on uncertainties surrounding climate impacts to biodiversity, the presence of uncertainty does not signal the lack of a consensus on multiple dimensions of the problem. Pollack writes, "when scientists acknowledge that they do not know everything about complex natural phenomena… the public sometimes translates that to mean that scientists do not know anything about the subject" (Pollack 2003). This is not the case with the defined problem of climate impacts to biodiversity.

While the evaluation of all uncertainties regarding climate impacts to biodiversity is beyond the scope of this paper, a summary is provided below. To begin, it is necessary to provide an overview of what is known about climate impacts to biodiversity in an effort to portray the level of consensus. The IPCC's Working Group II's recent publication of its Summary for Policymakers outlines the current state of knowledge (Intergovernmental Panel on Climate Change 2007):

- Ecosystem resilience will *likely* be exceeded by climate change impacts and non-climate drivers of species stress;

- Terrestrial sinks of carbon will *likely* peak in the middle of the coming century, weakening or possibly reversing thereafter, presenting a positive feedback;

- Roughly 20% to 30% of species will *likely* be at a higher risk of extinction with temperature increases greater than 1.5°C – 2.5°C, and at temperatures greater than this range, species interactions, ranges, and ecosystem structure will change, with negative impacts to biodiversity and ecosystem services; and

- Acidification of oceans will progress and have negative ramifications for shell-forming marine species, as well as species connected to those species through food chain relationships.

Given the consensus above, this section turns its attention to uncertainty with regard to climate impacts to biodiversity. First, it is important to note that there is lack of certainty pertaining to the number of species in the world, as well as how many – and which ones – will be driven to extinction due to natural processes and non-climate stressors, such as land use change, pollution, resource extraction, among others (Prestre 2002).

That said, what are key uncertainties regarding how biodiversity has been affected by climate change to date? The studies on climate impacts to biodiversity thus far have been largely correlational instead of experimental (Parmesan 2005). Also, while a consensus view has established that climate impacts to species are – and will continue to be – quite real and significant, the large majority of studies performed to date have been carried out in a limited geographical range. Thus, impacts in under-represented locations remain somewhat uncertain. For example, the recent IPCC Fourth Assessment Report's Working Group II's Summary for Policymakers depicts the geographic concentration of studies on climate impacts to biological systems, portraying a selection of 29,000 data series collected from 80,000 data series from 577 studies (Intergovernmental Panel on Climate Change 2007). While the Assessment Report demonstrates a high confidence in the correlational relationship between species impacts and human-induced climate change (e.g. of the 28,671 observed changes in marine, freshwater, and terrestrial biological systems, 90% of the changes were consistent with warming (Intergovernmental Panel on Climate Change, 2007)), the selection suggests that less is known about climate impacts to biological systems in under-studied regions. In addition, the study demonstrates that marine and freshwater systems have been studied less than terrestrial systems (e.g. 85 versus 28,586 significant observed changes), despite the high correlational relationships between impacts and warming in all systems. Indeed, "a strong picture is emerging, but the evidence still only touches a fraction of all species" (Parmesan 2005).

What are critical uncertainties with regard to how climate change will impact biodiversity in the future? Ultimately, impacts will depend on a species' vulnerability, which is defined by the harm from stress exposure, as well as adaptive capacity (Adger 2006). Species which are most vulnerable will have poor dispersal capabilities, restricted ranges, habitat or niche specialization, low tolerance to climate sensitive variables, and isolated population distributions such as mountaintops or islands (World Conservation Union 2005). These species will adapt in situ, migrate, or go extinct (Oglethorpe 2002). Species that have greater migration capabilities may seek other climatic zones. However, scientists do not know which species' current ranges are determined by climatic factors rather than other limiting factors, such as landscape fragmentation and/or human mediated migration (Midgley, Thuiller et al. 2007) (Oglethorpe 2002). Migration success is dependent on both species establishment and post-migration population growth, and, therefore, on dispersal regimes as well. Determinants of dispersal include fire disturbance (Canadell, Paraki et al. 2007) – which is in part determined by non-climate human-induced regime changes -- and wind and ocean currents. The timing of migrations has concomitant impacts on predator-prey relationships for migratory species, and uncertainties of range shifts will transmute these relationships as well.

Projections rely on forecasting of emissions trajectories and temperature increases, as well as resultant changes in precipitation and nutrient cycles, factors which have a range of possible distributions. This multi-factor interaction of global changes is a causal factor in species impacts, and projections that incorporate only a limited number of these factors are likely to be misleading (Norby, Rustad et al. 2007). Also, while global temperature change has been the "political yardstick," temperature changes need to be disentangled to reveal their impacts on species. For example, the magnitude of the gap between nighttime and daytime temperatures is a key determinant of biological impacts (Hannah, Lovejoy et al. 2005).

Future impacts to biodiversity can be assessed through either experimentation or modeling. With regard to experimentation, the external validity of some experiments, such as the Free Air CO_2 Enrichment (FACE) field experiments, which expose chambers to elevated levels of CO_2 concentrations, are unable to incorporate the large scale and complexity of biological systems (Norby, Rustad et al. 2007). In addition to experiments, there are also a number of different models that can be used to predict species impacts. However, forecasting is difficult because future species responses have no current analog and, therefore, modern correlational relationships cannot be relied upon (Williams, Jackson et al. 2007). That said, several models have been developed, largely falling into two distinct categories. The first set, single-species models, tracks the independent movement of individual species, while the other set, biome models, replicates species assemblage movements. Both approaches reflect omissions; models that compare the results from one with those of the other are needed to understand both individual species migration and the resultant effects on biome composition (Peterson, Tian et al. 2005). It is not clear whether conservation efforts will be better served by knowing rich details about a small number of species or by understanding dynamics in larger regions with more limited resolution (Botkin 2007) (Betts and Shugart 2005) (Tickner 2003). In addition, ecosystem models have to be coupled with earth system models, and there are numerous models that can provide this interaction, including gap models and dynamic global vegetation models. However, these models fail to integrate indirect relationships, such as fire regime changes (Keane, Cary et al. 2007), food web dynamics (Canadell, Paraki et al. 2007), changes in breeding, emergence, and metamorphosis (Root and Hughes 2005), and invasive species disturbances (Vila, Corbin et al. 2007). Moreover, there is a lag of mortality and range shifts after impacts are felt, further complicating the timing of projections (Vila, Corbin et al. 2007). Also, nonlinear earth system behavior, as well as cascading accumulation of smaller events, will also play a significant role in determining the fate of species in a changing climate, and forecasters' abilities to model these events are limited (Peters, Sr. et al. 2007).

B. "Wild cards"

Surpassing natural tipping points

There is no guarantee that stabilization at a chosen level of greenhouse gas concentrations – e.g. 500 ppm of CO_2equivalent – will ensure that we will not surpass tipping points in physical and biological systems. Warming can result in positive feedbacks in other parts of the climatic system, such as changes in the terrestrial sinks of carbon dioxide and methane (e.g. increased emissions resulting from the melting of permafrost); the decline in the ocean sink (e.g. as algal growth precludes CO_2 absorption, ions from calcium carbonate-based shells are released and the ocean becomes more saturated with CO_2); and/or changes in albedo (e.g. from loss of snow and ice cover). For example, the rate of ice sheet loss has been described as non-linear, and positive feedbacks could result in rapid disintegration of major ice sheets (Hansen 2005). Holland et al. suggest that the risk of complete Arctic summer sea ice loss after one year of accelerated ice retreat is higher under augmented greenhouse gas emissions, and it will be increasingly difficult to regain ice coverage during winters (Holland, Bitz et al. 2006). Feedback loops such as these may be found in other parts of the climate system. Overpeck et al. assert that sea level rise may be substantially faster and more significant than initially thought. Examining the last interglacial period 127,000 to 130,000 years ago, the Eemian interglacial, during which warming was approximately equivalent to that projected for the year 2100, they find sea levels 4 to 6 meters higher than current levels (Overpeck, Otto-Bliesner et al. 2006). Moreover, they find that sea level rise related to melting of the Greenland ice sheet and the West Antarctic ice sheet was extremely rapid. Overpeck et al. conclude that the potential for massive ice sheet loss is real, and that it may be triggered with even modest warming.

Tipping points exist in biological systems. There is great uncertainty regarding thresholds of biological systems.[2] For example, while it is not known what level of greenhouse gas concentrations would prompt massive permafrost melting, which would have significant positive feedbacks to the climate system, scientists do speculate that there is an "ice barrier" within permafrost, which – when surpassed – would lead to rapid thawing (Walker 2007).

In addition, climate change can exacerbate other stressors, bringing ecosystems closer to tipping points than they would be in the absence of climate change. For example,

[2] In an effort to resolve these uncertainties, the Heinz Center and the Nature Conservancy have established an "Eco-Thresolds" project to understand thresholds in the natural system, especially in light of how they impact decision-making.

increasing greenhouse gas concentrations in the atmosphere have been linked to the pronounced and lengthy periods of drought in the Amazon in 2005, which were a result of Atlantic Ocean surface warming and resultant air circulation changes (Hopkin 2005). Drought events can amplify impacts of deforestation and alter fire regimes. If fire dynamics were changed significantly, tropical forest ecosystems could be converted into scrub or savanna (Cochrane, Alencar et al. 1999).

Thus, if we overshoot natural tipping points, it is unclear whether ramifications could be reversed, given that processes with positive feedbacks have already been put in place.

Timing of mitigation stabilization

O'Neill and Oppenheimer suggest that the path society takes towards stabilization matters, and that physical and ecological systems can be adversely impacted if stabilization is either delayed or overshot in the approach to stabilization. For example, if a target of 500 ppm CO_2 is overshot before stabilization, there is a greater risk in widespread coral bleaching than in a more gradual approach to the target. Therefore, not only is the stabilization target important, but the timing of stabilization is a critical determinant of ecosystem stability (O'Neill and Oppenheimer 2007). For this reason and others, some scholars argue that climate change has the potential to "undermine more than a century of conservation efforts" (Lemieux and Scott 2005).

Unintended consequences of adaptation measures

Some adaptation strategies to contend with climate impacts to biodiversity may also result in unintended consequences. For example, while corridors have been documented to retain species diversity (Damschen, Haddad et al. 2006), it is unknown whether linkages will foster exotic species dispersal (Procheş, Wilson et al. 2005). Moreover, as mentioned above, because of the lag of impacts, there is no immediate test of prescriptions to contend with climate impacts to biodiversity, as consequences become manifest over long time horizons

Development of "no analog" ecosystems which may have wild cards that are impossible to predict (Williams, Jackson et al. 2007)

Human-induced climate change threatens to present ecosystems with "no analog" states and the disappearance of extant habitats (Williams, Jackson et al. 2007). Components within the biological system differ in their response to augmented greenhouse gas concentrations. The time scale of response can be long after atmospheric concentrations of greenhouse gases are stabilized. Perhaps most importantly, impacts are cumulative, and, thus, present added complexities and cascading effects, many of which may not be predictable.

Need for adaptive governance of climate impacts to biodiversity

Arguably the greatest challenge that the problem of climate impacts to biodiversity poses is its desperate need for solutions, despite the problem's uncertainty and complexity. Policymakers will need to embrace "such a risk, conscious that their work, even if full of uncertainties, could help rulers to reach the right decisions in time to influence the course of events" (Dogan and Pelassy 1990). Thus, the guiding hand of prescriptive research for this problem must be the precautionary principle. The precautionary principle states that prescriptions should be embraced in an effort to avert irreversible environmental harm even in the absence of certainty (Prestre 2002). Established in the 1970s as decision-makers were increasingly faced with problems that were characterized by a lack of scientific certainty (Tickner 2003),[3] the precautionary principle has been embraced in a number of environmental and social contexts, including the UNFCCC's Article 3, which states that "the parties should take precautionary measures to anticipate, prevent or minimize the causes of climate change and mitigate its adverse effects. Where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing such measures…" (United Nations Framework Convention on Climate Change accessed 2005). However, in practice, decision makers have been better at employing the precautionary principle to simple problems than to more complex problems. For example, we build bridges to withstand more stress than would ever likely be applied; yet, with many environmental and social problems, we fail to take the same measures of precaution (Pollack 2003). Yet, there is hope that the precautionary principle can still be used to contend with with the complex problem of climate impacts to biodiversity, as has been illustrated by the embrace of the principle to avert the further manifestation of terrorism (Adger, Paavola et al. 2006).

Prescriptions will require adaptive governance structures that can incorporate new knowledge and respond quickly, given the problem's dynamism and uncertainty. The next sections first define adaptive governance, and then explore both negative and positive prospects for adaptive governance and, lastly, adaptive governance functions and innovative structures that could be embraced to respond to new scientific knowledge.

Defining Adaptive Governance

Before defining adaptive governance, it is necessary to examine the standard definition of governance, which is "the establishment and operation of social institutions (in the sense of the game that serve to define social practices, assign roles and guide interactions among the occupants of these roles) capable of resolving conflicts, facilitating cooperation, or more generally alleviating collective-action problems in a world of independent actors" (Young 1994). Thus, adaptive institutions[4] are key components of adaptive governance.

The problem of climate impacts to biodiversity's complexity and uncertainty place a premium on adaptive institutional arrangements (Gertler and Wolfe 2002), which can make collective choices on behalf of multiple actors (Young 1994) and more readily acquire, synthesize, and disseminate the knowledge needed to adapt. Adaptive institutions will prepare for anticipated and unanticipated consequences, and they will integrate multiple

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[3] An early example of the use of the precautionary principle can be found as far back as 1854 when a physician suggested to decision makers that a central pump be removed during a cholera epidemic. This intervention was suggested based on only observation; no robust scientific findings existed on the disease mechanism (Tickner 2003).

[4] Institutions can be defined as "the formal rules, compliance procedures, and the standard operating practices that structure the relationship between individuals in various units of the polity and economy" (Hall 1986).

interests and knowledge sets (Brunner, Steelman et al. 2005). They can also retain flexible and redundant forms that facilitate adaptation and innovation.

Interestingly, adaptive governance can be conceived of quite similarly to adaptive management, which was coined in the late 1970s to contend with the weaknesses of conventional management tools. Adaptive management was first defined as "flexible, diverse and redundant regulation, monitoring that leads to corrective action and experimental problem of the continually changing reality of the external world" (Holling 1995) (Oglethorpe 2002). Adaptive management overcomes major hurdles of traditional management, as it increases adaptive capacity and incorporates uncertainty and surprises more readily. While adaptive management bolsters the resiliency of the managed subject, adaptive governance will manage the resiliency of institutions.

Negative Prospects for Adaptive Governance

In an effort to understand how institutions can adapt, a useful point of departure is an examination of the negative prospects for adaptation (Sjostrand 1993). Because institutions can be reduced to collectives of individuals, this section begins with an examination of the limits of the individual decision-maker. The section then turns to the limitations of institutions, as well as of change itself.

Limitations of the individual decision-maker

Human behavior is limited by cognitive capacity. First, short-term memory and attention spans are finite, and, as a result, heuristics have been developed that may not cater to adaptability or facilitate the consideration of complex problem attributes (Jones 2001). Pollack illustrates our short-term memory constraints with the following example: A driver is rarely able to detect whether his commute takes longer than it did ten years earlier because the change has been gradual and not noteworthy on a daily basis (Pollack 2003). Thus, he cannot notice incremental change and is unable to process new patterns of information. Pollack cites E.O. Wilson's genetic argument for this phenomenon, which suggests that because early humans were limited to a small geographical range and a select band of people, they did not have any genetic predisposition to process anything "far ahead nor far afield" (Wilson 2002) (Pollack 2003).

Also, as a result of latent reproducing forces such as education and culture, decision-makers have "bounded rationality" for processing new information (Singh 2005). Decision-makers are inclined to neglect or overvalue novel knowledge, which has resultant impacts on institutional capabilities to match operations accordingly. This limitation is especially pronounced when actors value a smaller component of the change and are, thus, able to ignore information pertaining to other aspects of change. Humans also tend to discount the future, and, therefore, information pertaining to future costs and benefits may not be considered in the same manner as those in the near term. In addition, they are rarely able to process all problem dimensions, especially if incoming information is updated since they last accessed the information (Jones 2001). Also, if problems are framed in multiple ways, there is little guarantee that the decision-maker will have the identical preference every time he is presented with the same choice; he will also find it difficult to switch frames of reference to view problems differently. Additionally, adaptive response is slower if the problem is not framed emotionally; yet, emotion can lead to errors in reasoning (Jones 2001).

Limitations of the institution

In addition to individual limitations, there are at least three sets of institutional barriers to adaptation: (1) path dependent effects which reproduce, rather than lead to change; (2) impediments to learning; and (3) mismatching of outcome with intended response.

Path dependent effects which reproduce, rather than lead to change

With regard to path dependent effects, historical problem-solving attempts will have lasting implications for current efforts (Jones 2001). Legacies of older regimes can dictate future outcomes (March and Olsen 1989). For example, in contending with the problem of climate impacts to biodiversity, past patterns of problem governance might have negative path dependent effects on future efforts. Under the Convention on Biological Diversity, the principal multilateral environmental agreement on biodiversity conservation, the problem of biodiversity loss is considered in a much broader mission than species preservation alone. The Convention also governs intellectual property rights, trade, technology derived from biodiversity. Therefore, future policies governing climate impacts to biodiversity may have to acknowledge this broader mandate if it has path dependent effects. In addition, the Convention has been characterized as being ineffective, without binding targets and enforcement and compliance mechanisms, which could have lasting effects on the perception of future conservation efforts. Perhaps most significantly, the Convention is judged to have failed to prioritize science. The Convention's scientific arm, or the Subsidiary Body on Scientific Technical and Technological Advice (SBSTTA), has a wide mission, similar to that of the Convention itself. Controversy surrounding the SBSTTA's appropriate role and mandate has existed since its creation. Currently, it does not collaborate well with other scientific bodies, communicates poorly with the Convention of Parties, and has an immense work load with little prioritization. In addition, it has been ordered to consider financial ramifications of recommendations, potentially at odds with the unbiased nature of the scientific enterprise (Prestre 2002). These attributes may have path dependent effects and hinder future progress, especially efforts that depend on the inclusion of scientific assessments in decision-making. Moreover, there are more than 300 multilateral environmental agreements peppering the biodiversity regime (Prestre 2002), with little coordination, which may have long-lasting implications for future coordination. And with regard to the climate change regime, there is no agreement on the scope of adaptation activities, nor a timetable for implementation; little funding; institutional bottlenecks; and limited capacity to assess vulnerability (Metz and Hulme 2005). Thus, institutional forms may endure long after they surpass their intended mandate for creation (Peters 1999).

Impediments to learning

In addition to path dependent effects, impediments to learning will compromise institutional adaptability. First, information generation has become increasingly decentralized, challenging the institution's ability to gather relevant data and knowledge.

Also, as a result of scant financial and time resources, there is little "slack" for experimenting, analytical thinking, and clear communication. In addition, the organizational culture may inhibit learning. For example, a decision-maker may be afraid of experimentation if he is penalized for his mistakes, or if there is limited tolerance for experimentation during times of political hardship (Ingraham 1994). Unlike for technological innovation, there are no patents or copyrights for institutional innovation, and, thus, there is little incentive to explore (March and Olsen 1995). In addition, there may be a lack of "talk in the hallways," high turnover and little information retention, and outmoded information dissemination technologies (Ingraham 1994) (March and Olsen 1995). Lastly, there are a limited number of items that are typically on an institutional agenda, and, thus, a finite capacity to learn about new issues. As a result, policymaking is "disjointed and episodic" as issues are constantly shuffled around, given the attention deficit (Jones 2001) (Cobb and Elder 1972).

Mismatching of outcome with intended response

Third, if adaptive capacity were to exist, deliberate change may result in unintended outcomes because of lags in matching and/or because of a different equilibrium reached. With regard to lags in matching, adaptation takes time and cannot respond immediately to and coevolve with environmental change (Jones 2001). Jones illustrates this point by citing President Coolidge, who was said to have stated that there are only two sets of problems that institutions confront: "those that solve themselves and those that can't be solved. Public problems are hard problems: by the time government gets around to examining them, the easy solutions have all been used up" (Jones 2001). Second, with regard to a different equilibrium reached, political institutions have multiple possible pathways forward, and path adoption is only in part determined by the variable that was tweaked intentionally (March and Olsen 1995). Thus, change cannot be controlled. March and Olsen argue that "efforts to reform political institutions are often unsuccessful in accomplishing precisely what was intended but that institutional processes make change possible" (March and Olsen 1989). For example, it has been demonstrated that reform cannot be imported readily to novel settings, and, thus, other factors play a role in the intended change. For this reason, many reform packages were rejected in developing countries, as they were not tailored to site-specific needs (Singh 2005). Similarly, Scott discusses reform efforts to enhance society's "legibility" in which states attempted to arrange society much like a beekeeper would arrange his bees in uniform cells. These efforts to perform "large-scale social engineering" lead to failure, including environmental and social degradation (Scott 1998).

Limitations of change itself

In addition to the limited capacity of both individuals and institutions to adapt, there are barriers to institutional change itself. Interestingly, scholarly efforts on institutions have largely focused on explaining the results of institutional change, and little research has been performed on the process of change itself (Steinmo, Thelen et al. 1992). This research deficit is also characteristic of global environmental governance scholarship. Biermann writes, "The conditions for effective global governance of large-scale earth system transformations during the 21st century within a stable and credible global institutional order are less understood" (Biermann 2006).

Tradeoff between efficiency and adaptive capacity

However, a few themes can be distilled from the existing literature. Most significantly, a paradox has emerged: those seeking adaptive governance will presumably want adaptable characteristics to be enduring; however, durability by definition militates against change. The checks and balances, and path dependent effects, typical of institutions present hurdles to rapid adaptive responses. Shepsle, an institutional theorist, introduced the concept of structure induced equilibrium, in which the institutional structure leads to policy stabilization. Because institutions establish transaction costs, such as negotiation costs, enforcement and compliance, institutions are "sticky" and hard to change (Shepsle 1986). For example, nations with parliamentary governments (e.g. Canada) with weaker party separation and stronger party discipline, are able to innovate more readily than separation-of-powers systems (e.g. United States), which have multiple veto points (Weaver and Rockman 1993) (Clemens and Cook 1999).[5] Institutions have been designed to resist change, even when exogenous environmental factors are dynamic, and, thus, change often connotes failure, whereas persistence translates to survivability. Institutional reliability is a key underpinning of democracy, which does not tolerate fleeting change carried out at the whim of a decision-maker (March and Olsen 1995). Therefore, while actors vying for adaptability will want institutions to be flexible, they do not want to create institutions that will succumb to impulsive change (Goodin 1996). March and Olsen illustrate the tradeoff between institutional efficiency and adaptive capacity (March and Olsen 1995):

> Efficiency refers to the short-term improvement, refinement, routinization and elaboration of existing ideas, paradigms, technologies, strategies, and knowledge. It thrives on focused attention, precision, repetition, analysis, sanity, discipline, and control. Adaptiveness refers to the long-term substitution of new ideas, paradigms, technologies, strategies and knowledge for old ones. It thrives on serendipity experimentation, novelty free association, madness, loose discipline and relaxed control. Politics persistently fails to maintain an effective balance between the two.

Indeed, this paradox has been recognized as the fundamental hurdle of adaptive governance and "one of the key challenges for earth system governance" (Biermann 2006).

Tradeoff between paradigmatic change and incremental change

If change were to occur, another significant hurdle is presented by the tradeoff between paradigmatic change and incremental change. Paradigmatic change, while relatively rapid, can retreat like a swinging pendulum to an equilibrium position with no net policy advancement. On the other hand, incremental change, while more resilient to countervailing

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[5] However, independent legislatures and judiciaries can facilitate the exchange of novel information, as they grant access to actors who do not represent the majority party's interests (Vogel 1993).

forces, is marred by a slower rate of change (Cashore and Howlett 2007). Examined collectively, the majority of institutional change has been achieved through incremental processes (North 1993). Incremental change can be long-lasting and act cumulatively to produce substantial directional change. Yet, incremental change can have a sluggish pace, and for this reason, Alston asserts that "we do not know how to create adaptive efficiency in the short run" (Alston, Eggertsson et al. 1996). In addition to the slow nature of incremental tinkering, there is no guarantee that it will produce a change of sufficient magnitude (Peters 1999). With regard to the fewer instances of paradigmatic change, while swift and powerful, it is unclear whether this can be achieved endogenously. For example, under the punctuated equilibrium model, institutions remain independent variables of policy outcomes, maintaining stability, until they become a dependent variable and are themselves changed. Thus, as Weaver points out, "The problem with this model is that institutions explain everything until they explain nothing" (Weaver and Rockman 1993). The question remains whether paradigmatic change can be achieved intentionally. Moreover, if the shock were successful in altering the institution, it might be difficult to control given its transformative nature (March and Olsen 1989).

Positive Prospects for Adaptive Governance

While the above account may be humbling to those seeking adaptive governance, there are a few positive prospects for institutional change. Although the previous section portrays the dangers inherent in change during times of uncertainty, it is also necessary for institutions to conform to their environments so that performance can be improved (Rondinelli and Cheema 2003). Fundamentally, institutions must adapt to change in an effort to reduce errors (March and Olsen 1995). Moreover, there are numerous historical examples of institutional change achieved both incrementally and paradigmatically.

Positive prospects for incremental change

With regard to incremental change, small changes can be made under the "veil of ignorance" under which others do not realize the ramifications of action (Weimer 1995). Scholar Jacob Hacker cites an example with his depiction of the emergence of the US welfare state, which resulted from a build up of tax-law revisions favoring private pensions plans. These small provisions for private welfare went largely undetected, but accumulated and played a significant role in crafting the current welfare state (Hacker 2002).

Positive prospects for paradigmatic change

In addition to incremental change, institutional change can be accomplished by accident via exogenous factors or through intentional intervention endogenously (Goodin 1996). As discussed above, paradigmatic change is commonly catalyzed by an external shock, which can be quite effective in spurring rapid and powerful institutional change. These reshaping events include war, depression, revolution, and collapse (Dryzek 1996). For example, a regime was created in only six months after Chernobyl, and in only two years after the ozone hole was detected (Young 1994). While rarer, paradigmatic change can also be sparked by endogenous factors. New ideas can initiate profound change and transform institutions quickly. And if ideas are mediated by institutional forms that facilitate change, rapid change can transpire. Hall argues that the two-party system and responsive nature of the cabinet in the British government in part enabled Monetarist ideas to swiftly transplant Keynesian paradigms, transforming British economic policy (Hall 1992).

Functions and Structures of Adaptive Governance

Before examining what adaptive governance structures might be constructed, it is important to establish what functions are required to facilitate adaptation so that "form will fit function." Thus, the architectural design of adaptable governance will require a "function-driven approach" (Esty and Ivanova 2002). Three key functions will enhance the adaptability of governance: a learning function; a coordination function; and a capacity building function. Structures that could fulfill these functions follow.

1) Learning Mechanism

Function

Arguably the most critical function of adaptive governance is its capacity to "learn." Learning is now considered a precursor to innovation (Kemp and Weehuizen 2005). In his seminal study of welfare policy, Heclo concluded that the interaction of actors through the exchange of knowledge is a critical, yet previously overlooked, factor in policy change (Heclo 1974). Building upon this finding, several academics have recently embraced "learning" as a dominant causal factor in adaptability (Sabatier 1988; Hall 1989). There are numerous types of learning that exist in the public policymaking process. Jones establishes three overarching categories: a) instrumental learning, which is in regard to the viability of policy instruments; b) social learning, which is instrumental in problem definition and the development of problem-solving fora; and c) political learning, which focuses on political feasibility (Jones 2001). While some types of learning require societal forces unrelated to institutional form (Bennett and Howlett 1992), this section will focus only on institutional learning. Scholarly efforts on the subject suggest that institutional structures and procedures, as well as institutional cultures, can be designed to enhance learning (Busenberg 2001).

Structure

How could institutions be designed to promote learning? Institutions will need to be agile in order to be adaptive (Oglethorpe 2002). Rules will have to include amendment procedures to retain flexibility (Hurrell and Kingsbury 1992). Also, a "learning structure" must exist. First, reflective learning, or the ability to learn from mistakes, will be a critical element (Ingraham 1994). This "learning-by-learning" (Gertler and Wolfe 2002) can be facilitated through continuous monitoring and performance review (Breit, Engels et al. 2003), which can lead to corrective action. Another important characteristic of a learning structure is an institutional culture that encourages experimentation and does not severely penalize failure (Ingraham 1994). In addition, learning will require redundant streams of incoming knowledge (Weimer 1995) (Hage 1988), which can enhance the opportunity to learn and maintain institutional memory.

2) Coordination Mechanism

Function

Adaptive governance will require a "complex interplay of different scales" of knowledge (Breit, Engels et al. 2003), due to the complex nature of the problems that need to be governed adaptively. Specialization, differentiation, and permeability are characteristics that favor innovation, as they provide more room for idea generation (Ingraham 1994). However, because knowledge generation will be decentralized, coordination among actors is a precondition for learning. Coordination may also boost institutional legitimacy, which is essential for the acceptance of novel information and learning (Haas 2000).

Structure

Coordination must be carried out horizontally, across levels of problem management (e.g. to contend with the problem of climate change impacts to biodiversity, the climate regime and biodiversity regime will require issue linkage), as well as vertically, across the decision-making process (e.g. climate impacts to biodiversity will be context-specific and networks of communication among local, national and international levels will be necessary) (Prestre 2002). Also, efforts must transcend institutional boundaries and permeate the entire policy subsystem to increase the odds of a "boomerang effect" for learning among levels (Keck and Sikkink 1998). "Contagion" (March and Olsen 1989) of knowledge from one institution to another, or from one individual to another, can enhance adaptability. For example, Paul Sabatier and Hank Jenkins-Smith have developed the theory of the "advocacy coalition framework" (ACF), arguing that "policy oriented learning" is a key determinant of policy emergence. The ACF contends that coalitions of actors are held together with beliefs, which can be accumulated through policy-oriented learning (Bennett and Howlett 1992). Advocacy coalitions endeavor to transform their beliefs into public policy, which can be achieved through learning within a coalition as well as among coalitions in the larger policy subsystem (Sabatier 1988). Thus, a coordination structure that facilitates the exchange of knowledge in a social and interactive (Gertler and Wolfe 2002) manner will catalyze change. Such meeting fora could take place in the form of international meetings (Haas 2000) or more virtual networks (Esty and Ivanova 2002).

3) Capacity Building Mechanism

Function

The capacity-building function will play two key roles: (1) funding; and (2) generating, collecting and disseminating information.

Funding

With regard to funding, extra resources will need to be stored for future demands and to enhance emergency preparedness (Ingraham 1994). Also, financial assistance can be granted to nation-states to bolster implementation, monitoring, and enforcement capabilities (Haas 2000). In addition, funding can be allocated to research. Because experimentation and competition drive innovation, funding could secure experimental learning through contests and research grants.

Information generation

Adaptive governance requires the generation of information that serves decision-makers' needs. Specifically, science is an industrious generator of knowledge, and scientific knowledge will be relied upon in an adaptive institution (Siebenhuner 2003).

Information collection

Information collection, through the tracking of knowledge generation, can improve institutional memory (March and Olsen 1995). In addition, a collection function can enhance the quality, comparability and benchmarking of data (Esty and Ivanova 2002).

Information dissemination

Information will have to be disseminated, which may be most successful in the form of a scientific assessment (Siebenhuner 2003) (Parson 2003). Parson argues that the ozone regime was not created simply because of novel information, but rather due to the way in which it was disseminated: namely, through an assessment process. He differentiates assessments from other scientific outputs by the following definition: "collective deliberate processes of scientific experts reviewing and evaluating the state of scientific knowledge and synthesizing it with a view of providing information of use to policy makers or decision-makers typically in the form of an official report issued under the authority of some organization" (Parson 2003). Parson has demonstrated that scientific assessments can lead to institutional change rapidly, as the production of a scientific assessment was the most important factor accounting for the ozone regime's emergence after a decade of impasse (Parson 2003).[6]

Structure

Funding

The capacity building structure will collect funding continually, even in the absence of need (Ostrom, Schroeder et al. 1993; Pollack 2003). Funding can be

[6] However, Haas suggests that institutional design, as well as the nature of the problem itself, is a determinant of an assessment's impact. The ozone assessment gained comparatively more traction than climate assessments in part because of organizational flexibility of the regime. Also, problem dimensions of the ozone case are less uncertain, and solutions have fewer economic repercussions (Haas 2000).

allocated to coordination; information generation, collection and dissemination activities; and institutional capacity-building.

Information generation

The information generation structure will have to establish clear parameters for policy-relevant research, including the information's timing, content and presentation form (Dietz, Ostrom et al. 2003). Scientific information that reveals early warnings should be prioritized. Given uncertainty, however, scientific information should present what is known, suspected, and unknown, including certainty and probability of outcomes. Also, future research needs should be outlined (Tickner 2003).

Information collection

New information will have to be gathered. The information collection structure could be modeled after Esty and Ivanova's "environmental information clearinghouse" (Esty and Ivanova 2002), designed as a central repository for information. It should be made public, and research methodologies should be transparent.

Information dissemination

Collections of experts with shared understanding of the problems and solutions, or epistemic communities, have been demonstrated to generate institutional change through the provision of assessments. Haas writes, "The involvement of an epistemic community in a regime is likely to encourage anticipatory action by providing a channel for timely environmental information" (Haas 1997). Thus, the establishment of fora for the gathering of epistemic communities may facilitate information dissemination.[7]

In addition, the information dissemination structure should contain provisions for revision. Parson suggests that the frequent assessment updates of the ozone regime fostered its adaptability (Parson 2003). Also, the information dissemination structure should be lean. Parson contrasts the ozone assessment's success from that of the IPCC's by arguing that the IPCC process is more cumbersome and demanding on scientists. And lastly, the structure should be transparent. While the information dissemination structure should remain policy-relevant, assessment processes should

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[7] A group of conservation advocates and scientists, endorsed by French President Jacques Chirac, hypothesizes that the creation of a scientific body devoted to biodiversity science will bolster the policy response to species degradation. This group has called for the establishment of an organization akin to the IPCC to translate scientific knowledge on biodiversity into the policymaking process. A consultative process exploring this concept of an International Mechanism of Scientific Expertise on Biodiversity (IMoSEB) has recently been launched by former President Chirac (Loreau, Oteng-Yeboah et al. 2006).

be sheltered from political interference – both in the election of scientists to assessment bodies, as well as assessment language.[8]

Conclusion

Despite climate change's dramatic impacts, a number of adaptation strategies can be employed to strengthen the resiliency of biodiversity in a changing climate. However, a coordinated policy response has yet to emerge, and binding targets and timetables are needed to ensure that appropriate strategies are adopted to contend with climate effects. Enhancing the governance of climate impacts to biodiversity will necessitate overcoming hurdles of uncertainty and complexity, such as the presence of "wild cards." Governance of the problem will require adaptive features that can respond to new scientific information, and architects of adaptive governance must design learning, coordinating, and capacity-building structures that will be proactive enough to avert the worst manifestation of climate impacts to biodiversity. The ultimate goal of institutional change will be to facilitate societal value change, making problem-solving intuitive. Solutions to the problem of climate impacts to biodiversity must generate a "logic of appropriateness" that prevails over a "logic of consequences" (March and Olsen 2004) (Peters 1999). For example, just as a soldier will enter a battlefield weighing his obligations to his country over the consequences of his action, putting him at risk, effective governance of climate impacts to biodiversity will require a transition from valuing short-term "consequences" to the "appropriateness" of conserving biodiversity for future generations.

[8] For example, political interference -- such as that characterizing the IPCC's assessment process, which "watered down" the recent Fourth Assessment Report's Summary for Policymakers -- should not be permissible (Eilperin 2007).

Resources

Abramovitz, J. et al. Adaptation to Climate Change: Natural Resource Management and Vulnerability Reduction: Background Paper to the Task Force on Climate Change, Adaptation and Vulnerable Communities. Gland, Stockholm Environment Institute, World Conservation Union IUCN, International Institute for Sustainable Development, and Worldwatch Institute.

Ad Hoc Technical Expert Group (2005). Report on the Meeting of the Ad Hoc Technical Expert Group on Biodiversity and Adaptation to Climate Change. Montreal.

Adger, W. N. (2006). "Vulnerability." Global Environmental Change 16: 268-281.

Adger, W. N., J. Paavola, et al., Eds. (2006). Fairness in Adaptation to Climate Change. Cambridge, The MIT Press.

Alston, L. J., T. Eggertsson, et al., Eds. (1996). Empirical Studies in Institutional Change. Cambridge, Cambridge University Press.

Australian Government Department of the Environment and Heritage (2004). National Biodiversity and Climate Change Action Plan: 2004-2007.

Bennett, C. J. and M. Howlett (1992). "The Lessons of Learning: Reconciling Theories of Policy Learning and Policy Change." Policy Sciences 25(275-294).

Bennett, C. J. and M. Howlett (1992). "The Lessons of Learning: Reconciling Theories of Policy Learning and Policy Change." Policy Sciences 25.

Bernstein, S., R. N. Lebow, et al. (2000). "God Gave Physics the Easy Problems: Adapting Social Science to an Unpredictable World." European Journal of International Relations 6(43).

Betts, R. A. and H. H. Shugart (2005). Dynamic Ecosystem and Earth System Models. Climate Change and Biodiversity. T. E. Lovejoy and L. Hannah. New Haven, Yale University Press.

Biermann, F. (2006). "'Earth System Governance' as a Crosscutting Theme of Global Change Research " Global Environmental Change.

Blanco, A. V. R. (2004). Comprehensive Environmental Projects: Linking Adaptation to Climate Change, Sustainable Land Use, Biodiversity Conservation and Water Management. Amsterdam, Both ENDS.

Botkin, D. B. S., Henrik; Araújo, Miguel B.; Betts, Richard; Bradshaw, Richard H.W.; Cedhagen, Tomas; Chesson, Peter; Dawson, Terry P.; Etterson, Julie R.; Faith, Daniel P.; Ferrier, Simon; Guisan, Antoine; Hansen, Anja Skjoldborg; Hilbert, David W.; Loehle, Craig; Margules, Chris; New, Mark; Sobel, Matthew J.; Stockwell, David R.B. (2007). "Forecasting the Effects of Global Warming on Biodiversity." BioScience 57(3): 227-236.

Breit, H., A. Engels, et al., Eds. (2003). How Institutions Change: Perspectives on Social Learning in Global and Local Environmental Contexts. Opladen, Leske + Budrich.

Brunner, R. D., T. A. Steelman, et al. (2005). Adaptive Governance: Integrating Science, Policy and Decision Making. New York, Columbia University Press.

Busenberg, G. J. (2001). "Learning in Organizations and Public Policy." Journal of Public Policy 21(2): 173-189.

Canadell, J. G., D. E. Paraki, et al., Eds. (2007). Terrestrial Ecosystems in a Changing World. Berlin, Springer Verlin
Cashore, B. and M. Howlett (2007). "Punctuating Which Equilibrium? Understanding Homeostatic Policy Dynamics in Pacific Northwest Forestry " American Journal of Political Science Forthcoming.
Clemens, E. S. and J. M. Cook (1999). "Politics and Institutionalism: Explaining Durability and Change " Annu. Rev. Sociol. 25: 441-66.
Cobb, R. W. and C. D. Elder (1972). Participation in American Politics: The Dynamics of Agenda Building. Boston, Allyn and Bacon, Inc.
Cochrane, M. A., A. Alencar, et al. (1999). "Positive Feedbacks in the Fire Dynamic of Closed Canopy Tropical Forests." Science 284.
Convention on Biological Diversity (2004). Biodiversity and Climate Change, Decision VII/15 biodiversity.
Damschen, E. I., N. M. Haddad, et al. (2006). "Corridors Increase Plant Species Richness at Large Scales." Science 313(5791): 1284-1286.
Dharmaji, B. P., Balakrisha; and Helen Baulch (2003). Mainstreaming Biodiversity and Climate Change. India, IUCN.
Dietz, T., E. Ostrom, et al. (2003). "The Struggle to Govern the Commons." Science 302.
Dogan, M. and D. Pelassy (1990). How to Compare Nations: Strategies in Comparative Politics. Chatham, Chatham House Publishers, Inc.
Dryzek, J. S. (1996). The Informal Logic of Institutional Design. The Theory of Institutional Design. R. E. Goodin. Cambridge" Cambridge University Press.
Eilperin, J. (2007). U.S., China Got Climate Warnings Toned Down. Washington Post. Washington.
Environmental News Service (2006). UNESCO Adopts Climate Change Strategy for World Heritage Sites. Vilnius, Lithuania.
Esty, D. C. and M. H. Ivanova (2002). Revitalizing Global Environmental Governance: A Function-Driven Approach. Global Environmental Governance: Options & Opportunities. D. C. Esty and M. H. Ivanova. New Haven, Yale School of Forestry and Environmental Studies.
Forrest, J. (2003). EarthTrends Featured Topic: Protecting Ecosystems on a Changing Planet. Washington DC, World Resources Institute.
Gertler, M. S. and D. A. Wolfe, Eds. (2002). Innovation and Social Learning: Institutional Adaptation in an Era of Technological Change. International Political Economy Series, Palgrave Macmillan.
Glacier National Park (2004). Glacier National Park Environmental Management Plan.
Global Environment Facility (2005). GEF: Global Action on Climate Change. Washington DC.
Goodin, R. E., Ed. (1996). The Theory of Institutional Design. Cambridge, Cambridge University Press.
Haas, P. M. (1997). Scientific Communities and Multiple Paths to Environmental Management. Saving the Seas: Values, Scientists and International Governance. L. A. Brooks and S. D. VanDeveer. College Park, Maryland Sea Grant College.
Haas, P. M. (2000). "International Institutions and Social Learning in the Management of Global Environmental Risks." Policy Studies Journal 28(3): 558-575.

Hacker, J. S. (2002). The Divided Welfare State: The Battle over Public and Private Social Benefits in the United States. Cambridge, Cambridge University Press.
Hage, J., Ed. (1988). Future of Organizations: Innovating to Adapt Strategy and Human Resources to Rapid Technological Change. Lexington, Lexington Books.
Hall, P. (1986). Governing the Economy: The Politics of State Intervention in Britain and France. Oxford, Oxford University Press.
Hall, P. A., Ed. (1989). The Political Power of Economic Ideas: Keynesianism across Nations. Princeton, Princeton University Press.
Hall, P. A. (1992). The movement from Keynesianism to monetarism: Institutional analysis and British economic policy in the 1970s. Structuring Politics: Historical Institutionalism in Comparative Analysis. S. Steinmo, K. Thelen and F. Longstreth. Cambridge Cambridge University Press.
Hannah, L., T. E. Lovejoy, et al. (2005). Biodiversity and Climate Change in Context. Climate Change and Biodiversity. T. E. Lovejoy and L. Hannah. New Haven, Yale University Press.
Hannah, L., G. Midgley, et al. (2007). "Protected Area Needs in a Changing Climate " Front Ecol Environ 5(3): 131-138.
Hansen et al (2003). Buying Time: A User's Manual for Building Resistance and Resilience to Climate Change in Natural Systems. Berlin, World Wildlife Fund.
Hansen, J. (2005). Is There Still Time to Avoid 'Dangerous Anthropogenic Interference' with Global Climate?: A Tribute to Charles David Keeling. American Geophysical Union, San Francisco.
Heclo, H. (1974). Modern Social Politics in Britain and Sweden. New Haven, Yale University Press.
Holland, M. M., C. M. Bitz, et al. (2006). "Future Abrupt Reductions in the Summer Arctic Sea Ice." Geophysical Research Letters 33.
Holling, C. S. (1995). What Barriers? What Bridges? Chapter 1. Barriers and Bridges to the Renewal of Ecosystems and Institutions. L. H. Gunderson, C. S. Holling and S. S. Light. New York, Columbia Press.
Hopkin, M. (2005). "Amazon Hit by Worst Drought for 40 Years: Warming Atlantic Linked to Both US Hurricanes and Rainforest Drought." Nature News.
Hurrell, A. and B. Kingsbury, Eds. (1992). The International Politics of the Environment: Actors, Interests and Institutions. Oxford, Clarendon Press.
IGES (2005). UNFCCC COP 11 and COP/MOP1 side event: Adaptation to Climate Change: Pathways into the Future Beyond 2012. Institute for Global Environmental Strategies News and Events. Montreal.
Ingraham, R. (1994). New Paradigms for Government. San Francisco, Jossey-Bass, Inc.
Intergovernmental Panel on Climate Change (2001). Third Assessment Report (TAR): Climate Change 2001. Geneva, Intergovernmental Panel on Climate Change.
Intergovernmental Panel on Climate Change (2007). Climate Change 2007: Climate Change Impacts, Adaptation and Vulnerability. Working Group II Contribution to the Intergovernmental Panel on Climate Change Fourth Assessment Report. Geneva, Intergovernmental Panel on Climate Change.
Intergovernmental Panel on Climate Change (2007). Climate Change 2007: The Physical Science Basis: Summary for Policymakers. Contribution of Working Group I to

the Fourth Assessment Report of the Intergovernmental Panel on Climate Change Geneva, Intergovernmental Panel on Climate Change,.

Intergovernmental Panel on Climate Change Working Group I. (2001). Summary for Policymakers: Climate Change 2001: Impacts, Adaptation, and Vulnerability. Geneva, Intergovernmental Panel on Climate Change.

Jones, B. D. (2001). Politics and the Architecture of Choice: Bounded Rationality and Governance. Chicago, The University of Chicago Press.

Keane, R. E., G. J. Cary, et al. (2007). Understanding Global Fire Dynamics by Classifying and Comparing Spatial Models of Vegetation and Fire. Terrestrial Ecosystems in a Changing World. J. G. Canadell, D. E. Paraki and L. F. Pitelka. Berlin, Springer Verlin.

Keck, M. E. and K. Sikkink (1998). Activists Beyond Borders: Advocacy Networks in International Politics. Ithica, Cornell University Press.

Kemp, R. and R. Weehuizen (2005). Policy Learning: What does it mean and how can we study it? Innovation in the Public Sector. Oslo, NIFU STEP.

Lemieux, C. J. and D. J. Scott (2005). "Climate Change, Biodiversity Conservation and Protected Area Planning in Canada " The Canadian Geographer 49(4).

Lovejoy, T. E. and L. Hannah, Eds. (2005). Climate Change and Biodiversity. New Haven, Yale University Press.

March, J. G. and J. P. Olsen (1989). Rediscovering Institutions: The Organizational Basis of Politics. New York, The Free Press.

March, J. G. and J. P. Olsen (1995). Democratic Governance. New York, The Free Press.

March, J. G. and J. P. Olsen (2004). The Logic of Appropriateness. Oslo, University of Oslo Centre for European Studies.

McKibbin, W. a. P. J. W. (2004). Climate Policy and Uncertainty: The Roles of Adaptation versus Mitigation. Brookings Discussion Papers in International Economics. Washington DC, Brookings Institution.

Meehl, G. A. e. a. (2005). "How Much More Global Warming and Sea Level Rise?" Science 307.

Metz, B. and M. Hulme, Eds. (2005). Climate Policy Options Post-2012: European Strategy, Technology and Adaptation after Kyoto. Climate Policy. London, Earthscan.

Midgley, G., W. Thuiller, et al. (2007). Plant Species Migration as a Key Uncertainty in Predicting Future Impacts of Climate Change on Ecosystems: Progress and Challenges. Terrestrial Ecosystems in a Changing World. J. G. Canadell, D. E. Paraki and L. F. Pitelka. Berlin, Springer Verlin.

Ministry of Agriculture and Forestry of Finland (2005). Finland's National Strategy for Adaptation to Climate Change. Vammala, Ministry of Agriculture and Forestry of Finland.

Morgan, M. G. and M. Henrion (1990). Uncertainty: A Guide to Dealing with Uncertainty in Quantitative Risk and Policy Analysis. Cambridge, Cambridge University Press.

NASA. (2005). "NASA Datasets and Images: GISS Surface Temperature Analysis." http://data.giss.nasa.gov/gistemp/, 2005.

National Climatic Data Center (2006). 2006 Annual Climate Review: U.S. Summary. Asheville, U.S. Department of Commerce.

Nesmith, J. (2005). Global Warming Said to Create 'Islands of Extinction'. Cox News Service. Washington DC.
Norby, R. J., L. E. Rustad, et al. (2007). Ecosystem Responses to Warming and Interacting Global Change Factors. Terrestrial Ecosystems in a Changing World. J. G. Canadell, D. E. Paraki and L. F. Pitelka. Berlin, Springer Verlin.
North, D. C. (1993). Institutional Change: A Framework Analysis. Institutional Change: Theory and Empirical Findings. Armonk, M.E. Sharpe.
O'Neill, B. C. and M. Oppenheimer (2007). "Climate Change Impacts are Sensitive to the Concentration Stabilization Path." Proceedings of the National Academy of Sciences.
Oglethorpe, J., Ed. (2002). Adaptive Management: From Theory to Practice. SUI Technical Series Vol. 3. Gland, International Union for Conservation of Nature and Natural Resources.
Ostrom, E., L. Schroeder, et al. (1993). Institutional Incentives and Sustainable Development. Boulder, Westview Press, Inc.
Overpeck, J. T., B. L. Otto-Bliesner, et al. (2006). "Paleoclimatic Evidence for Future Ice-Sheet Instability and Rapid Sea-Level Rise " Science 311.
Parmesan, C. (2005). Biotic Response: Range and Abundance Changes. Climate Change and Biodiversity. T. E. Lovejoy and L. Hannah. New Haven, Yale University Press.
Parson, E. A. (2003). Protecting the Ozone Layer: Science and Strategy. New York Oxford University Press.
Peters, B. G. (1999). Institutional Theory in Political Science: The New Institutionalism. London, Pinter.
Peters, D., R. P. Sr., et al. (2007). Spatial Nonlinearities: Cascading Effects in the Earth System. Terrestrial Ecosystems in a Changing World. J. G. Canadell, D. E. Paraki and L. F. Pitelka. Berlin, Springer Verlin.
Peterson, A. T., H. Tian, et al. (2005). Modeling Distributional Shifts of Individual Species and Biomes. Climate Change and Biodiversity. T. E. Lovejoy and L. Hannah. New Haven, Yale University Press.
Pollack, H. N. (2003). Uncertain Science...Uncertain World. Cambridge, Cambridge University Press.
Prestre, P. G. L., Ed. (2002). Governing Global Biodiversity: The Evolution and Implementation of the Convention on Biological Diversity. Aldershot, Ashgate Publishing Company.
Prime Minister's Office. (2004). "Prime Minister Speech on Climate Change."
Procheş, Ş., J. R. U. Wilson, et al. (2005). "Landscape Corridors: Possible Dangers?" Science 310(5749).
Rittel, H. W. J. and M. M. Webber (1973). "Dilemmas in a General Theory of Planning." Policy Sciences 4.
Rondinelli, D. A. and G. S. Cheema, Eds. (2003). Reinventing Government for the Twenty-First Century: State Capacity in a Globalizing Society. Bloomfield, Kumarian Press, Inc.
Root, T. L. and L. Hughes (2005). Phenological Changes in Plans and Animals. Climate Change and Biodiversity. T. E. Lovejoy and L. Hannah. New Haven, Yale University Press.

Sabatier, P. (1988). "An Advocacy Coalition Framework of Policy Change and the Role of Policy-Oriented Learning Therein." Policy Sciences 21.

Sarup, P. S., JG; Dimitrov, K; Barker, JSF; and V. Loeschcke (2006). "Climatic Adaptation of Drosophila buzzatii Populations in Southeast Australia " Heredity 96(6).

Scott, D. (2003). Climate Change and Canada's National Parks. Ontario, Environment Canada.

Scott, J. C. (1998). Seeing Like a State: How Certain Schemes to Improve the Human Condition Have Failed. New Haven, Yale University.

Secretariat of the Convention on Biological Diversity (2003). Convention on Biological Diversity: Text and Annexes, Secretariat of the Convention on Biological Diversity.

Shepsle, K. A., Ed. (1986). Institutional Equilibria and Equilibrium Institutions. Political Science: The Science of Politics.

Siebenhuner, B. (2003). Social Learning at the Science-Policy Interface: A Comparison of the IPCC and the Scientific Assessments under the LRTAP Convention. How Institutions Change: Perspectives on Social Learning in Global and Local Environmental Contexts. H. Breit, A. Engels, T. Moss and M. Troja. Opladen, Leske + Budrich.

Siegenthaler, U. et al. (2005). "Stable Carbon Cycle-Climate Relationship During the Late Pleistocene." Science 310.

Singh, A., Ed. (2005). Administrative Reforms: Towards Sustainable Practices. New Delhi, Sage Publications.

Sjostrand, S.-E., Ed. (1993). Institutional Change: Theory and Empirical Findings. Armonk, M.E. Sharpe.

Spahni, R. e. a. (2005). "Atmospheric Methane and Nitrous Oxide of the Late Pleistocene from Antarctic Ice Cores." Science 310.

Steinmo, S., K. Thelen, et al., Eds. (1992). Structuring Politics: Historical Institutionalism in Comparative Analysis. Cambridge, Cambridge University Press.

Subsidiary Body for Scientific and Technological Advice: UNFCCC (2004). Application of Methods and Tools for Assessing Impacts and Vulnerability, and Developing Adaptation Responses. Background Paper. FCCC/SBSTA/2004/INF.13.

The Ramsar Convention on Wetlands (2002). Resolution VIII.3 on Climate change and wetlands. 8th Meeting of the Conference of the Contracting Parties, Valencia, Spain.

Tickner, J. A., Ed. (2003). Precaution, Environmental Science, and Preventative Public Policy. Washington, Island Press.

Tickner, J. A., Ed. (2003). Precaution: Environmental Science and Preventive Public Policy. Washington, Island Press.

United Nations Development Program and Global Environment Facility. (2006). "Programming Climate Change Adaptation: Availability of Funds " Retrieved March 16, 2007.

United Nations Development Program and Global Environment Facility. (2006). "Programming Climate Change Adaptation: UNDP's Adaptation Portfolio." Retrieved March 16, 2007.

United Nations Framework Convention on Climate Change "United Nations Framework Convention on Climate Change website." http://unfccc.int/2860.php, 2005.

US Climate Change Science Program. (2006). "Preliminary review of adaptation options for climate-sensitive ecosystems and resources at http://www.climatescience.gov/Library/sap/sap4-4/sap4-4prospectus-final.htm." 2007.

Vila, M., J. D. Corbin, et al. (2007). Linking Plant Invasions to Global Environmental Change. Terrestrial Ecosystems in a Changing World. J. G. Canadell, D. E. Paraki and L. F. Pitelka. Berlin, Springer Verlin.

Vogel, D. (1993). Representing Diffuse Interests: Environmental Policy. Do Institutions Matter: Government Capabilities in the United States and Abroad. R. K. Weaver and B. A. Rockman. Washington, D.C. , The Brookings Institution.

Walker, G. (2007). "Climate Change 2007: A World Melting from the Top Down." Nature News Feature.

Weaver, R. K. and B. A. Rockman, Eds. (1993). Do Institutions Matter: Government Capabilities in the United States and Abroad. Washington, D.C. , The Brookings Institution.

Weimer, D. L., Ed. (1995). Institutional Design. Recent Economic Thought. Boston, Kluwer Academic Publishers.

Wetlands, T. R. C. o. (2007). Report of the Chair of the Scientific and Technical Review Panel. 35th Meeting of the Ramsar Standing Committee, Gland, Switzerland.

Wigley, T. M. L. (2005). "The Climate Change Commitment." Science 308.

Williams, J. W., S. T. Jackson, et al. (2007). "Projected Distributions of Novel and Disappearing Climates by 2100 AD." Proceedings of the National Academy of Sciences 104(14).

Wilson, E. O. (2002). The Future of Life. New York, Alfred A. Knopf.

Wood, S. (2007). Australia plans massive conservation corridor. Cosmos Online. Sydney.

World Conservation Union, W. W. F., English Nature, Royal Society for the Protection of Birds (2005). Climate Change and Nature: Adapting for the Future. Gland.

World Resources Institute (2005). Ecosystems and Human Well-Being: Biodiversity Synthesis. Millennium Ecosystem Assessment. Washington DC.

Young, O. R. (1994). International Governance: Protecting the Environment in a Stateless Society. Ithaca, Cornell University Press.