Reducing the Impact of Global Warming on Wildlife:

The Science, Management and Policy Challenges Ahead

DEFENDERS OF WILDLIFE

Defenders of Wildlife is a national, nonprofit membership organization dedicated to the protection of all native wild plants and animals in their natural communities.

ACKNOWLEDGEMENTS

This report is a synthesis of *Innovations in Wildlife Conservation: Reducing the Impact of Global Warming on Wildlife,* a national symposium hosted by Defenders of Wildlife in Washington, D.C., on September 27, 2007. Support for the symposium was provided by the Wilburforce Foundation and Dr. Benjamin C. Hammett. The complete proceedings of the symposium are available at **www.defenders.org/symposium2007**.

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Preferred citation: Brennan, E.J. (2008) *Reducing the Impact of Global Warming on Wildlife: The Science, Management and Policy Challenges Ahead.* Defenders of Wildlife. Washington, D.C.

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1. Introduction

Human-induced global warming is emerging as the greatest threat facing the planet today. Wildlife is especially vulnerable. Negative impacts of climate change are already evident, including loss of critical habitat in the polar and high mountain ecosystems; damage to oceans, coastlines and coral reefs due to sea level rise and increased storm activity; and more frequent and intense periods of drought.

Although the science of climate change investigation began in the 1950s, the most recent work of the Intergovernmental Panel on Climate Change (IPCC), the United Nations advisory body composed of scientists and climate change experts from around the world, provided the scientific framework to systematically review and evaluate the latest studies on global warming.

Based on decades of investigation involving direct Earth observations and measurements, climate modeling and impact documentation, the now broad scientific consensus is that climate change due to global warming is occurring. Moreover, according to Susan Solomon, senior U.S. government scientist and co-author of the most recent IPCC report, "there can be no question that the increases in greenhouse gases are dominated by human activities." Global warming is affecting every part of the globe and will continue to do so well into this century and possibly beyond. To address the threat of global warming effectively, we must act now to reduce the primary cause of human-induced global warming: the greenhouse gases emitted when we burn fossil fuels.

However, even with immediate action, it will still be too late to prevent the extinction of some species, and others will edge closer to extinction as the Earth continues to warm. Until the greenhouse gases already accumulated in the atmosphere break down and the climate system achieves a new equilibrium, global warming will continue to alter climate patterns around the globe and threaten the natural world for decades, if not centuries.

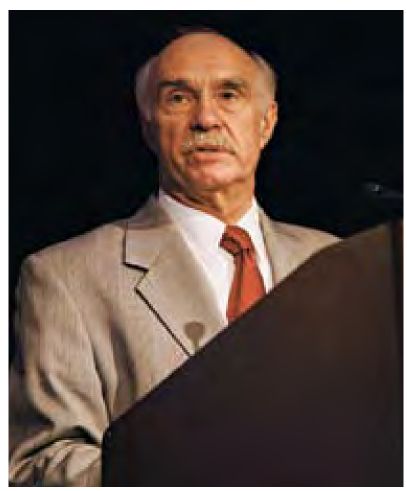
Fortunately, we can take many actions to help wildlife survive until we make progress in reducing greenhouse gas emissions. The timescale and order of magnitude for the loss of our biological diversity depend on if—and when—we take these actions. By taking careful steps now, we can avoid the most dramatic losses.

To identify these steps, Defenders of Wildlife hosted *Innovations in Wildlife Conservation: Reducing the Impact of Global Warming on America's Wildlife,* a national symposium (Appendix A). The September 2007 symposium brought together three panels of experts from the scientific, wildlife management and policy communities (Appendix B) to identify what we can do to enhance the ability of wildlife to survive this century.

Scientists presented the latest scientific findings and outlined the challenges related to the impacts of global warming. Wildlife managers identified actions that can assist wildlife and ecosystems to better adapt to climate change. Policy analysts considered the existing policy framework and discussed what might be necessary to implement adaptation strategies and to address the impacts of global warming. This report is a synthesis of the symposium, summarizing the panel presentations, discussions and key recommendations that emerged.

"We hope that the results of this symposium will help all of us begin to understand the kind of new and more dynamic conservation strategies that are necessary if we are to help as many species as possible survive the climate changes that lie ahead."

–Rodger Schlickeisen, President and CEO, Defenders of Wildlife



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2. Scope of the Challenge

The challenges associated with climate change due to global warming are negatively affecting both the physical and biological elements of nature. The impacts of sea-level rise associated with climate change alone present not only an ecological challenge, but also a social, economic and cultural threat exceeding anything mankind has ever faced. These physical changes and other observed impacts are discussed in this section.

"There is nothing more sensitive to the impacts of climate change than the natural world."

—Tom Lovejoy, The Heinz Center

PHYSICAL CHANGES

The Earth's climate system is extremely responsive to changes in temperature. As a result, global warming is affecting climate patterns and has already changed the physical world. For example, as a result of rising temperatures, lakes are freezing later, spring ice is breaking up earlier, glaciers are retreating and the Arctic ice cap is melting.

The polar region has seen the greatest rise in temperature and is already suffering the most extreme climate impacts. In recent years, the Arctic has experienced a dramatic decline of sea ice, especially during summer. The increased flow of fresh water into the oceans via surface runoff from melting snow and ice has caused sea levels to rise globally, although at different rates geographically. The greatest rise is on the Atlantic and Gulf coasts of North America. Rising sea levels and increasing storm and wave intensity are claiming coastal and salt marsh habitats. Salt marsh habitats along shorelines in the temperate zone are increasingly inundated. As a result, the ability of many areas to function and sustain critical ecosystem services is compromised.

Other changes in the physical world not directly attributed to global warming, but correlated with temperature increases and decreased precipitation, are the increased incidence and intensity of storms and wildfires. In the western United States, for example, the incidence and intensity of wildfires are increasing following longer, hotter and drier summers and earlier snowmelt. The frequency and intensity of hurricanes are also showing strong correlation to increased land and sea surface temperatures.

ARCTIC AND BOREAL IMPACTS

Alaska clearly represents "ground zero" for global warming in North America, according to Glenn Juday of the University of Alaska and Deborah Williams of Alaska Conservation Solutions. Loss of sea ice is particularly evident, threatening the polar bear (*Ursus maritimus*) and other ice-dependent species. Ice-dependent species lose both the quality and quantity of physical sea-ice habitat. They can also lose access to their prey. For example, polar bears rely on the ice platform to hunt ringed and bearded seals (*Phocidae*). Seals frequent the thin edges and openings in the ice—breathing holes—where polar bears lie in wait. Now, however, due to the rise in surface and sea temperatures, less ice is forming, making it more difficult for bears to hunt and requiring them to expend more energy to swim between widely separated ice packs in search of prey. It is also increasingly difficult for female polar bears to acquire food and to successfully reproduce and rear their young.

Loss of sea ice also affects prey species. For seals, sea ice interacts with oceanography to enhance prey production in cold marine environments. As sea ice declines, so do the numbers within fish populations that sustain these seal populations. Seals either move farther out to sea or decline in numbers. These impacts of global warming are causing a cascading collapse of this Arctic system.

"I wanted to bring Alaska prominently to the global warming discussions to help convince America. We see it first. We see it most intensely. The crisis is now."

—Deborah Williams
Alaska Conservation Solutions

Terrestrial ecosystems in the Arctic are also showing impacts from global warming. Alaska is a world centerpiece for boreal species and genetic diversity. Climate changes evident in the state due to global warming are unprecedented in recent history. "The biggest change in the boreal region of the last several thousand years is underway now," said Glenn Juday. Tree growth on boreal forest sites is decreasing and, as temperatures continue to warm, is nearing absolute lethal limits. Fire and insect outbreaks have reached record-high levels with massive tree die-offs across thousands of acres. Because of warming, tundra is now flush with more combustible vegetation and tundra habitats are, in fact, burning.

By all indications, these changes to the boreal forest will not only continue but also intensify. As warming continues, biomes in much of boreal Alaska and northwest Canada are highly likely to shift within a decade. The ranges of boreal species and resources are likely to be either significantly reduced in abundance or eliminated altogether. Boreal forests are one system with potential to "flip"—to change completely in character and function. The western North American boreal region, for example, could change from a spruce/moose/beaver ecosystem to a grassland/bison/elk ecosystem. There is no known compensation mechanism to alter completely this trajectory of loss and change.

> "[Boreal] species will probably persist somewhere. Except it will be an unstable transition as species' migrations from current to new locations will be slow and risky if unaided."
>
> *–Glenn Juday, University of Alaska*

Lemon damselfish swim amid bleached coral–the skeleton that remains after the algae that live within coral tissues and give it color move out in response to sustained higher ocean temperatures.

MARINE AND COASTAL IMPACTS

In his global survey of climate impacts on marine and coastal ecosystems, Charles "Pete" Peterson of the University of North Carolina noted that global warming will negatively impact everything from the smallest plankton species that sustain the Arctic food web to the delicate, symbiotic algae that nourish tropical corals. It will also cause fundamental changes within the broader marine environment.

Plankton species have an upper temperature tolerance limit. As sea surface temperatures increase, the limits of their southern ranges in the Northern Hemisphere are moving progressively northward year after year. These changes in distribution are also evident in the fish and marine mammal species that feed on phytoplankton and zooplankton. Increased ocean temperatures are further threatening marine communities as novel conditions enhance the incidence and spread of disease.

Warm tropical ocean regions of the world are not immune to climate change impacts. If Alaska and the Arctic are "ground zero" in terrestrial ecosystems, then coral reefs are the "frontlines" of the global warming battle in the marine environment. This is evident most profoundly in what are widely known as coral reef "bleaching events." Bleaching occurs when the algae, which coexist within the coral and help to build its skeletal structure, move out of the coral as ocean temperatures rise above a threshold. The white coral skeleton remains, giving the reefs a bleached appearance due to the loss of the bright-hued algae that once colored it. If ocean temperatures remain high for too long, the algal colony does not return and the coral dies. Coral death can precipitate the collapse of the commensal marine community composed of myriad fish and marine invertebrates.

Bleaching events have now become an annual occurrence in many parts of the world. Current estimates in the Indo-Pacific ocean region indicate a loss of more than half the coral cover in the last 30 to 40 years.

A most disturbing result of recent studies is the realization that increases in atmospheric carbon dioxide (CO_2) levels change the ocean chemistry and threaten the entire marine food chain. As part of the Earth's natural carbon balance, oceans absorb atmospheric CO_2. The excess CO_2 in the atmosphere is now being absorbed in the ocean, increasing pH levels, a process now referred to as "ocean acidification." These more acidic conditions reduce the availability of calcium carbonate, a critical compound many organisms at the base of the food chain need to build their cell coverings or outer skeletal structure. As a result of ocean acidification, entire marine invertebrate communities could literally dissolve.

> "The public, and even a lot of scientists, talk about global change as a future threat. I'm here to tell you…it is happening today."
>
> *–Charles 'Pete' Peterson*
> *University of North Carolina*

TROPICAL AND TEMPERATE IMPACTS

Tom Lovejoy of The Heinz Center considered the response of terrestrial species to climate changes in both temperate and tropical ecosystems. It is not surprising that tropical mountain glaciers are melting, but what has surprised scientists is that climate change impacts are observed even in tropical forests.

A critical climatic factor in the tropics is not so much rising temperature, but rather loss of moisture. The Monteverde cloud forest in Costa Rica is perhaps the most well-documented site to report correlated negative climate impacts. It is also perhaps the first known location to record the extinction of a species, the golden toad (*Bufo periglenes*), as a possible result of climate change brought about by global warming. Another example is the decline of the quetzal (*Pharomachrus mocinno)*, the ornate bird found only in the mountain highlands of Central America. Until recently, this area was only hospitable to quetzals. Now, with temperatures warming, toucans (*Ramphastidae*) are expanding their range upward to elevations where they threaten to out-compete the quetzal. Fire ants, insects previously not seen in these cooler mountain regions, have also moved higher, challenging the reproductive success of the quetzal with swarms that prey on nestlings.

Terry Root from Stanford University reviewed impacts in temperate regions. Numerous studies have documented various changes such as altered flowering phenology in plants and changes in the timing of breeding, nesting and migration for many animals. Such changes can have profound impacts on the population numbers and demographics of species that have evolved together over time. These biotic communities are now vulnerable to falling out of synchrony as species may respond differently to changed environmental cues.

For example, plants that time flowering, pollination and seed production events to climatic factors may now respond more quickly than the bird populations that rely on these plant resources to rear their offspring. Animals may respond more to day length or light intensity cues that are not being influenced by global warming. Animal migrations and breeding may thus fall out of synch with the plant resources required to feed and rear offspring.

Cases of wildlife populations in decline due to global warming are not isolated; they are occurring in areas around the world. Although the impacts are varied, changes in the timing of events or behavioral changes in response to climate changes are well-documented, and the data are statistically robust.

U.S. FISH AND WILDLIFE SERVICE

Once abundant in Costa Rica's Monteverde cloud forest, the golden toad is now extinct, and global warming's impact on the formation of clouds and mist crucial to the ecology of the area is believed to be the major factor.

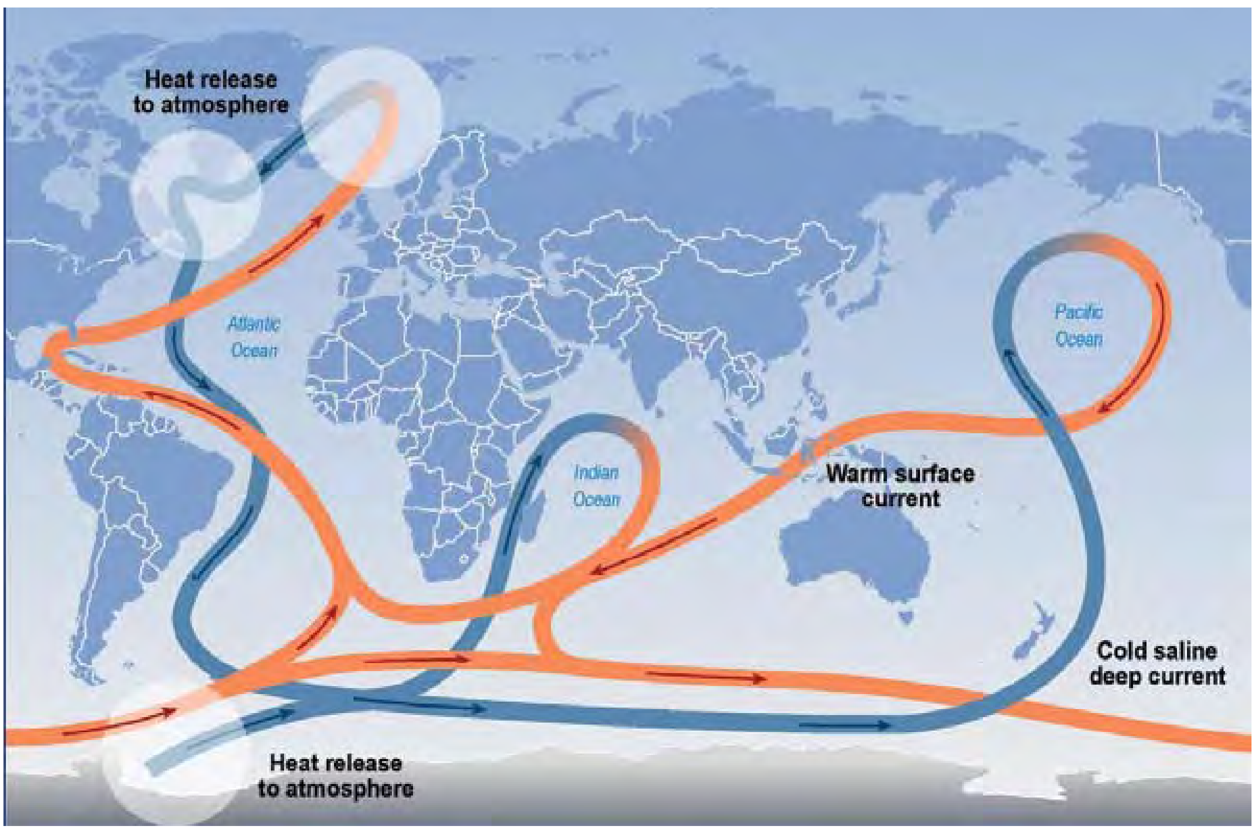
3. Serious Complications

Any efforts to refine and use our predictions to help mitigate impacts or to assist species in adapting to climate changes face serious complications due to physical and biological aspects of the environment and interactions among organisms. Several of these challenges are described in this section.

THRESHOLD EFFECT

The fact that not all change related to global warming will be gradual or linear is especially worrisome. There will be threshold changes and abrupt climate shifts. Such changes have already been recorded in the climate system itself. One example is the ocean currents of the so-called "global conveyor belt," the large-scale movements of ocean water in response to temperature and density (Figure 1). Cold and/or more saline water is dense and sinks below warmer and less salty waters that originate from freshwater runoff or melting sea ice. This cold water continues to sink farther in the depths of the ocean

Figure 1: Great ocean conveyor belt



The global circulation system in the world's oceans consists of major north-south circulation routes in each ocean basin joining in the Antarctic circumpolar circulation. Warm surface currents and cold deep currents are connected in the few areas of deepwater formation in the high latitudes of the Atlantic and around Antarctica (blue), where the major ocean-to-atmosphere heat transfer occurs (transparent white circles). This current system contributes substantially to the transport and redistribution of heat. Global warming could disrupt it, which would have a strong impact on regional-to-hemispheric climate. (Source: IPCC) until it reaches equilibrium and moves horizontally, producing ocean movement. Warmer water does not sink as readily. Increased sea surface temperature caused by fresh water runoff further reduces salinity, thus retarding this ocean movement and global circulation.

With their ability to capture and transfer heat, the world's oceans greatly influence our climate today. Deep circulation patterns in the ocean due to variation in water density influence climate because oceans also transport heat. Over geological time, ocean movements have shut down when certain temperature thresholds were reached. Lack of ocean circulation is not only an example of a threshold effect, it is also an illustration of an additional risk of climate change, namely negative feedbacks within the climate system. A breakdown in ocean circulation will accelerate warming impacts due to the heat-trapping and transporting properties of the ocean.

The ability of marine organisms to sustain life in our oceans is another marine system with a climate-vulnerable threshold. Increasing pH levels linked to excessive CO_2 in the atmosphere threaten the productivity of our oceans.

Threshold changes are also becoming evident in the biological elements of terrestrial ecosystems. These changes can be among the most difficult to fully understand, model and predict. Researcher Glenn Juday cited the example of the devastating losses caused by pine bark beetles in the forests of the Northwest, southern Alaska and British Columbia. This native beetle, which resided in forest ecosystems at manageable levels until recently, bores through bark to feed and breed in the phloem, the thin layer of plant tissue beneath the bark, thereby killing the trees. Longer, warmer and dryer seasons in the Arctic have tipped the balance to allow the beetle to produce one more generation per season. The result is a population explosion of this tree pest, resulting in numbers beyond what the forest system can sustain.

Warmer temperatures allow beetle numbers to exceed a threshold level that had previously kept tree losses within sustainable limits. Without cool temperatures and wet summers to reduce beetle populations, these insects will continue to multiply and swarm across the boreal forests of Alaska and the Yukon Territory, producing a landscape covered with dead or dying trees. The beetles literally eat themselves out of house and home and respond by moving yet farther across the landscape. The scale of this infestation is exceeding the limits of human intervention.

Other terrestrial systems with climate-vulnerable thresholds include the tropical forests of the Amazon basin and the permafrost of the Arctic tundra**.** Water availability in much of South America strongly depends on the Amazon basin. The area functions as a giant rain machine concentrating the intense local humidity created by the moisture of heavy tropical rainfall, constant cloud cover and transpiration or water loss through the leaves of dense tropical forest vegetation. A threshold may be exceeded if deforestation in the area is excessive and this rain machine ceases to function. On the Arctic tundra, another region approaching a dangerous threshold change, previously "permanently" frozen Arctic substrate is starting to thaw, releasing large quantities of methane, a more potent greenhouse gas than CO_2, and further accelerating global warming. This release of additional greenhouse gases is another example of a negative feedback loop created when a threshold is exceeded.


White spruce forest before and after infestation with pine bark beetles. These beetles are surviving in greater numbers thanks to warming trends and have claimed nearly 4 million acres of mature white spruce forest on Alaska's Kenai Peninsula.

ENVIRONMENTAL OBSTACLE COURSE

One factor that can be better modeled and predicted is the shift in species' ranges due to climatic change. Unfortunately, human-altered land uses such as agriculture, cities, suburbs, roads and other development now dominate the American landscape. As Lovejoy noted, "When species attempt to track their required climate conditions…they will be facing an obstacle course." Most species within protected areas are isolated with limited connectivity between natural sites. This is a serious constraint to their ability to shift their ranges outside of currently protected areas in response to climate change. Many wild species that exist outside of these protected areas may be forced into them as their habitat is lost with further human expansion and land conversion across the landscape. Protected areas and other conservation lands will become refugia for species on the move or will serve as potential sources of individuals to colonize new sites under changing climatic conditions. The reduction of natural habitat, increased isolation of populations and potential disruption of resident populations by migrating individuals adding to the density may threaten population viability in protected areas. Effects on species' population biology and genetics will have the most profound long-term impacts.

U.S. FISH AND WILDLIFE SERVICE

There is no escaping the urbanization that surrounds south Philadelphia's John Heinz National Wildlife Refuge (outlined in yellow), the largest remaining freshwater tidal wetland in Pennsylvania.

If a significant proportion of the breeding population is lost or unable to reproduce successfully, the ultimate result can be a serious loss of genetic diversity. Such losses can stem from unsustainable hunting or harvesting, increased competition, reduced access to resources or critical habitat, or competitive disruption of social organization or reproduction. All of these factors may come into play as species move in response to climate changes from global warming. Such "bottleneck" events, so-called because they constrict population size or genetic characteristics, will become increasingly prevalent. Populations will become more isolated due to global warming as critical habitat and connectivity between areas shrink and the extent of natural areas declines across the landscape. A great challenge for wildlife and resource managers will be to help species "navigate" such bottlenecks. Maintaining connectivity between natural areas and establishing travel corridors are also major components of meeting this challenge. In rare cases, moving animals to new locations may have to be considered if a population is otherwise unable to move or adapt to the changing conditions. Effects of prolonged periods of isolation or drastic reductions in population numbers and genetic diversity tend to increase the incidence of inbreeding, thereby reducing a species' resilience as measured by the population's ability to adapt to environmental variability.

Another serious complication not yet fully appreciated by the general public is the relevant timescale involved in species' ability to adapt and respond to change. Global warming contrarians may point to the Earth's history to argue that species are able to evolve and adapt to changes in climate. However, current rates of change far exceed earlier evolutionary timescales, therefore negating this simplistic argument for downplaying the significance of global warming and the need for humans to reduce greenhouse gas emissions. In the past, climate changed as much as 1 degree Centigrade (°C) per 1,000 years. Now, however, species are facing changes of 1°C per century and are unlikely to genetically and physiologically adapt to this rate of change. Current climate and environmental changes are too rapid for species to adapt solely through evolutionary processes such as the

"With only genetic mutations and selections to adapt, species are going to face challenges that they simply cannot manage on their own."

–Barry Noon, Colorado State University

accumulation of genetic change in a population. We have entered a new chapter in the Earth's history, one often referred to as the sixth extinction event. Unlike previous events, this one features human beings as the dominant force in species evolution or extinction.

NOWHERE TO GO

In response to changing temperature, precipitation or moisture regimes, cold-adapted species of North America will migrate poleward in latitude or upward in elevation to stay within their zone of physiological tolerance. As species continue to move in response to global warming, eventually they may run out of habitat altogether. Some species will simply have nowhere else to go. This scenario is already unfolding in Arctic and high-elevation species and more cases are anticipated. The decline of the polar bear due to loss of summer sea ice is perhaps the best-known example. Another is the plight of the pika (*Ochotona princes*), a small mammal also called "rock rabbit."

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The pika is a mountain-dwelling species being pushed to higher elevations by a changing climate.

Pikas live on talus slopes—rugged, steep, rocky areas between timberline and subalpine vegetation zones. The talus slopes provide critical burrowing sites and the plants that pikas collect and store in "haystacks" to meet their nutritional needs through the winter. Human activities and climate change have pushed the pika to higher elevations, beyond areas that offer the ideal type of rock formations and plant food. Consequently, the pika is one of the mountaintop species most vulnerable to climate change in the continental United States. As pika populations become increasingly isolated and their critical habitat is lost over time, groups or populations may remain, but the loss of genetic diversity due to prolonged periods of isolation may leave them functionally extinct.

Another impact of climate change that can leave species with nowhere to move is rising sea levels. One such species is the key deer (*Odocoileus virginianus clavium*), an animal that exists only on low-lying islands in the Florida Keys. As the island land mass is submerged by rising seas, the key deer population will have to swim to find new habitat in the nearby Everglades or be transported there by humans.

CHANGES IN COMMUNITY STRUCTURE

Biological communities in ecosystems are made up of assemblages of various species. Each species responds independently to climate change and moves in its own direction and at its own pace. Thus it is difficult—if not impossible at this time—to predict how the entire biological community or ecosystem will be affected.

"We are having surprises. And that is basically what I'm concerned about.... with global warming we are pushing communities in ways that we are not sure how they are going to react."

–Terry Root, Stanford University

Root expressed particular concern that global warming is tearing apart plant and animal communities as we know them. It is likely that ecosystems and biological communities will literally disassemble, and species will reassemble into novel combinations not previously seen. Impacts on key biotic interactions such as competition, predator-prey interactions and obligate pollinators are difficult to foresee. Range shifts, timing of phenological events and synergistic effects are observed when climate-induced changes decouple these important biotic interactions. Extinctions are already being reported. Synergistic relationships, such as the bay checkerspot butterfly (*Euphydryas editha bayensis*) and the obligate plant species associated with it, are harder to study and model, making it difficult to predict precisely what will happen to them.

The bay checkerspot's life cycle relies on a few different host plants. Females lay eggs on native dwarf plantain (*Plantago erecta*). The hatching larvae feed on this host plant until it dries up in the summer heat, and the larvae enter a period of dormancy. One season is not enough for the species to complete its development, so the caterpillar larvae must emerge from dormancy the following winter when the rains stimulate plant growth. The larvae may require a second host plant of clover (*Castilleja densiflora* or *C. exserta*) before they emerge to feed and pupate in late winter and emerge as adults shortly thereafter.

Urban expansion and land development across the San Francisco Bay area has reduced native plants and fragmented checkerspot populations. Development impacts in combination with plant responses to climate changes threaten the species with extinction. Elevated California mean temperature and greater variability in rainfall will shift growing seasons of the plants on which the caterpillars depend.

Root stressed the difficulty in predicting such synergistic effects and how these interactions may vary in response to climate changes. However, increasing numbers of cases show how climate changes can alter species interactions, which in turn may alter community structure, leading in some cases to population or species extinction.

BIOTIC INTERACTIONS

The Hawaiian honeycreeper (*Fringillidae*) also exemplifies how a species may be severely impacted by climate change because of its intricate biotic interactions. Honeycreepers were once abundant along the entire altitudinal gradient of the forests on the Hawaiian Islands. More than half the species in this bird family are already extinct due to recently introduced threats such as predation, competition and degradation of habitat. The surviving species have been restricted to high-elevation forests by the introduction of avian malaria, a disease transmitted by mosquitoes that until recently occurred only at lower, warmer elevations. As temperatures continue to rise with global warming, the vegetation and the distribution of the mosquito vectors will move to higher elevations and infect more native birds.

Unlike mainland birds, native honeycreepers on Hawaii have not co-evolved with avian malaria and thus have not developed any resistance to it. As a result, they are highly susceptible to this often-fatal disease brought to the islands by birds from the mainland that were introduced by humans. Avian malaria is now transmitted to susceptible native birds by mosquitoes that have bitten introduced birds that are asymptomatic carriers of the disease. As average temperatures increase the "mosquito line" is moving up in elevation and transmitting avian malaria to honeycreepers. Ultimately, these birds will have nowhere to go, and this biotic interaction may drive the last of the wild Hawaiian honeycreepers to extinction.

Global warming threatens the key deer (left) with rising sea levels that could submerge its habitat in the Florida Keys, and the bay checkerspot butterfly (right) with population fragmentation caused by the disappearance of plants it needs to complete its lifecycle.

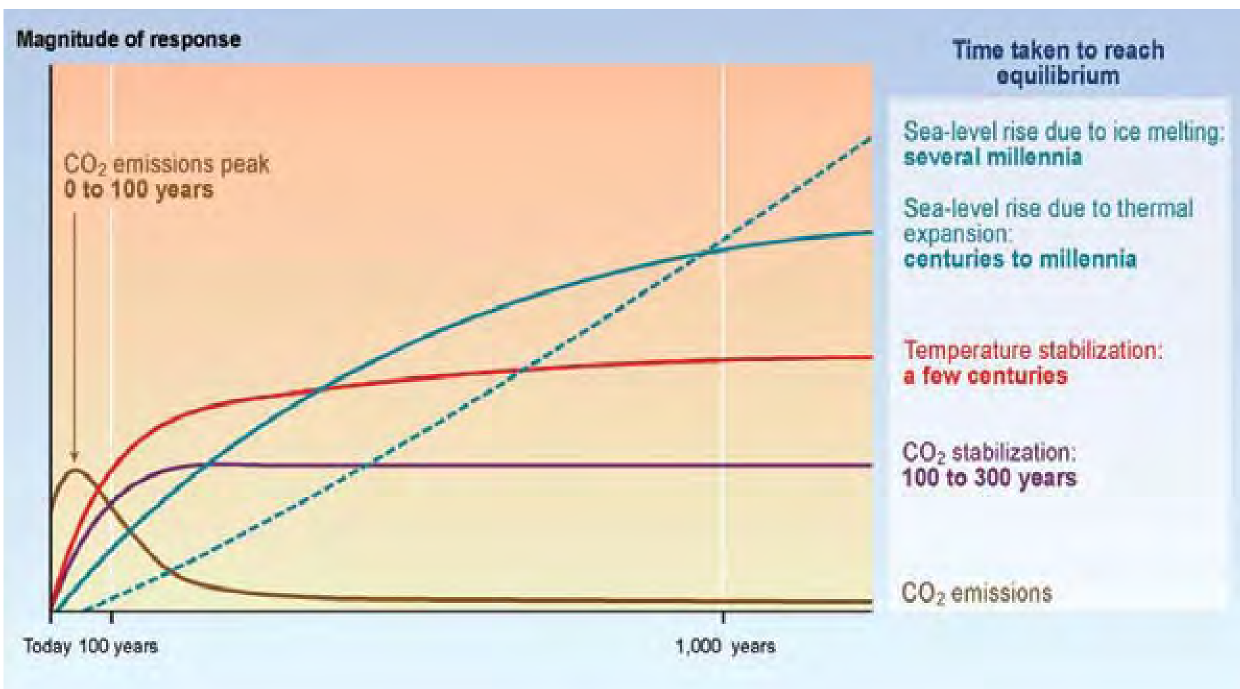
4. Mitigation

The examples of impacts due to global warming are sobering, especially considering how large the problem of greenhouse gas emissions really is. As atmospheric levels of greenhouse gases are the driving force behind global warming and its impact on climate, there will be a lag between when we reduce emissions and when we see the effects in the climate system and in the natural world. The response time depends on the rate of mixing in the ocean, climate feedbacks and the concentration, lifespan and warming potential of the various gases and aerosols already in the atmosphere. As the discussion of global impact predictions and lag times in this section indicates, the Earth will experience a certain level of additional warming even if we act immediately to stop additional greenhouse gas emissions.

PREDICTIONS AND LAG-TIME EFFECTS

As Lara Hansen of World Wildlife Fund reminded the symposium audience, CO_2, the major greenhouse gas driving global warming, was maintained at concentrations between 180 and 200 ppm (parts per million) in the atmosphere during pre-industrial times. With the advent of the combustible engine and the ensuing suite of

Figure 2: CO_2 concentration, temperature and sea level continue to rise long after emissions are reduced



After CO_2 emissions are reduced and atmospheric concentrations stabilize, surface air temperature continues to rise slowly for a century or more. Thermal expansion of the ocean continues long after CO_2 emissions have been reduced, and melting of ice sheets continues to contribute to sea-level rise for many centuries. This figure is a generic illustration for stabilization at any level between 450 and 1,000 ppm, and therefore has no units on the response axis. Responses to stabilization trajectories in this range show broadly similar time courses, but the impacts become progressively larger at higher concentrations of CO_2. (Source: IPCC) human activities related to power generation, transportation and land-use changes, CO_2 concentrations are now at approximately 385 ppm. An additional amount of climate change is already a given because of the lag time between the accumulation of greenhouse gases (Figure 2) and the consequent buildup of heat. The implication of this lag-time effect in the climate system translates into serious impacts if pre-industrial levels of CO_2 are doubled (550 ppm). Heating will be greater at the poles, particularly in the Northern Hemisphere, resulting in changes in water distribution, quantities and locale. According to Martin Perry, the editor of the second working-group report of the IPCC, the Earth is heading toward a tripling of CO_2 concentrations unless dramatic reductions are made very quickly. By the end of the century, emissions are expected to be somewhere between 550 ppm and 950 ppm.

Terry Root presented a disturbing review of the latest global impact predictions, based on the most recent work of the IPCC. Human-induced global warming raised the world's average surface temperature by 0.7°C during the reference period of 1980 to 1999. The result has been a decrease of surface water, an increased incidence of drought, floods and storm damage and heightened risk of fire and future species extinctions. An increase of the global average temperature beyond 1.5°C to 2.5°C will increase the risk of extinction to 20 to 30 percent. Corals will experience more frequent bleaching events and widespread mortality. This will also coincide with an increased incidence of flooding and drought. If we allow the global temperature to rise 3°C, 30 percent of the world's wetlands will be lost and human food production will decline. A rise of 4°C or more will bring melting of ice sheets and increased rise in sea level and an estimated loss of 40 percent of the Earth's known animal species.

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A polar bear climbs onto the sea ice, which is critical to its survival and rapidly disappearing.

As these extinction estimates include only loss of *known* species, the true magnitude of loss of our planet's biological diversity will be far greater than any estimate that can be made. But there is reason for optimism. As Root noted, if action is taken immediately to reduce our emissions, thereby limiting future average rise in global temperature to 2 to 3°C, it may be possible to avoid the most extreme extinction predictions.

REDUCING GREENHOUSE GAS EMISSIONS

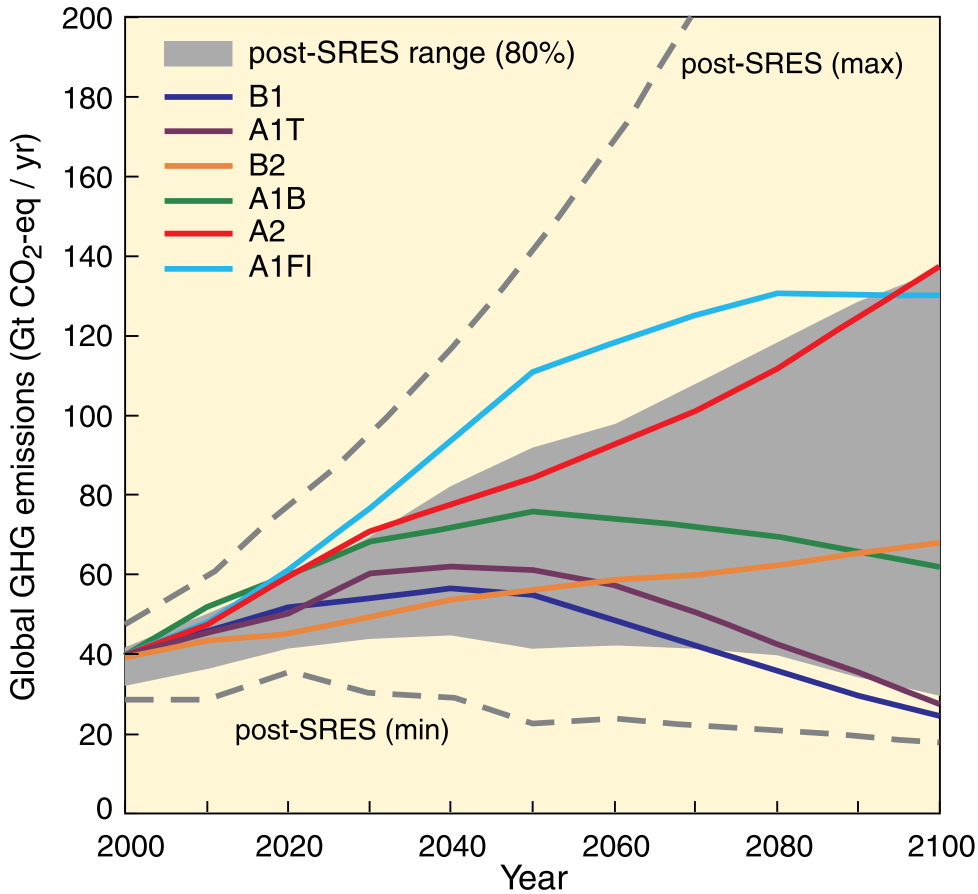
To be truly effective in addressing the impacts of global warming, greenhouse gas emissions must be decreased and carbon capture increased worldwide. Total emissions must then be reduced to a level that will stabilize the atmospheric concentration (Figure 3). If significant reduction and stabilization of greenhouse gas concentrations is not achieved, no amount of conservation or wildlife management effort is likely to reverse the species extinction trajectory of this century. Pursuing mitigation efforts—reducing greenhouse gas emissions associated with human activities—is the most essential component of any plan for addressing global warming. It also offers three additional benefits.

First, tackling greenhouse gas reduction promotes an open national dialogue aimed at the question: At what level will we stabilize greenhouse gas concentration? For Americans this represents an opportunity to debate national energy and transportation priorities and to question the country's global role in trade that serves to promote tropical deforestation and other land-use changes such as destruction of wetland habitats. The trade issue has received inadequate attention in the international climate change negotiations, despite its significant impacts on the global climate system. Tropical deforestation alone is estimated to account for 20 to 25 percent of the total annual greenhouse gas emissions.

Second, addressing greenhouse gas emissions provides the American people an opportunity to examine the issue of global warming as an ethical decision. Such a national debate also helps Americans examine both national priories and the choices that influence individual behaviors that contribute to the emissions of greenhouse gases. The nation must examine the environmental, economic and social impacts of climate change to future generations and to the preservation of the nation's wildlife and natural areas. This debate can be supported by scientific and economic studies but ultimately will be a moral or ethical decision.

The challenge for conservationists is to ensure that a broader and a more complete valuation of wildlife

Figure 3: Scenarios for greenhouse gas (GHG) emissions from 2000 to 2100 in the absence of additional climate policies



This graph shows six marker greenhouse gases scenarios (colored lines) described in the 2000 IPCC Special Report on Emissions Scenarios (SRES). The scenarios are based on different projections of future population and economic growth and energy sources. The A1 scenarios describe very rapid economic growth, a global population that peaks mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. The three A1 scenarios are distinguished by their technological emphasis–fossil intensive (A1FI - bright blue line), non-fossil energy sources (A1T - purple line) or a balance of all sources (A1B - green line). The A2 scenario (red line) is characterized by economic development that is primarily regionally oriented and per capita economic growth and technological change that are more fragmented and slower than other scenarios. The B1 scenario (dark blue line) considers the same global population situation as A1, but with rapid change in economic structures and an emphasis on global solutions to economic, social and environmental sustainability without additional climate initiatives. The B2 scenario (orange line) describes a world in which the emphasis is on local solutions to economic, social and environmental sustainability but with global population continuously increasing at a rate lower than A2, intermediate levels of economic development and less rapid and more diverse technological change than in the B1 and A1 scenarios. The gray shaded area shows the 80th percentile range of recent scenarios published since SRES and the full range of post-SRES scenarios (gray dashed lines). (Source: IPCC) and ecosystem services that benefit society are recognized and included in this debate. Wild species are the "ambassadors" for intact ecosystems and the benefits these natural areas provide to our nation and to our economy.

Third, reducing emissions offers "win-win" solutions, a feature underscored by symposium speaker Deborah Williams. Whether these solutions are the pursuit of renewable energy or reducing emissions through carbon capture or energy efficiency, they have the potential to improve the economy, bring jobs to the nation and improve health and environmental security.

Tom Lovejoy stressed the need to reduce deforestation and loss of wetlands. These areas merit protection not only for the biodiversity and ecosystem services they provide, but also because they release large quantities of greenhouse gases when they are cleared, burned or drained. Preventing deforestation and wetlands loss will be an important element in any national arsenal of mitigation options implemented.

In earlier U.N. climate change negotiations, the notion of crediting activities to reduce deforestation as part of a national response to limit greenhouse gas emissions was contentious among governments party to international climate regulations. Several nongovernmental environmental organizations even blocked them, believing that including forest and land-use issues would take the pressure off industrialized countries to address the energy side of the issue. Obviously, we need to facilitate and extend this dialogue to develop consensus. Stopping deforestation while also promoting reforestation and other improved forest management and land-use practices will contribute to offsetting the problem of increasing annual greenhouse gas emissions.

Ignoring any one element of our mitigation response "is hugely short-sighted," according to Lovejoy, "because the reality is we are at a point already, which is a crisis for climate change and for life on Earth. Remember that we have an additional amount of climate change already built in that is going to come in and just shape the biological systems of the planet like we have never seen or even are capable of imagining. So we really need to be doing absolutely everything we can. Whether it is energy efficiency or renewables or avoided deforestation, we need to be doing that all at once."

Deforestation, like this in Panama, accounts for 25 to 30 percent of the greenhouse gases released each year.

5. Managing Under Uncertainty

Given the volume of data, improved modeling efforts and thousands of experts contributing to the IPCC's recent assessment of climate change, scientists have a high degree of certainty that global warming is real, extensive and attributable to human activities. Policymakers, however, are only now beginning to understand the magnitude of these findings. Their hesitancy in responding may be due in part to the uncertainty in predicting what the outcome of future climate changes will be and determining what preemptive actions to take.

Most computer models treat the climate system on a global scale, which lacks sufficient detail to guide policymakers and resource managers. Without predictive models it is difficult to determine how best to proceed and respond and that level of uncertainty must be weighed against the risk of species extinctions if we fail to respond at all. Despite this challenge, conservationists can, and must, move forward as described in this and the following sections.

> "We have an obligation based on the idea of stewardship to protect species from the trends we have set in motion and in trends that continue."
>
> *–Bryan Norton, Georgia Tech*

APPLYING A SAFE MINIMUM STANDARD

Bryan Norton of Georgia Tech laid out an ethical argument/moral imperative, for managing within uncertainty. "Some of the species that do not look very useful or important now may be keystone species in future systems. [And because once] a species is lost it is lost forever, we should be applying the safe minimum standard of conservation as the rule," said Norton. This standard directs "that in a situation of uncertainty, always save the resource provided the social cost is bearable." Considering climate response in North America, Norton contends that "given the wealth of our society, almost any social cost is bearable to protect biological diversity… saving the biodiversity resource protects options and opportunities for the future."

MAINTAINING RESILIENCE

Over the decades, the United States has taken a variety of legislative, financial and active-management approaches to conservation. Protected areas have been legally designated as national parks, reserves, refuges, etc. Conservation land trusts, easements, concessions, contracts and market-based incentives to promote ecosystem services or biological conservation have been used as financial tools. Wildlife and resource managers have translocated populations or reintroduced animals propagated through captive-breeding programs created to save critically imperiled species.

Researchers monitor water flows as part of a project that has shown that major rivers are discharging much more fresh water into the Arctic Ocean, another impact of climate change.

These proven conservation approaches will continue to serve in addressing the new conservation challenges and pressures of a changing climate, but maintaining biological diversity is the most cost-effective management tool of all in our conservation toolkit. Given mankind's rudimentary understanding of nature, it may also be our most practical tool. Therefore, efforts to maintain or enhance the resilience of natural systems represent a prudent or safe standard that we can promote immediately.

Measures to promote resilience include designation, protection and management of adequate and

"The existing protected area system represents the safe havens from which future biogeographic patterns can emerge. And so, in the end, the message is…Past conservation achievements are really important. But we need even MORE conservation than we ever understood before."

—Tom Lovejoy, The Heinz Center

appropriate space and the creation or maintenance of travel corridors in a conservation network. Management of these sites involves minimizing the negative impacts of other stressors (such as injurious non-native invasive species and diseases, unsustainable harvests, pollution and decline in water quality or availability) and improving habitat quality and rehabilitation or restoration of degraded lands. Resilience is also enhanced through management and careful planning outside conservation areas to reduce fragmentation or loss of habitat to land conversion or infrastructure such as roads. Active manipulation within and between sites may be required in extreme cases where populations have experienced a bottleneck event (the reduction of numbers or genetic diversity in a population). In such cases, resilience may be improved through the introduction or exchange of parent stock to genetically depleted populations.

Under the predicted impacts of climate change, the boundaries that currently delineate protected areas may no longer afford species protection as increased global warming shifts ecological zones. Some environments will be altered or reduced to such an extent that enough critical habitat to maintain the populations or species will no longer be available. Other habitats will be eliminated entirely. Species that need to respond to survive the temperature, moisture or pH changes may have to move outside current protected areas. Ice-dependent species in the Artic or high-alpine species in mountainous areas present a type of climate challenge in which no amount of management effort to maintain resilience will ensure the species' survival. Mankind's reach in terms of our impact on nature has exceeded our grasp in terms of our ability to protect.

ADOPTING A NEW CONSERVATION PARADIGM

Tremendous changes in the physical and biological world are already evident with only a 0.7°C increase in average global temperature over the past century. The global community is woefully unprepared for the changes envisioned in merely the minimum 2°C to 3°C predicted increase expected over the next several decades. Even if we were able to stop all human-induced greenhouse gas emissions immediately, we can expect to see a rise of 2°C due to the lag effect in the climate system. The scope of the challenge in terms of the complexity and lag times of this system and how species respond and interact has massive implications for how conservationists respond to the impacts of global warming. A new conservation paradigm recognizing this is necessary.

Several symposium speakers stressed the need to rethink what conservation is and how to do it. Lara Hansen examined this in the greatest detail. She noted that the assembled group of symposium panelists and moderators represented a great proportion of the "national capital" in terms of a fairly small number of people working on the conservation response to the impacts of climate change on wildlife**.** This newly evolving area of conservation biology requires us to redefine what conservation is and what it must become to address climate change. To meet this challenge—the greatest of this generation—we must change the conservation paradigm.

Dan Ashe of the U.S. Fish and Wildlife Service elaborated on the conservation challenge ahead as the impacts of climate change call into question the fundamental concepts and principles that have guided conservation efforts until recently. Scientists and managers must throw out some preconceived notions and consider what climate change means for ecology. Concepts and definitions such as succession, integrity and resilience must also be entirely re-evaluated.

For example, the concept of restoration will have to be studied as it typically refers to some historic states and reference periods. Restoration is an effort to return to a state or condition, but how will that be defined now that habitats or systems have changed and are no longer part of the natural area under changing climate conditions? Similarly, categories such as native and invasive or subspecies and populations will also need to be revisited. It is a challenging time.

"Anything, any concept founded on assumptions of stability and global-level ecology, must now be questioned."

—Dan Ashe, U.S. Fish and Wildlife Service

6. Adaptation

The challenge of formulating a new conservation paradigm to address global warming is tightly tied to the question: *What is the conservation vision?* To answer, society will have to define the American conservation landscape. Wildlife and resource managers will then have to determine where that landscape will be, what it will contain and who is going to make it happen. This section covers the conservation efforts it will take to define and achieve this common vision and the sophisticated computer models linked to landscape-level planning and adaptive management if scientists and managers are to help wildlife adapt to the impacts of future climate change.

NATURAL RESOURCES CONSERVATION SERVICE

A riparian buffer on private land exemplifies the kind of project that helps wildlife and unites citizens and natural resource managers with a shared conservation vision.

DEFINING THE VISION: THE INITIAL CHALLENGES

Arriving at a common conservation vision in the context of the global warming crisis will require conservation efforts to move beyond the safe minimum standard and meet the important challenges briefly described below.

Linking human welfare and environmental integrity

Barry Noon of Colorado State University believes the first challenge of defining a common conservation vision is reaching a point at which the American public understands the link between human welfare and environmental integrity. According to Noon, society is at a very early stage and level of understanding. We have a long way to go to reach the next point at which people embrace and accept this link. The problem has been that the American public, as well as wildlife and resource managers, tend to focus on a human experience timeframe when global climate change really requires ecological and evolutionary thinking to allow species to survive and adapt. Thus, the new conservation vision requires framing in fundamentally different temporal and spatial scales.

Defining population viability

To serve as a management tool, climate models will need to be linked with population genetic and demographic models. Wildlife and resource managers will have to address how they wish to define "population viability" for their computer-guided management goal. J. Michael Scott of the University of Idaho and U.S. Geological Survey considered this component in identifying a common vision and future modeling and management needs for national wildlife refuges in 2050. "What is it that we are trying to protect?" Scott asked. Is it the *minimally viable*, *demographically viable* or *ecologically viable* population?

The difference between them may be an order of magnitude. To reinforce that point, Scott reported that 59 percent to 73 percent of current refuges can maintain *genetically viable populations* of threatened and endangered species found there, half the *demographically viable populations* and perhaps as little as one-eighth of *evolutionary viable populations.* Defining population viability—the modeling objective—will require input not only from biologists but also from society at large.

Determining how far to go to protect a species

Perhaps the starting point in defining a common vision is to figure out what species to protect and how, and to determine the lengths to which we will go to save them as climate change and habitats shift. Scott summed it up with the refrain from a Kenny Rogers hit song: *"You got to know when to hold 'em, know when to fold 'em, know when to walk away…"* In response, Dan Ashe of the U.S. Fish and Wildlife Service said, "I think in the end the species themselves are going to decide when they are done—when they are going to blink out—and I, from my own perspective, would rather not have the Fish and Wildlife Service making those decisions. I would rather see the Fish and Wildlife Service holding them and playing as hard as they can."

Accepting risks

As species migrate out of their historic ranges in response to climate change, conservationists will be challenged on all fronts—at the scientific, managerial and policy levels. To illustrate the difficulties for wildlife managers as they wrestle with efforts to define a common vision, H. Ron Pulliam of University of Georgia used the example of whether or not to assist species movement or migration. If a species cannot move on its own to colonize more climatically suitable habitat that develops in the future, should it be moved deliberately and purposely even if the relocation takes it outside its historic range? By definition under current U.S. law, species introduced

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A Bengal tiger drinks from a river. Scientists predict rising sea level will drive these animals from the low-lying islands of India and Bangladesh to the more populous mainland, and are working with communities there to set aside land.

outside their historic range are considered "invasive species." Many of the same fears, such as unknown impacts on local ecosystems and plant and animal communities, exist for these "neo natives" as for non-native species introduced by humans. Moreover, mankind's history of trying to engineer nature and correct environmental problems has had some colossal failures. Undoubtedly, the number of species eligible for consideration for such intervention will be limited, perhaps to only the most endangered or most valuable to society. It is clear that future conservation challenges under climate change will require action when inaction carries a real risk of extinction.

"I think we are to the point where risk aversion is no longer an option," Pulliam noted. "We have to take risks that we have not taken in the past because the impacts of global warming are going to get far worse before they get better. We cannot afford to sit back and do nothing. We are going to have to take risks."

> "Are we smart enough to do it? Are we dumb enough not to?"
>
> –*H. Ron Pulliam, University of Georgia*

PREDICTIVE MODELING AS A MANAGEMENT TOOL

Predictive models must be an integral part of the conservation toolkit for dealing with climate change impacts. Unfortunately, high-quality coupled models with sufficient sensitivity, accuracy and precision at a finer spatial scale are not yet a reality. Existing models are also limited. Most do not incorporate species' physiological tolerance and response to climatic factors, nor do they model complex biotic interactions and future human land-use changes. These limitations are described in more detail below.

Insufficient scale

Current climate models are of great help in examining global climate change, but lack sufficient resolution to be useful to wildlife and resource managers at regional or local scales. Climate models are complex computer programs run on sophisticated super computers using quantitative mathematical equations to simulate the dynamic interactions of the atmosphere, oceans, land masses, ice and snow. Based on these simulations, future climate and climate impacts can be predicted. Direct Earth observations have been used to derive the mathematical relationships between variables and to provide the relevant data.

The level of sophistication of these models has led to a greater understanding of the climate system in recent years. However, the smallest area or unit considered in the global circulation models is too large to be of practical use to resource managers who need to manage at the level at which climate interacts with species and habitats. Fortunately, efforts are now shifting to downscale climate projections to generate more fine-scale climate predictions.

Inability to account for abrupt change

Current predictive efforts are limited because scientists are still unable to model abrupt climate system changes. In addition, current principles of conservation biology and wildlife management are based on an assumption of stability. In fact, the entire human enterprise—agriculture, land and resource use and harvesting levels—is based on this assumption. How to adequately model the potential of wildlife and natural ecosystems and accommodate the uncertainty of the impacts of abrupt changes is simply unknown.

Limit in number of species modeled

Even with the development of modeling programs on a finer-scale, only a limited number of individual species can be modeled based on a sufficient understanding of that species' physiological tolerance and response to changes in temperature, moisture, pH or chemistry. Thus, although it may be possible to model the distribution of single species—where a particular species might occur in the future—attempts to model the total number of endemic vertebrate species over time and temperature change may prove untenable. Only a limited amount of this type of climate prediction can be anticipated. Large charismatic or economically important species are most likely to receive this level of analysis. It is just too huge a job to tackle species-by-species.

Difficulty of monitoring complex community and biotic interactions

Modeling the primary impacts of global warming on a single species is the simple part of the picture. As previously noted, there are

> "Our biggest challenge is going to be protecting and reintegrating conservation areas into the American landscape."
>
> –*J. Michael Scott, University of Idaho and U.S. Geological Survey*

serious complications to consider in determining what climate change will mean and how species and communities will respond. With no real analogs in nature of the impacts of climate change, the secondary impacts, species interactions or synergistic responses are far more difficult to model. Potential dissolution of community structure will be unpredictable throughout an unstable period of transition and under continuing climate changes.

Despite an inability to model secondary and tertiary impacts, these must still be anticipated in future planning and response. Deborah Williams pointed out one such scenario. Mosquitoes that can carry the West Nile virus are not yet found in Alaska. However, she noted that as global warming increases, the northern range of the mosquito-vector could move into the state. The initial human response is likely to be spraying with pesticides, a response with potentially serious environmental impacts.

Challenge of modeling human behavior and societal responses

The example of mosquitoes carrying West Nile virus moving north into Alaska introduces another aspect and limitation of climate modeling as a predictive management tool: how to model human or societal responses. As Dan Ashe put it, "fear the turtle but do not ignore the hare," climate change being the turtle (relatively slow, deliberate), human society, the hare. Human responses to climate change will be aggressive, energetic and additive with very proximal effects on wildlife, he warned, and managers will need to pay close attention to these effects.

A prime example is the national frenzy to support biofuels production reflected by the growing amount of land placed under corn cultivation in the midwestern United States. Another example is the proliferation of wind turbines and photovoltaic panels across the southwestern deserts as society pursues alternative energy. The impact that such energy infrastructure will have on sensitive ecosystems already stressed in recent years by drought due to global warming is a concern.

LANDSCAPE-LEVEL PLANNING

Symposium speakers unanimously concluded that changing climate conditions will require managing wildlife across a much larger area—beyond the individual unit-level and the system-level. Maintaining North American wildlife over the next century will take broad-scale planning, linking natural areas and refugia of native wildlife and the collaboration of multiple governmental and nongovernmental landowners and stewards.

Managing public lands

The president of Defenders of Wildlife, Rodger Schlickeisen, cited a recent U.S. Government Accounting Office (GAO) report that found the United States is "inadequately prepared; … federal land agencies lack guidance on what to do, and have not made addressing global warming a priority…[and] official advisors are reluctant to talk about climate change." Dan Ashe confirmed that there has been a policy shift, pointing to several recent consultations, reviews and training efforts currently underway within the Fish and Wildlife Service.

Mike Scott, who has given serious thought to how to manage for climate impacts on National Wildlife Refuge System lands, stressed the need to consider management at two levels: the entire system and the individual unit. He noted that his conclusions, which are presented below, apply equally to national parks, private reserves and other protected lands.

At the system level: Until recently, federal land management authorities' consideration of climate change has been mostly limited to supporting research documenting the impacts of climate change on select species, rather than focused on managing public lands at the system level. From a local biologist's or manager's perspective, the system-level focus of climate change on public lands will have to be reconciled with grand and far-reaching policy decisions.

In terms of diversity or population numbers, some species and refuges will be "winners," and some will be "losers." This raises the question of how to prioritize species conservation. As species distributions shift in response to changing climate and habitat, refuges established to protect and sustain them may prove inadequate. Thus, according to Mike Scott, we need to do three things.

First, we must identify the "winning" and "losing" species and the refuges on which they occur to prioritize response efforts to protect species at highest risk. These will be species that occur at high altitudes, in the polar region, along coastal areas, at the limits of their geophysical, technological or geographical range, at the boundaries of their range on a national wildlife refuge, as well as threatened and endangered species that already have narrow distributions and are otherwise vulnerable. For example, in developing a vision for the future of our national wildlife refuges, Scott and his colleagues looked at climate predictions out to the year 2100 and identified 309 refuges that will lose waterfowl species as a result of range contraction and 229 refuges that will gain species. These projected results varied across species and also geographically.

Second, we must take a global approach to protecting North American breeding birds or other globally migrating species that are threatened not only on their breeding grounds but also on their wintering grounds and stopover areas. Scott considered birds that breed in North America and winter elsewhere. The federal response to global climate change on our national wildlife refuges cannot be restricted to the United States; it must also consider the relevant global impacts.

Third, we must recognize that a management response will have to adapt to dramatic shifts as ecosystems are lost or transformed and take on conditions for which we have no prior analog. Referencing results of climate modeling scenarios on national wildlife refuges, Scott and his fellow researchers found that 10 percent are likely to undergo these kinds of dramatic ecosystem shifts, including 16 Alaskan refuges that account for 85 percent of the entire National Wildlife Refuge System's landmass. Coastal refuges are the most numerous, with 161 units that may be threatened by rising sea level. There is also a subset of these refuges that may require special consideration, such as coastal refuges that face bulkheads or are bounded by cities, towns and highways. Scott also found that some inland refuges that are now grasslands are likely to experience a shift in major ecosystem type or biome over the next 100 years. These shifts represent unprecedented challenges that require the development of new policies to facilitate managers' ability to respond to these unanticipated changes. This is a research challenge scientists and managers must meet together.

At the individual area level: Examining the response at the individual refuge or area level, the GAO report also reveals that "resource managers focus first on near-term required activities, leaving less time for addressing longer-term issues like climate change," a finding not surprising to federal staff. As federal employees Scott and Ashe indicated, the reality of managing public lands is that, given current funding levels and priorities, resource managers must focus on these short-term requirements, the everyday demands. This will not change, at least until adequate resources are made available to do the long-term job as well.

Maintaining connectivity and corridors

Dan Ashe called for a strategic approach to developing migration corridors. He noted that the National Wildlife Refuge System was built on a concept of corridors, so the United States does have experience managing corridors across the landscape. The current challenge, in the context of climate change, is going to be dealing with the unpredictable and asynchronous movement of species and the loss or shifts of critical habitat moving to higher, cooler elevations or longitudinally toward the poles. Planning corridors is only one part of the solution.

Mike Scott offered one additional reason for creating wildlife corridors. Current protected areas, whether they are parks, refuges or other conservation areas, are too small, he said, and too fragmented to maintain the integrity, diversity and health of the populations that are found in these areas. Parks and refuges are isolated "islands" embedded in inhospitable "seas" of land development. Therefore, a landscape-level approach will require not only the physical and mechanical aspects of creating connectivity and corridors, but also an expanded system of land acquisition, planning for and examining subsidies and land incentives and multi-stakeholder consultation.

Like other protected areas around the world, America's national wildlife refuges must be reintegrated into the broader landscape. Efforts toward achieving this could serve to demonstrate U.S. leadership in conservation and help promote similar conservation efforts around the world.

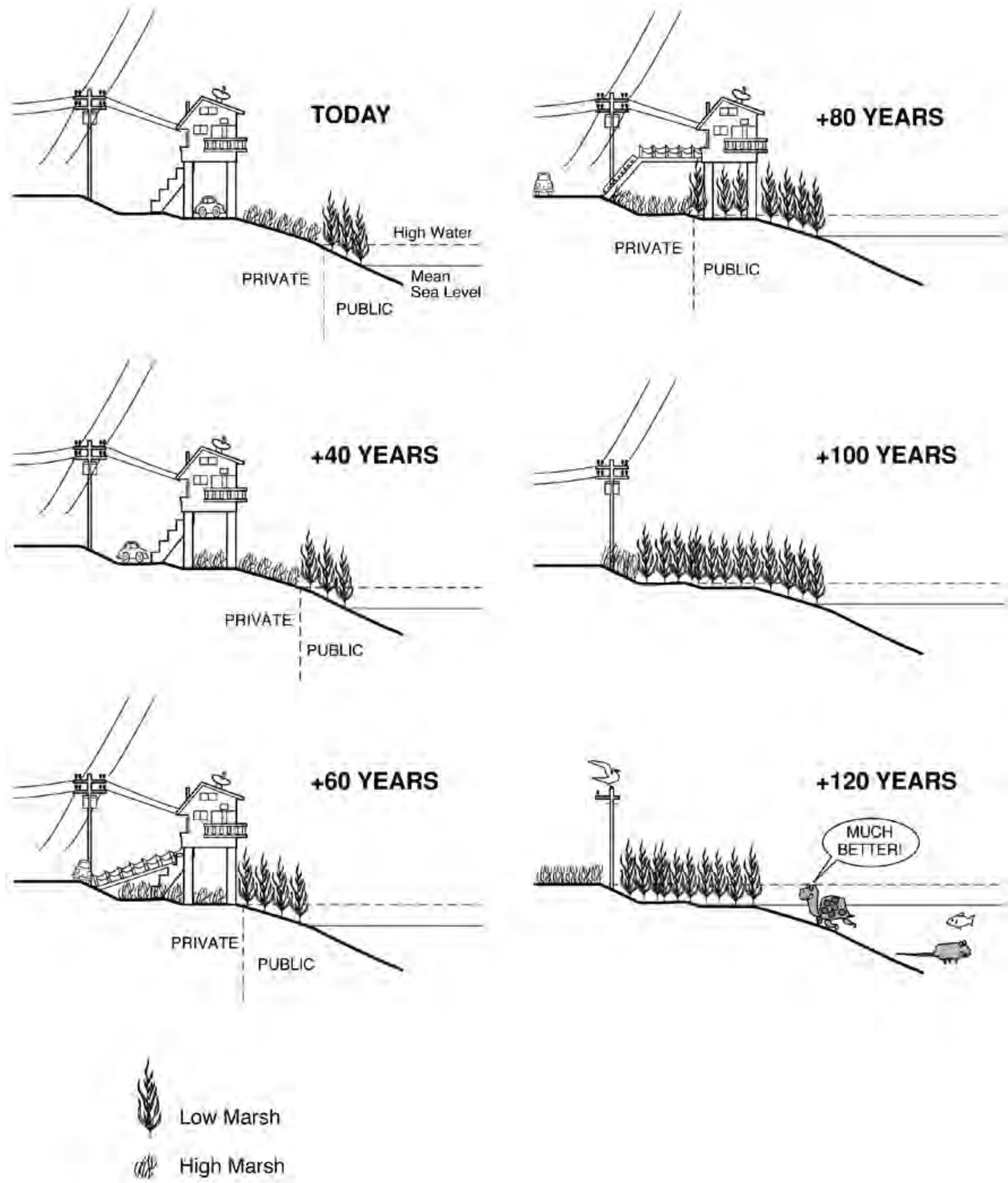
To focus conservation efforts on a landscape level to a greater extent than before, there is a need for greater cooperation among federal agencies, state agencies and private landowners, noted David Hayes of the law firm Latham & Watkins. He stressed that although science is showing a way forward, top-level direction among all wildlife and resource managers of state and private lands must be "job one" in terms of wildlife protection.

Michael Mantell, an attorney with the Resources Law Group LLP, pointed to the state of California as an example of where this is starting to happen. California has increased funding and research to consider the need and placement of corridors. However, he noted the frustrating disconnects between the studies and the follow-up actions, agency expenditures and priorities of the nonprofit land trusts. "We increasingly have the science and the knowledge to underpin that," he said. "We do not have yet the other vehicles in place to actually translate it into action, although we have made progress."

Creating dynamic networks of protected areas

Society must be fully engaged if conservation objectives are to be achieved in the face of increasing global warming. Given the scope and scale of the climate change challenge, managing wildlife and protecting adequate and appropriate

Figure 4: Rolling Easement



A rolling easement allows construction near to shore, but requires the property owner to recognize nature's advance inland as sea level rises. In the scenario depicted here, the high marsh reaches the footprint of the house 40 years hence. Because the house is on pilings, it can still be occupied. After 60 years, the marsh has advanced enough to require the owner to park along the street and construct a catwalk across the front yard. After 80 years, the marsh has taken over the entire yard. The footprint of the house is now seaward of mean high water and thus on public property. At this point, additional reinvestment in the property is unlikely, and the state might charge rent for continued occupation of the house. Twenty years later, the house has been removed, although older houses on the same street may still be occupied. Eventually, however, the entire area returns to nature. (Source: Maryland Law Review, 57 (1998): 1279-1399) space will only be possible through strategic conservation partnerships among adjacent landowners and other interested parties. An integrated conservation landscape requires the design of dynamic networks of protected areas or “rolling easements” (Figure 4). A rolling easement is a special type of easement that has been applied to coastal shore properties. Unlike setbacks that prohibit development near the shoreline, this easement ‘rolls’ landward as the sea advances. The objective is to ensure dry or intertidal lands for public access to the shore. But the idea of applying this rolling concept in response to changing or advancing climate boundaries is only now being considered. The concept is still in its infancy and will take much more research and policy analysis to work out how to best implement it. As Scott noted, it is a promising approach to a daunting problem.

ADAPTIVE MANAGEMENT

In his symposium presentation considering the challenge of managing under uncertainty, Bryan Norton introduced two strategies for dealing with uncertainty. One strategy is to “study then act,” which characterizes the primary policy of the U.S. government. The alternative, and recommended strategy, is to “act and then study,” an approach widely known as adaptive management. Three characteristics help to define adaptive management: It is experimental, involves multi-scalar modeling and is formulated from a particular location outward.

Adaptive management embeds science in an experimental and proactive management process. The experimental aspect of adaptive management is a response to the uncertainty of taking reversible actions, then studying the outcomes to reduce uncertainty at the next decision point. The multi-scalar modeling that adaptive management calls for involves thinking and planning around what Norton called “layered time,” allowing for the consideration of broader drivers, such as species interactions, and how they affect the broader system, and for the formulation of solutions that are more complex but more appropriate. Finally, the issue of “place” is critical because adaptive management is germane to a specific location, it emphasizes that there is no one-size-fits-all solution and that critical efforts must still be made at the local level.

Scott, Hansen and Ashe reiterated the need for wildlife and resource managers to apply adaptive management in responding to the threats of increasing global warming. This kind of experimental management will be necessary because at this stage we simply do not have the answers. “If we were to try and figure out what the uncertainty is in various strategies,” Hansen said, “by the time we work out the uncertainties, climate change would have changed the playing field yet again, and that guidance would now be useless. We need to take bold steps now, and change the way we are thinking and start implementing it.”

Management opportunities

Hansen illustrated the adaptive management approach using three projects supported by World Wildlife Fund. These projects help species adapt to climate change and include protecting coral reefs by restoring coastal mangrove forest across the equator, planning for tiger conservation on the Indian islands of the Sundarbans based on climate modeling, and assessing hawksbill turtle nesting habitat across the tropics.

The first project, working with local communities to restore coastal mangrove forests to protect coral reefs offshore, is an example of building ecosystem resilience, a climate change adaptation approach long championed by Hansen and her colleagues. The adaptive management component was creating a model to show other communities how to benefit from similar conservation efforts and to modify it to suit any unique local considerations and conditions.

This project engaged communities with a vested interest in taking immediate action by participating in a mangrove restoration and coral reef protection program. These communities understood the benefits a mangrove shelter belt offers in buffering wave surge and coastal erosion and the value of fisheries supported by the coral reefs. By restoring the mangrove

> “We need some sort of extension agency model that allows for that dialogue and that synthesis to be going on. Currently we are just too few people spread out doing too many different things.”
>
> *–Lara Hansen, World Wildlife Fund*

ecosystem, they are protecting the coral reef ecosystem and enhancing its resiliency to the impacts of a rise in sea surface temperature associated with climate change.

The second example, tiger conservation on the low-lying islands of India and Bangladesh, underscores the fact that adaptive management requires conservation planning that anticipates human-wildlife conflicts that will emerge as wildlife and people face the impacts of climate change. Climate modeling data were used to predict the change in sea level and the resulting inundation, loss of tiger habitat and the movement of tigers swimming to more populated areas on the mainland to escape these climate impacts. The adaptive management aspect was to work with governments and engage local communities in areas likely to receive displaced tigers and to develop new spatial arrangements that afford protection to both human and tiger populations.

The sea turtle conservation project Hansen cited as a third example considers various hawksbill turtle nesting beaches across the tropics. With sea level and temperature rising, conservation managers will have to address disappearing coastal vegetation, coastal land development and changes in coral reefs and global currents that will affect historic nesting beaches and how sea turtles feed. Another way to assist species adaptation to climate change is to replicate conservation efforts or to plan for redundancy as a way of "hedging our bet" against the unpredictable nature of climate change.

A hawksbill turtle, a species losing vital nesting beaches to global warming, glides over a coral reef.

The adaptive management angle of this project is recognizing that conservation planning must now anticipate the "wild card" of climate change. Areas that have historically served as nesting grounds or other habitat critical to species survival may shift or be entirely lost. Species conservation therefore must consider the species' entire distribution and set aside conservation areas or ensure that spatial replication is possible.

It is the element of replication—doing similar but multiple projects—that managers must consider at the system-level to implement a truly adaptive management approach. Doing many similar projects around the world will be necessary to compare and further refine the appropriate management response to climate change. It is essential to identify from this replication effort what guidance can be generalized and drawn from such comparisons. So little is known right now, and there is so little time.

"We need to come up with not the answer for a particular site; we need to come up with answers that will work fairly generally, fairly broadly, so that knowledge can be shared and implemented as quickly as possible," said Hansen. "[We need] networks of similar projects where we can combine the studies at the end to do meta-analysis approaches of what works and what does not; what is good guidance and what is not," said Hansen.

7. Policy Response Challenges

Implementation of many federal conservation statutes (Endangered Species Act, National Environmental Policy Act, Marine Mammal Protection Act) has often proven inadequate to fully address the nation's current conservation challenges and is unlikely to fully address the more complex, far-reaching and long-term problem of global climate changes. The climate challenge thus offers an opportunity for conservationists and policymakers to be proactive. As Eric Glitzenstein of the public-interest law firm Meyer Glitzenstein & Crystal observed: "If we fail to be proactive, we may be forced to be reactive." This section reviews several of the existing conservation laws protecting U.S. wildlife and the policy changes needed at the federal and state levels to cooperatively address climate change.

EXISTING POLICY TOOLS

Endangered Species Act

The Endangered Species Act (ESA) has not always been successful in promoting landscape-wide decision making. It is difficult to make changes when the causality between an action and its impact on species is not clear. This difficulty is at the core of the ESA's limitation in addressing climate impacts: "How does the law deal with assessing the threat when the causes of the problem are, by definition, global in nature?" said Glitzenstein. He further described the ESA as "too slender a reed on which to hang this entire [global climate change] problem, [but] it will be one of the reeds that people try to hang it on." The 2007 petition to list the polar bear as threatened under the ESA was the first and most obvious example of how conservationists are trying to use existing laws to secure the need for conservation response and legal protection. But, if Glitzenstein is

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Walrus herds rest on a chunk of pack ice. A shortage of pack ice in 2007 forced these marine mammals to crowd on shore in such numbers that thousands were killed in stampedes.

> "Let's try to not only address global climate change but be preemptive in understanding how humans are going to react to that and try to factor wildlife protection into those responses, which may, in the long run, turn out to be as important from a wildlife standpoint, as actually doing something about global climate change itself."
>
> *–Eric Glitzenstein, Meyer Glitzenstein & Crystal*

correct, many more species will be listed and moving along the "critical habitat pipeline," if policymakers fail to take more proactive steps to address the shortcomings of current legislation.

National Environmental Policy Act

The National Environmental Policy Act (NEPA) can be "a tremendous help, potentially, in putting the spotlight on what is happening to the environment in connection with major federal actions," said David Hayes. "[But] it is a disclosure statute at its root and it has limited enforcement in terms of mandating requirements."

Marine Mammal Protection Act

During the discussion at the end of the symposium, the policy speakers were asked to consider the use of the Marine Mammal Protection Act (MMPA) to combat impacts of ocean warming on marine mammals that depend on the ocean for their survival. Deborah Williams said that it will be critical to use existing laws as fully as we can in the face of global warming. David Hayes agreed. "It is absolutely worth thinking creatively about it," he said, noting that MMPA has some of the same inherent problems as NEPA and may "not have quite the hook that we need."

Global Warming Wildlife Survival Act

Hayes concluded "the best ground to plow is the new legislation." He noted that the Global Warming Wildlife Survival Act promoted by Defenders and other conservation groups provides a fundamental component to future legislation in response to global warming (see page 29). This act calls for the development and implementation of appropriate plans by federal and state agencies, the formulation of a national strategy to protect wildlife and oceans, the establishment of a national science advisory board and a global warming and wildlife science center at the U.S. Geological Survey, and the creation of a framework for funding.

NEED FOR COOPERATION AND COORDINATION

At the federal level

As noted previously, wildlife management in the face of climate change will require a landscape-level management approach. However, according to David Hayes, the problem is management authorities are not very good at landscape-level management. At the federal level, for example, there are many agencies (Bureau of Land Management, National Park Service, Forest Service, U.S. Fish and Wildlife Service, Bureau of Indian Affairs) responsible for managing land. "All of these have land managers," Hayes noted, "and they do not all get along." In addition, there are disconnects between the scientific or technical units and the management authority, as in the case of the U.S. Geological Survey, which is independent of the U.S. Fish and Wildlife Service within the Department of the Interior administration and management structure.

Hayes, however, pointed out that there is a precedent for federal agencies and federal, state and private landowners to work together: the National Interagency Fire Center (NIFC). The NIFC brings the Forest Service, U.S. Fish and Wildlife Service, National Park Service, Bureau of Indian Affairs and state agencies together to consider the kind of information needed to deal with the complicated issue of fire management and response. Dan Ashe also cited the NIFC as an impressive program all the way down the line, from training to science to execution and beyond. In considering the climate change challenge, Ashe supported the idea of adopting the NIFC model: "We need a central capacity to think about the science and to drive that to the management community." He also noted that the successful cross-collaboration in this program was born

> "We need a big, big bunch of money going toward wildlife adaptive management. And it is probably going to have to be a big straw coming out of the cap-and-trade system."
>
> *–David Hayes, Latham & Watkins*

The Global Warming Wildlife Survival Act

In addition to national legislation that takes immediate steps to significantly reduce greenhouse gas emissions, we will also need legislative action to protect our wildlife. Even with immediate and significant emission reductions, wildlife will continue to suffer from the impacts of global warming through the century, and possibly beyond, until greenhouse gases already in the atmosphere dissipate. We also need a comprehensive strategy to address the impacts of global warming on wildlife. The Global Warming Wildlife Survival Act creates the framework necessary to carry out such a strategy. The act, which has been passed by the House as part of broader energy and global warming legislation, and has been introduced in the Senate, will:

Defenders and other groups joined forces to garner support for the Global Warming Wildlife Survival Act by running ads like this one in publications read by members of Congress and their staff.

- Ensure that federal and state agencies develop and implement plans to reduce the impact of global warming on wildlife and its habitat.
- Coordinate a national strategic response, based on the best available science, to enable wildlife to adapt to the current and future impacts of global warming as we work to reduce emissions.
- Establish a national science center within the U.S. Geological Survey to investigate the impacts of global warming on wildlife and to propose management responses to assist wildlife adaptation to these impacts.
- Create a funding mechanism for allocating significant levels of new federal funds to conduct the necessary research and management interventions to help wildlife survive the impacts of global warming. One proposed source of funding for this legislation is a portion of the proceeds generated through the sale of greenhouse gas pollution permits under a federal cap-and-trade system created under future climate change legislation.

To read the bills as introduced, visit **http://thomas.loc.gov** and search for H.R. 2338 or S. 2204. To learn more about the act, visit **www.defenders.org/wildlifesurvivalact**.

of a crisis in which the imperative to act was overwhelming.

Hayes identified three key elements that make the NIFC model work, all of which could apply to climate change and landscape management.

First, and most important, is leadership from the top.

The second element is clear direction specified in the statutory language, providing federal land mangers with clear priorities. "When it comes to resource agencies, this kind of direction is extremely meaningful and with appropriate leadership can be pushed through," said Hayes.

The third element is funding. Addressing the magnitude and scale of the climate change impacts on wildlife and lands will require additional financial support for scientific research, resource management training and land acquisition. Mobilizing the federal Land and Water Conservation Fund could be a logical first step, but a steady flow of future funding will also be essential.

Hayes pointed to two additional funding opportunities. One, carbon cap-and-trade, is already making its way into proposed legal and market mechanisms. Another option, perhaps more problematic but worth continuing study, is forest carbon offsets. The ability to channel funding through a proposed cap-and-trade system of carbon dioxide emissions regulations on energy holds real promise. The second, carbon sequestration through forest carbon offsets, "is very complicated to figure out [and it is] extraordinarily difficult to measure what the benefit is," Hayes said. "It is a policy morass because there are folks who want to take advantage of sequestration in an inappropriate way. But somewhere in that pile, there is a diamond that has the potential to bring dollars to maintaining intact landscapes because of the carbon benefit associated with forest, range, wetlands and other undisturbed lands that can [store carbon]. Keep your eye on that ball. I think it could become a very important funding mechanism."

At the state level

Clearly, the federal government alone cannot solve the problems associated with climate change nor can they be resolved within the confines of federal lands. State and private landowners will also have to be involved. Future climate change opportunities have the potential to get federal, state and private landowners working together because the challenge is imperative and so overwhelming.

States will be crucial in addressing the climate change challenge because the management and regulation of most wildlife and habitat outside of federal lands resides within state purview. States offer major opportunities for integrated planning. For example, the State Wildlife Action Plans produced under federal law should be integrated with regional water and energy infrastructure development and management plans. State land trusts should stay up to date on climate change impacts and make them a consideration in efforts to assist wildlife adaptation. Michael Mantell pointed out that states can also serve as "laboratories for innovations" and are particularly key for day-to-day land-use decision making.

Thus, greater efforts should be made to strengthen federal-state relationships. Working examples include the memorandum of understanding (MOU) developed in the previous administration between California and the Department of the Interior and the California Biodiversity Council, created to bring together land-managing agencies. Formalized agreements among agencies such as these provide a framework short of statutory changes and go a long way toward creating the kind of collaborative interactions necessary to achieve landscape-level management.

However, most states, like the federal agencies, are underfunded with overworked personnel and therefore may have little inclination to take on climate change planning. Such planning activities while going beyond the immediate, day-to-day activities that need attention must nevertheless become a higher priority among resource agencies. States are already able to pass bond measures to provide needed capital for restoration, land acquisition, creation of corridors and control of invasive species. Mantell pointed to attempts in California to redirect those bond dollars to areas most in need of support for designating and setting-aside corridors to help wildlife species adapt to climate change. Part of that effort relies on public education. "People need to better understand not just the problems, but the potential solutions and their role in solutions, and how it affects all living things," said Mantell.

"We have great opportunities, but also great responsibilities to bring [our citizenry] more into the process of helping us work on solutions."

–Michael Mantell, Resources Law Group LLP

8. Vital Framework

Jamie Rappaport Clark, executive vice president of Defenders of Wildlife, led a closing discussion among panel moderators Barry Noon, Ron Pulliam and Eric Glitzenstein. They focused on the two vital questions covered in this section: *How do we shift the U.S. climate change debate to a less politically charged dialogue? What first steps should the next administration take to address global warming and wildlife challenges?* The answers constitute fundamental actions that we must take immediately to build the national framework necessary to meet our responsibility and take leadership in making global warming a top-priority issue.

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Al Gore (center) and Rajendra Pachauri (right), accepting on behalf of the IPCC, receive the 2007 Nobel Peace Prize for their work on global warming.

TAKING POLITICS OUT OF THE ISSUE

Pulliam offered two approaches to taking politics out of the policy dialogue. The first is to take the approach exemplified by the symposium and turn the issue into a science-based problem to study and analyze to derive objective recommendations. Moving forward on this approach would set up a process dictated by objective outcomes. For example, under the proposed Global Warming Wildlife Survival Act, a scientific advisory board could provide policy-neutral analysis and recommendations. "If you get people on board with the notion that we should have science-based decision making, it is hard to be partisan about that," said Pulliam. It is one strategy that has already been shown to work with some degree of success in other settings.

Noon concurred that the climate change challenge is primarily and foremost a science issue. However, he noted, success will rely on addressing the drivers of global warming, which quickly moves the dialogue into social and economic dimensions central to Pulliam's second approach to getting away from the politics: focus on linking the fate of wildlife to the fate of human beings. Pulliam noted that the message that humans and wildlife alike are going to suffer the same fate in the long run has gotten increased currency in the last couple of years. That message will continue to take hold, and have even more impact in the future.

Eric Glitzenstein pointed out that addressing global warming may seem to be a partisan issue, but this is just an illusion based on current history. Politics shift. He noted that environmental issues have not always been embraced by just one party. There have been extremely strong supporters of the environment—and successes with big issues, even global issues—on

> "We hope we can return to a period of civility and rationality in terms of this issue–which affects everyone of us, affects all of our children–and does not discriminate on the basis of left and right. It is one of common sense."
>
> *–Eric Glitzenstein, Meyer Glitzenstein & Crystal*

both sides of the aisle. “Remember,” said Glizenstein, “there is a need to work across the aisle.”

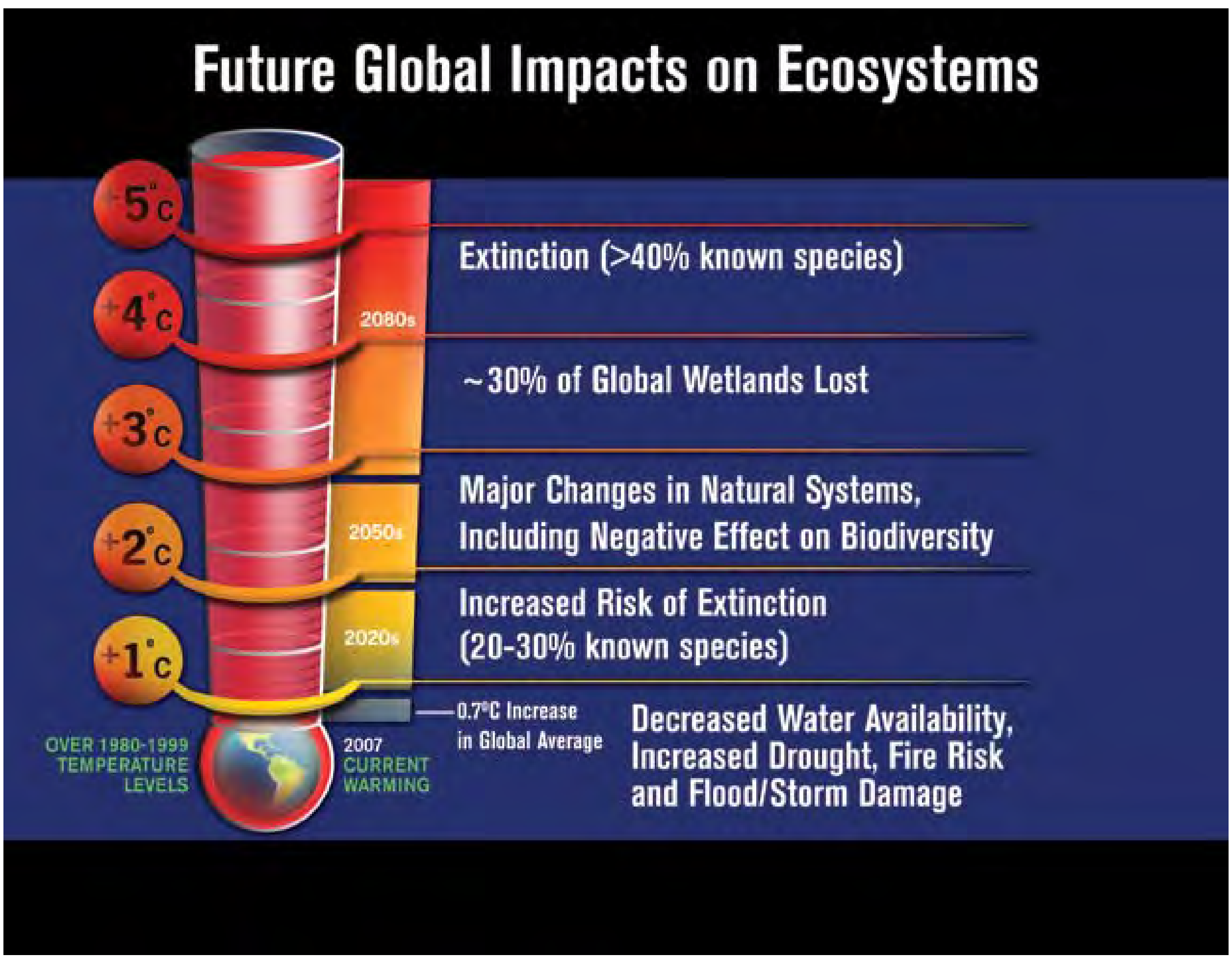
TAKING LEADERSHIP: FIRST STEPS FOR THE NEXT ADMINISTRATION

The general consensus of the panelists was that adequate funding is essential. To address the scope of the work ahead, the next administration will need funding for land acquisition programs to protect habitat and for educating land managers and bringing all parties together in an ongoing, iterative and mutually reinforcing process of consultation, analysis and planning.

Two big parts of the solution, which have been missing, were noted in this discussion: a need for greater involvement of the states at the policy, resource and land management levels; and a need for a more effective and supportive role by the federal executive branch. “We were talking about this as if it is a federal issue,” Pulliam said, “but when we get away from a few species, those endangered and threatened species, down to migratory species, most species are not federal responsibility; they are state responsibilities [and this] will require coordinated efforts across state boundaries.”

Glitzenstein raised the need for further legislation to help the states deal with climate change and coordinate responses across state boundaries. He noted that there is an “enormous range of things in the executive branch that [the president] can do, short of a legislative fix.” These things include directing agencies to consider, pursuant to NEPA processes, the potential of their actions to exacerbate or improve the conditions created by the global climate change crisis. These could be done by executive directive with no additional legislation. If the next U.S. president is willing to use the bully pulpit to actually declare the emergency that global climate change truly is, that declaration alone would go a long way toward changing attitudes and ultimately making the necessary changes to mitigate and adapt to climate change.

Figure 5: Rising impacts of global warming



THERMOMETER ART COURTESY OF PEW ENVIRONMENT GROUP

9. Recommendations and Conclusion

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Oregon Islands National Wildlife Refuge, a rocky coastal haven for seabirds, seals, sea lions and other wildlife, is one of many areas where warming-related changes in ocean currents are rattling the marine food chain.

Mitigation and adaptation are inextricably linked, but the most fundamental need in responding to climate impacts due to global warming is to reduce the primary cause, greenhouse gas emissions. Efforts to pursue safe and reasonable measures to reduce greenhouse gas emissions must be supported because the reality is that there is only so much we can do on the management side to help wildlife to survive through adaptation. Given the lag time in the climate system, it is imperative that we act now to reduce greenhouse gas emissions. Some species and some ecosystems, such as those found in Arctic or high alpine regions, may already be beyond the system's resilience or ability to adapt. It is hard to imagine how the loss of pack ice or the acidification of our oceans can be reversed without an aggressive response.

A national dialogue is necessary. Society and our government must face the biggest environmental question: *At what level do we stop emitting additional greenhouse gases into the atmosphere and stop interfering with the climate system?* All other aspects of climate change, species and habitat survival and energy supply should derive from answers to that question. The gathered panel of scientists and experts convened for this symposium agreed that the answer is that *greenhouse gas emissions must be capped at or near where they are at present.*

We must act now. There is still hope. By taking immediate and aggressive action so that warming can be stabilized at only 2°C or 3°C, we can avoid the worst of the predicted extinction wave.

Beyond the immediate need to reduce greenhouse gas emissions, 10 specific recommendations for helping wildlife adapt to the impacts of global warming emerged from the symposium. These recommendations fall into three broad categories: (1) buying time while we "act and study;" (2) moving forward with plans to manage wildlife and land resources under increased global warming; and

(3) providing a legislative framework and new conservation paradigm to forge solutions.

BUYING TIME

1. Apply proven approaches to maintain resilience in managing under uncertainty.

Our current understanding of climate science and species' response to climate change is insufficient to model and make precise predictions. We do, however, know enough to guide some prudent actions. The suite of conservation practices and approaches currently employed continues to serve some of the needs, thereby buying time for us to make the investment necessary to narrow the uncertainty. Building the resilience of natural systems, for example, is one strong tool in the current conservation toolkit.

Numerous proven conservation efforts contribute to ecosystem resilience. Acquiring and safeguarding protected areas creates safe havens from which future biogeographic patterns will emerge. Adding corridors restores natural connections to the landscape. Stopping tropical deforestation and promoting reforestation contributes to climate mitigation and protects important areas of biological diversity and vital ecological services. Reducing other non-climate stresses such as unsustainable harvests, invasive species introduction, pollution and habitat loss and degradation is also important. These other stressors can interact synergistically with climate change stresses, making it more difficult for organisms, communities and ecosystems to respond to the climate impacts. Proven conservation efforts are essential, but we need to do more. Future management decisions must be based on a much longer temporal scale and, most importantly, on preventing ecosystems from exceeding critical threshold levels.

2. Ameliorate the impacts that human adaptation to climate change actions will have on wildlife and habitat.

Society, governments and institutions that provide for basic human services such as water, sanitation, energy and agriculture are already being affected by global warming and will face an increasing need to adapt to the impacts. However, not all human-centric adaptations are compatible with natural ecosystem conservation. For example, farmers are planting alternative crops to supply biofuels rather than food, but these alternative crops require more water. Deserts are being gouged to support the solar panels that now blanket large sectors of the arid landscape. Water is being diverted in anticipation of changing snowpack and spring runoff rates. Bulkheads are being constructed along coastlines to address sea level rise in terms of human property loss, but they also prevent natural coastlines from rebuilding. Public health officials are proposing pesticide-spraying programs to respond to an expanding range of disease-carrying insects moving north into new areas.

The environmental cost of these secondary and tertiary climate change impacts may be significant and far worse for the environment than the primary climate impacts on species and natural habitat. Human responses to climate change will be aggressive and additive and will have significant and proximate effects on fish and wildlife, if more appropriate responses to the climate threat are not implemented.

3. Identify the questions needed to frame our response to the threat posed by global climate change.

Wildlife and resource managers will need a new suite of monitoring and analytical tools to guide future conservation efforts. This will require that scientists and managers work in closer collaboration. Scientists have a particular challenge in this respect: To be more aggressive about working with managers and framing research questions that are truly relevant to the needs of management and policy. Analytical tools, models and results must all be promulgated in a way that management can easily use and adapt, given changing conditions and the need for experimentation.

MOVING FORWARD

4. Develop predictive modeling as an integral management tool.

General climate models developed over decades have been invaluable in educating the general public and governments around the world about the impacts of global warming. However, such models are inadequate to guide on-the-ground management decisions relevant to most wildlife and resource managers at the scales at which they typically work. Development of finer-scale models is only beginning, but hopefully will expand over the coming years.

Models focused at the smaller, regional level will be instrumental in indicating where species might find conditions they need to survive in the future. Yet current levels of modeling cannot predict where, when or how species might move to these new areas, assuming travel corridors exist and there are no major landscape obstacles. Nor can existing models predict what will happen when they get there: Will more aggressive competitors or predators occupy the habitat? Will exposure to novel disease pathogens cripple the species' ability to successfully colonize the new area?

If such climate-environment modeling efforts are undertaken, only a limited number of species, populations and areas will benefit from such focused analysis. Some species will be difficult to model as our understanding of their life history, habitat and physiological requirements are too limited. Most likely, only a highly select subset of species, including the most charismatic, will benefit from such analysis. Depending on the degree of global warming, it still remains unknown whether or not wildlife managers will have any options available in real time to assist every species in their adaptation to changing climate conditions.

5. Develop and articulate a common vision.

Climate change is a moral and ethical issue and may ultimately prove to be society's greatest challenge. It not only affects poorer nations disproportionately, but also threatens all life on Earth. The decision on how to respond does not rest solely with scientists, resource managers or even policy makers, but with society as a whole. Implementation of society's response, however, may fall mostly to the scientists, managers, policy makers and other technical specialists.

A common vision of what the management mandate should be under changing climate conditions will help galvanize and focus resources and identify areas in need of innovative solving problems. Within protected areas on public lands this vision must encompass the reality of shifting biomes and changes in phenology and other life history timing events and changes in species range and distribution and community structure. Wildlife and resource managers must know what they will be asked to protect, what the conservation targets are, and what the maintenance of the integrity, diversity and health of a population means under stable climatic changes. What is the vision for the American conservation landscape? For some species that vision must extend beyond our national borders.

Climate change due to global warming is our common enemy. With a shared common vision and joint goals wildlife and resource managers will be better able to work across national, political and generational lines.

6. Invest in many small-scale and reversible pilot projects.

The climate change challenge is too grand and the rate of loss too swift for us to wait to perfect our knowledge before acting. It is clear that a successful strategy for dealing with climate change will ultimately be gained in the face of multiple uncertainties. Wildlife and land resource managers, nongovernmental partners and the research community should shift the incentive patterns to encourage many small-scale and reversible pilot projects and experimental actions.

An incentive program that invests in innovations and proactive creation of future wildlife habitats is needed. Successful examples exist, such as micro-credit programs used to promote overseas development assistance. These foreign assistance dollars help to fund innovators looking for entrepreneurial means to reduce energy use, restore habitat or encourage climate change adaptation experimentation and associated pilot projects.

7. Institute an adaptive management approach and learn through action.

The concept of experimental management must guide our response to current climate impacts and future climate changes. Adaptive management is an experimental and proactive management process. More studies of species and habitat must be supported. Experiments must be crafted with providing habitat for refugee species and examining the problem of migrating climate impacts in mind. Adaptive management approaches must be encouraged by state, federal and other land managers. Further delay in working out all the uncertainty in various strategies means that climate will have changed yet again and the guidance developed may be of little use. A system of comprehensive monitoring will also be essential. We must take bold steps now.

8. Adopt landscape-level and seascape-level planning.

Current protected or conservation areas are too small, too fragmented and too surrounded by human-altered lands for maintaining the integrity, diversity and health of the nation's fish and wildlife populations. Protected and conservation areas must therefore be reintegrated into the broader landscape. This will require new tools, new ideas and, most especially, new relationships. The wildlife and conservation community will need to build new relationships, think across disciplines and boundaries and apply different temporal and spatial scales. Federal, state and private landowners must begin working together at a broader landscape level that addresses not just the ecological challenge, but also social, economic and cultural limitations.

The concept of landscape-level management is not new. Ecosystem-based management has been practiced within certain management units. However, in the context of addressing climate change, it requires planning well beyond the management unit, a far longer time horizon and the incorporation of all components and stressors wherever they occur. Global warming will have increasingly greater influence as habitat shifts, temperature or moisture levels exceed species' tolerances and protected areas come under increased pressures.

Species will try to move into already established communities or move out of protected areas and into inhospitable landscapes. Threats to protected lands and conservation areas will likely exceed anything we have ever seen. To protect species, habitat and the ecosystem services that they provide, we will have to change the *status quo* of our management approaches.

FRAMEWORK FOR SOLUTIONS

9. Develop a national strategy and enact legislation to address the impacts of global warming on wildlife.

Existing legislation, such as the Endangered Species Act, National Environmental Policy Act, Marine Mammal Protection Act and the Clean Air Act, is being used to tackle some of the threats associated with global warming. It is clear, however, that the architecture of these acts does not fully address most climate change threats. New legislation is needed to address impacts of global warming on wildlife. The Global Warming Wildlife Survival Act is the type of legislation that is needed. A central provision of this legislation is the required development of a national strategy to respond the climate change impacts on wildlife survival.

10. Develop a new conservation paradigm.

One of the most difficult tasks facing conservation biologists addressing the impacts of global warming is to develop a new conservation paradigm. We must question and critically examine the scientific and technical underpinnings of many of our academic disciplines. Revising principles under very different spatial and temporal scales of climate change can be equally intimidating. Science-driven management will need to be revised with observational data provided by on-the-ground managers as well as researchers. A well-defined system of monitoring will be essential in developing this paradigm. Ultimately, as the new conservation paradigm takes form, it will be essential to deal with the inherent uncertainty in the climate and biotic systems. It will be necessary to cultivate a new cohort of wildlife and conservation professionals who can serve as the intellectual workforce to face all of the daunting climate change challenges well into this century and beyond.

CONCLUSION

Defenders' Executive Vice President Jamie Rappaport Clark closed the symposium with a call to action. "All of us can agree that climate changes everything we have ever known about conservation. Mitigation and adaptation have been emphasized as appropriate societal responses to global warming, and both are important and neither is enough alone. It is also clear that global warming is compelling us to rethink the basic concepts of ecology and land management. And we need to let the public know honestly and quickly that nature needs our help. Responding effectively will require our country to recommit ourselves to our nation's wildlife and wild places by providing significantly greater resources and by making global warming a priority at all levels. But the most important steps that we take are the ones that we take now. We cannot ignore this issue."

"This is surely a time for great vision, for innovation and for creativity."

–Jamie Rappaport Clark, Executive Vice President, Defenders of Wildlife

Appendix A

Innovations in Wildlife Conservation: Reducing the Impact of Global Warming on Wildlife

Symposium Agenda

7:30-8:00 a.m. **Registration and Continental Breakfast**

8:00-8:15 a.m. **Welcome and Opening Remarks**
Dr. Rodger Schlickeisen, Defenders of Wildlife

8:15-9:00 a.m. **Keynote Address**
Dr. Thomas E. Lovejoy III, The Heinz Center for Science, Economics and the Environment

9:00-10:30 a.m. **Panel 1. Science and Impacts: Global Warming and Wildlife**
Moderator: Dr. Barry Noon, Colorado State University
Dr. Glenn Juday, University of Alaska
Dr. Charles H. "Pete" Peterson, University of North Carolina
Dr. Terry Root, Stanford University

10:30-11:00 a.m. **Coffee Break**

11:00-12:30 p.m. **Panel 2. Adaptation Strategies: Wildlife Management and Climate Change**
Moderator: Dr. H. Ron Pulliam, University of Georgia
Dr. Bryan Norton, Georgia Institute of Technology
Dr. J. Michael Scott, University of Idaho and U.S. Geological Survey
Dr. Lara Hansen, World Wildlife Fund U.S.

12:30-2:00 p.m. **Lunch and Featured Speaker**
The Honorable Norman D. Dicks, U.S. House of Representatives (D-Wash.)

2:00-3:30 p.m. **Panel 3. Policy Response: Government, Citizens and Global Warming**
Moderator: Mr. Eric R. Glitzenstein, Meyer Glitzenstein & Crystal
Mr. Daniel Ashe, U.S. Fish and Wildlife Service
Mr. David J. Hayes, Latham & Watkins
Mr. Michael Mantell, Resources Law Group LLP
Ms. Deborah L. Williams, Alaska Conservation Solutions

3:30-4:30 p.m. **Final Discussion and Closing Remarks**
Moderator: Ms. Jamie Rappaport Clark, Defenders of Wildlife
Dr. Barry Noon
Dr. H. Ron Pulliam
Mr. Eric R. Glitzenstein

Appendix B

Innovations in Wildlife Conservation: Reducing the Impact of Global Warming on Wildlife

Symposium Panelist Biographies

Daniel Ashe is the science advisor to the director of the U.S. Fish and Wildlife Service, appointed to this position in March 2003. He previously served as the chief of the National Wildlife Refuge System, the service's land acquisition program, and has directed the service's migratory bird management and North American wetlands conservation programs.

The Honorable Norman D. Dicks represents Washington state's 6th District in the U.S. House of Representatives. A native of Bremerton, Wash., Rep. Dicks received his undergraduate and juris doctor degrees from the University of Washington. He served on the staff of Senator Warren G. Magnuson prior to being elected to the House. Now serving his 16th term, Rep. Dicks is chairman of the Interior Appropriations Subcommittee and a sponsor of the Global Warming Wildlife Survival Act.

Eric Glitzenstein is a partner with the Washington, D.C.- based public interest law firm of Meyer Glitzenstein & Crystal. The firm specializes in federal and state court litigation on wildlife, animal protection, environmental and energy issues.

Dr. Lara Hansen is the chief climate change scientist for World Wildlife Fund, and leads their impacts and adaptations program. Her main focus is the redesign of conservation strategies to incorporate responses to climate change.

David J. Hayes is the global chair of the environment, land and resources department at Latham & Watkins, where his practice focuses on counseling, litigation and transactions involving energy, environmental, and natural resources. He served as the Deputy Secretary of the Interior during the second term of the Clinton administration, and played a lead role in many of the department's most difficult and important matters.

Dr. Glenn P. Juday is a professor of forest ecology in the school of natural resources and agricultural sciences at the University of Alaska. He specializes in forest biodiversity, climate change assessment, climate change and forest growth, and old-growth forest ecology.

Dr. Thomas E. Lovejoy is the president of The Heinz Center. Before coming to the center in 2002, he served as the World Bank's chief biodiversity advisor and lead specialist for environment for Latin America and the Caribbean, and senior advisor to the president of the United Nations Foundation. Dr. Lovejoy has also been assistant secretary and counselor to the secretary at the Smithsonian Institution, science advisor to the U.S. Secretary of the Interior, and executive vice president of World Wildlife Fund–U.S.

Michael Mantell is an attorney with Resources Law Group LLP, a multidisciplinary firm he founded in 2000 to design and administer conservation initiatives for philanthropic foundations and other private and public sector interests. He previously served as undersecretary for resources for the state of California, as general counsel for World Wildlife Fund and as director of the land, heritage and wildlife program of The Conservation Foundation.

Dr. Barry Noon is a professor of wildlife ecology in the department of fishery and wildlife biology at Colorado State University. He specializes in the application of ecological concepts and theory to environmental problems.

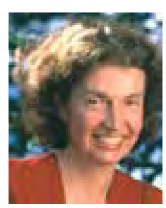
Dr. Bryan Norton is a professor in the school of public policy at Georgia Tech. He works on intergenerational impacts of policy choices, endangered species policy, sustainability theory and cultural aspects of environmental protection.

Dr. Charles (Pete) Peterson is an alumni distinguished professor in the institute of marine science at the University of North Carolina. He specializes in natural resource management, fisheries management, environmental regulation and ecosystems ecology.

Dr. H. Ronald Pulliam is a professor of environment and ecology at the University of Georgia. He was the director of the National Biological Service under U.S. Secretary of the Interior Bruce Babbitt and later science advisor to the secretary. He is also the former president of the Ecological Society of America and serves on the board of the National Council for Science and Technology.

Dr. Terry Root is a research fellow at Stanford University. She specializes in wildlife population and distribution response to changing climate.

Dr. J. Michael Scott is a professor at the University of Idaho's department of fish and wildlife as well as a senior scientist with the U.S. Geological Survey. His research areas of interest include the limiting factors of endangered species, estimating animal numbers and ornithology.



Deborah L. Williams is founder and president of Alaska Conservation Solutions, an organization devoted to addressing the effects of global warming on Alaska and its wildlife. Williams has also served as the executive director of the Alaska Conservation Foundation, special assistant to the U.S. Secretary of the Interior for Alaska during the Clinton administration, and as a representative of the National Park Service and the U.S. Fish and Wildlife Service in Alaska.

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