

Chapter 9

Natural Resource Stewardship

The Earth's natural systems were in trouble long before global climate change became a visible issue. Most of the trouble can be traced to rapid growth in human population and the corresponding consumption of natural resources for human needs.

When the first members of the Baby Boom generation were born 60 years ago, the world's population was 2.3 billion. It took more than 10,000 generations for the population to reach that point.¹ It has taken only one lifetime for the number to nearly triple, to 6.5 billion. As our numbers have grown, so have our demands on Earth's living systems and finite natural resources.

The expanding footprint of human settlement, combined with unsustainable consumption of natural resources, is resulting in habitat loss, pollution and the spread of invasive species via global commerce. This toll on natural diversity, productivity and vital ecological functions is compounded by a warming planet with changing precipitation patterns. These changes are altering habitat ranges and threatening to "disassemble" entire ecosystems; causing mismatches among interdependent species in the timing of budding, migration, pollination, etc.; increasing infestations and diseases that favor warmer conditions; causing saltwater intrusion and threatening inundation of coastal habitats; and increasing extinctions, especially among rare or highly specialized species.

Some of these changes will be systemic, with global ramifications (e.g., ocean acidification); others will vary, with damage and costs borne most heavily in some

regions (e.g., polar regions and high northern latitudes, tropical highlands, Africa). (See Figure 1 for projected regional impacts within the United States.)

Dr. Peter Raven, director of the Missouri Botanical Gardens, projects that if the present rate of habitat loss continues, we are likely to experience a yearly extinction of 15,000 species due to the destruction of habitat alone – just one factor in the loss of biodiversity.²

“Over the past 50 years, humans have changed ecosystems more rapidly and extensively than in any comparable period of time in human history, largely to meet rapidly growing demands for food, fresh water, timber, fiber, and fuel,” the Millennium Ecosystem Assessment reported. “This has resulted in a substantial and largely irreversible loss in the diversity of life on Earth.”³

The Economics of Ecosystems

Natural systems perform critical “ecosystem services.” Among them are pollination (vital to agriculture), water filtration and storage (vital to fresh water supplies), oxygen production (vital to breathing), raw materials (vital to industry), flood control (vital to life and property), natural beauty (vital to the tourism industry), fish and wildlife (important to sportsmen and sportswomen) and carbon sequestration (to reduce global warming). By one calculation, the average value of these services is \$33 trillion annually, nearly twice the global GDP (\$18 trillion).¹

The Millennium Ecosystem Assessment identifies four types of ecosystem services:

- 1. **Provisioning services:** The products obtained from ecosystems, including, for example, genetic resources, food (plant and animal) and fiber, and fresh water.*
- 2. **Regulating services:** The benefits obtained from the regulation of ecosystem processes, including, for example, the regulation of climate, water, and some human diseases.*
- 3. **Cultural services:** The non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experience, including, e.g., knowledge systems, social relations, and aesthetic values.*
- 4. **Supporting services:** Ecosystem services that are necessary for the production of all other ecosystem services. Some examples include biomass production, production of atmospheric oxygen, soil formation and retention, nutrient cycling, water cycling, and provisioning of habitat.¹*

Losses and reductions in these natural services will be reflected in the economy as will the costs of mitigation and adaptation to a rapidly changing climate. The Stern Review, produced by Nicholas Stern, former chief economist of the World Bank, estimates that “if

we don't act, the overall costs and risks of climate change will be equivalent to losing at least 5% of global GDP each year, now and forever. If a wider range of risks and impacts is taken into account, the estimates of damage could rise to 20% of GDP or more.”¹

“In contrast,” the report further notes, “the costs of action – reducing greenhouse gas emissions to avoid the worst impacts of climate change – can be limited to around 1% of global GDP each year.” It summarizes “The investment that takes place in the next 10-20 years will have a profound effect on the climate in the second half of this century and in the next. [Failing to act now] and over the coming decades could create risks of major disruption to economic and social activity, on a scale similar to those associated with the great wars and the economic depression of the first half of the 20th century. And it will be difficult or impossible to reverse these changes.”¹

Some of the costs of a rapidly changing climate are obvious; others are more subtle.

- *Extreme weather is extremely costly -- 2005 set records as the costliest year for extreme weather with more than 200 billion dollars in losses, of which insurance companies were hit with covering \$70 billion dollars. Wilma, the strongest-ever hurricane, caused an estimated 15 billion dollars in economic losses. Damages caused by Katrina, the sixth strongest hurricane on record, were significantly greater, estimated at 125 billion.¹*
- *If water levels continue to decline in the Great Lakes, shippers, consumers and taxpayers will foot the bills. Shippers estimate that \$22,000 to \$28,000 of cargo has to be removed from each carrier for every inch of water the lakes lose,¹ and in 2007, Lake Superior dropped to near record lows. Dredging would be environmentally dangerous and costly. One estimate projects annual dredging costs to maintain shipping may run at a minimum of \$75million to \$125 million a year.¹*
- *Tree losses from warm-weather invasive species like the mountain bark beetle have already wreaked havoc on the timber economy of British Columbia and the Pacific Northwest. In British Columbia alone, which has lost up to 40% of its lodgepole pines, one estimate places the value of the lost timber at a \$32.5-billion direct loss to the forest industry, and an additional loss of between \$4.5 and \$6.5 billion to the government from lost revenue from stumpage fees and licenses.¹*

The 2007 Intergovernmental Panel on Climate Change (IPCC) report states, “The resilience of many ecosystems is likely to be exceeded this century by an unprecedented combination of climate change associated disturbances (e.g., flooding, drought, wildfire, insects, ocean acidification), and other global changes drivers (e.g. land use change, pollution, over-exploitation of resources.)”⁴

Allowing ecosystems to degrade is a failure in stewardship and imperils human well-being and economic security. Increasingly, a growing number in both the faith and secular communities now consider climate change to be an ethical issue – evidence that we are not caring for creation or the welfare of future generations. Jim Wallace, author of *God's Politics*, observes, “Our earth and the fragile atmosphere that surrounds it are God's good creation. Yet, our environment is in jeopardy as global warming continues unchecked and our air and water are polluted. Good stewardship of our resources is a religious and moral question.”⁵

Anthropogenic greenhouse gas emissions are, in effect, an additional encroachment on one of the most sensitive of Earth's systems, the atmosphere. Under a business-as-usual scenario, with the global population expected to climb to more than 9 billion people by mid-century, climate change alone will lead to devastating, irreversible losses of ecosystem services, species and biodiversity. “Approximately 20-30% of plant and animal species assessed so far are likely to be at increased risk of extinction if global average temperatures exceed 1.5-2.5° C.” the IPCC estimates.⁶

Most natural resource management strategies are based on assumptions drawn from human experience over the last 10,000 years—a particularly stable period in Earth's climate history.⁷ A longer view shows that climate change patterns often are abrupt, based on thresholds and filled with environmental upheaval. The pace and scale of predicted ecological impacts from climate change may be the single largest threat to ecological vitality in human history, and will require an unprecedented response by human institutions. In addition to responding to ecological changes driven by greenhouse gasses and traditional stresses, we should anticipate and plan to minimize potential environmental impacts from new energy strategies. Our rapid response to reduce greenhouse gasses should be designed in ways that solve, rather than create, other environmental and social problems.

Presidential leadership will be essential to the commitment and resources the United States needs to develop and sustain responsive environmental management and protection strategies.

Key Issues in Brief

► Unstable climate; unstable ecosystems

As the climate continues to change, scientists project an increasing likelihood of less stable weather and more extreme weather events, and thus less stable growing conditions for forests, grasslands and crops. This trend includes more variability (e.g., extremely dry periods followed by extremely wet periods), as well as increased frequency and intensity of heatwaves, droughts, and floods.⁸ We can also expect more intense precipitation events, such as downpours and hurricanes.⁹ All of these influences will affect the viability and resilience of natural systems.

Average temperature increases are just that: *averages*. Some areas will experience much more significant warming than others. Models show that some of the most dramatic shifts will happen to the polar regions and high northern latitudes. Rapidly melting sea ice will threaten the loss of entire ice-dependent ecosystems; melting permafrost will change entire habitats and release greenhouse gasses into the atmosphere.¹⁰ A major concern, for example, is the permafrost in Siberia, an area of 1 million km² that has been frozen since the last ice age. This area is storing an estimated 70 billion tons of stored carbon, 10 times the amount emitted each year from anthropogenic sources.¹¹

Drought-stressed parts of the world including major regions in Africa, are trending toward more intense and prolonged drought conditions.¹²

Other particularly sensitive ecosystems include: northern and boreal forests, alpine and other mountain habitat, coral reefs, mangroves and other coastal wetlands, prairie wetlands, remnant native grasslands; coldwater and some coolwater fish habitat; and ecosystems overlying permafrost.¹³ Because increases in evaporation from warmer

conditions are expected to exceed projected increases in precipitation in many areas of the world, freshwater habitat, from wetlands to lakes and rivers, is likely to diminish.¹⁴

The broader consequences of ecological upheaval from climate change will be the loss of sensitive ecosystems and species, the loss of ecosystem services (and the resulting increased competition for shrinking resources such as fresh water), the loss of cultural and aesthetic values, and mass extinctions. Although polar ecosystems will be disproportionately affected, ecological changes at the lower latitudes will also raise serious environmental, social, humanitarian, and security concerns.

► **Shifting ranges, unraveling ecosystems**

Plants and animals are adapted to particular climate ranges, and even small changes in temperature or moisture can make a landscape unsuitable habitat for some species. Gardeners and farmers are familiar with plant hardiness maps that serve as guides for which kinds of plants will thrive in their region. Growing conditions in the U.S. have warmed significantly over the last 15 years, and the revised (2006) U.S. Arbor Day Foundation hardiness map shows a definitive northward shift of the warmer zones.¹⁵ (Click [here](#) to see an animation of the shift.) This map also illustrates the regional variations within the larger warming trend. Some areas, such as Texas, have experienced widespread and significant warming; changes in northern New England are notable, but less dramatic.

While a gardener can opt to plant a different flower variety as climatic conditions change, entire forests and grasslands are not so flexible, nor are many of the species that depend on them. Similarly, coral reefs, alpine meadows and other threatened ecosystems are often fixed in their geographic location, and shifts are not possible.

Much of Earth's living landscape is dominated by human settlement, and natural habitats are highly fragmented.¹⁶ As a result, in much of the world, we now lack the natural corridors that might enable species to transition to new ranges. Even where corridors

exist, other factors such as different soil conditions and topography may pose barriers to successful transitions to new locales.

Forests provide a good illustration of the scale and scope of shifting ranges. In the United States, the iconic maple forests of New England will fade from a landscape that will be too warm and potentially too dry to sustain them. The northern pine and hemlock forests of the upper Great Lakes are likely to disappear from the “north country,”¹⁷ and the aspens that fill the slopes of the Southern Rockies may be more suited to habitat in Canada.¹⁸

As ranges shift, so will species composition. Even when species can move in and out of systems, we cannot expect that they will do so in cohesive units. “Individual species will very likely migrate at different rates and have different degrees of success in establishing themselves in new places,”¹⁹ according to the U.S. Global Change Research Program (USGCRP).

A new study forecasts that entire climates and unique ecosystems may disappear from the Earth. “In general, the models show that existing climate zones will shift toward higher latitudes and higher elevations, squeezing out the climates at the extremes—tropical mountaintops and the poles—and leaving room for unfamiliar climes and new ecological niches around the equator...The most severely affected parts of the world span both heavily populated regions, including the southeastern United States, southeastern Asia, and parts of Africa, and known hotspots of biodiversity, such as the Amazonian rainforest and African and South American mountain ranges.”²⁰

Modeling has become increasingly reliable in projecting changes, but when we face change at the scale of entire ecosystems breaking up and reassembling, we can't be certain about how well reassembled systems will function.²¹ It isn't safe to assume that entirely different and unknown systems will provide the same ecological functions and services that currently support human life and well-being and diverse species.

Modeling and Projections

Models and computer programs are often used to predict the impacts of climate change. According to the Intergovernmental Panel on Climate Change's (IPCC) most recent assessment, the confidence in climate models is high and is constantly improving.²²

There still may be some uncertainty in modeling as it relates to specific variables, such as the impact of cloud cover, but climate models typically err on the conservative side. An article in Science magazine asserts that models from the IPCC tend to underestimate impacts from climate change, such as the affect on sea level.²³ A recent study from the National Snow and Ice Data Center and the National Center for Atmospheric Research also states the models underestimate the loss of ice in the arctic.²⁴

The accuracy of predictions is tested by comparing the modeled data to previous years' known climate information. Consistent analysis also occurs to allow for a high degree of certainty in the data and fine tuning of the models continues to occur.²⁵

Hundreds of thousands of species could be threatened by global warming, from massive predators to tiny insects. Polar bears, salmon, Edith's Checkerspot butterfly, Adelie penguins, California Quail, New England sugar maples, the southwestern willow flycatcher, bighorn sheep, and loggerhead sea turtles, are only a tiny sample of what could disappear from the tapestry of life. With them, they will take the functions they played in the global ecosystem, a storehouse of genetic information, sources of food, medicine, natural beauty and ecological resilience.²⁶

► The trouble with timing

Migration, budding, seed dispersal, nesting patterns, etc., are all part of a grand and complex rhythm of biological behaviors and the optimal environmental conditions to express them, within and across species. The rapid rise in global average temperatures is tinkering with nature's own "biological clock." In this case, however, it isn't so much about running out of time as it is about getting misleading cues as to when to act, and being out of synch with what is happening with other interdependent species and local

conditions. For example, warmer winter conditions are cueing many migratory bird species to fly north earlier in the spring than they did historically. They can starve, however, if local insects upon which they feed haven't yet hatched at the sites where they rest and nest.

Migratory species aren't the only ones being confused by mixed signals in seasonal patterns and conditions. In the plant world, many cold-climate species require a cold dormant period in their life cycle. Northern oak species, for example, require 30-40 days below 40 degrees Fahrenheit over the course of a winter for successful reproduction.²⁷ The sweet sap run of maple trees is triggered by days above freezing and nights below freezing that typically used to happen in March. Over the last 20 years, sap runs have shifted, and now are more likely to occur in February. Early sap runs are an outward sign of an altered life cycle for maples, which in turn, may be an indicator of their diminishing ability to survive in their native zone as temperatures rise.²⁸

Changing seasonal conditions have long-term implications for the survival and range of many other species. Evolutionary adaptations are unlikely to keep pace with the rapid pace of climate change, further exacerbating the disassembly of ecosystems and the likelihood of extinctions.

► Invasion of warm-weather pestilence

Warmer temperatures, or aspects of them such as warmer nights, or shorter winter freeze periods, have opened whole new ranges and capabilities for a wide variety of pests. In most cases, their host environments are not adapted to successfully resist these new species, and widespread damage and mortality is the result.

The aggressive spread of mountain pine bark beetles in the Rockies and Northwest Canada is a widely cited example of the complex relationship between forests and forest pests, and the difference a few degrees in winter temperatures can make. Over the last several decades, winter conditions have warmed enough for the mountain pine bark beetle to explode in the vast lodgepole pine forests of the western U.S. and Pacific

Canada. The *New York Times* reports that the Canadian infestation “may be the largest forest insect blight ever seen in North America, and it seems nowhere near its peak... Officials expect 80 percent of British Columbia’s mature lodgepoles to be dead by 2014,”²⁹ with the attendant loss of wildlife habitat and timber for the forest economy, plus a higher risk of wildfire. Fewer trees also mean less carbon sequestration.

While the western pine bark beetle is feasting on conifers in the Rocky Mountain foothills, farther north in Alaska, a biologist reports that “the spruce budworm, aspen leaf miner and the spruce bark beetle, pests once kept in check by winter cold, are flourishing here. Statewide, insect outbreaks have killed more than 4 million acres of forest in a decade and a half.”³⁰

Warmer temperatures are opening the door for other types of invasive and damaging pests in other ecosystems. The invasive zebra mussel in the Great Lakes is devastating the native fishery, filling beaches with broken shells, and costing municipal drinking water systems billions of dollars. Lake Superior, the largest and coldest of the Great Lakes, has so far been spared this damage because it is too cold for zebra mussel reproduction. But there, too, temperatures in are rising, with summer surface temperatures of Lake Superior having increased approximately 2.5°C since 1979,³¹ and thus it may be only a matter of time before the lake can support zebra mussels and suffer their effects on the foodweb and beyond.

In Hawaii, warmer conditions on mountain slopes are enabling avian malaria to invade more territory of the few remaining native honeycreeper populations in the islands.³² At the global and species scale, global warming is a key factor in the rapid extinction of frog and amphibian species around the world, as warmer temperatures facilitate the spread of disease. According to a leading researcher: “Disease is the bullet killing frogs, but climate change is pulling the trigger...global warming is wreaking havoc on amphibians and will cause staggering losses of biodiversity if we don't do something first.”³³

Throughout the world, warmer temperatures are laying the groundwork for unprecedented pests and diseases that will diminish biodiversity and ecological resilience and degrade ecosystem services.

► **Forests ablaze and on the move**

Projections indicate that we will see major changes in ecosystem composition around the world, and forests will be among the most affected systems. The massive pine die-offs in the North American West and Northwest are already changing the ecological structure and function of thousands of acres of forestlands. Globally, “over half the world's boreal forest could disappear due to the effect of climate change as conditions shift.”³⁴ And, as noted, forest ranges are changing dramatically. The EPA projects “that a 2° C warming could shift the ideal range northward, or higher in altitude, for many North American forest species by 200 miles over the next century.”³⁵

Some forests, such as those in the American South, may benefit from increased precipitation, but this may shift species toward hardwoods and away from conifers, which are currently the dominant species for commercial harvest in the South.

Scientists have viewed tropical rainforests as a vital factor in climate stabilization, but rainforest productivity and capacity to sequester carbon are not givens, and vary by region. In Panama and Malaysia, “Tree growth rates have decreased dramatically for the majority of species in two lowland tropical forests over the past couple of decades,” notes a Harvard Study.³⁶ Such decreases could have negative impacts on wildlife, human communities, and strategies for carbon sequestration. In some cases, warmer temperatures may be increasing the CO₂ that rainforests release and reducing the amount they sequester. Drier and warmer conditions are also reducing the cloud cover that defines cloud forests on tropical mountainsides, changing the composition of life that depends on these environments.³⁷

As noted, warmer conditions have fostered a wide range of pests that are damaging forest health, resilience, and productivity. Pest damage can have a ripple effect on other species beyond the trees. In forests infested with the mountain pine bark beetle, for example, one of the most damaged trees is the whitebark pine, which produces pine nuts, a particularly important food for grizzly bears, especially in the Yellowstone region. Thus warmer conditions mean more beetles, fewer pines, fewer pine nuts, and possibly fewer grizzlies, because when available, this food source helps the bears build up fat reserves to survive their winter hibernation.³⁸

Stress on many forests will be exacerbated by drier soil conditions. Models project less productivity in forests affected by warmer temperatures and higher evaporation rates, which is the trend for forests of the American West and Midwest. These warmer, drier conditions stress trees and forests, as will extreme variability between wet and dry years. Another source of stress will be regional increases in ground-level ozone because of warmer summer temperatures. All these factors set the stage for more and increasingly intense forest fires.

Already, the intensity and scale of forest fires is on the rise. According to the Consultative Group on Biological Diversity, “The Boise Fire Center, which is the central command point for fighting large-scale forest fires, reports that whereas fires rarely burned more than 20,000 to 30,000 acres throughout the 20th Century, fires now scorch upwards of 500,000 acres at a time throughout western North America. In the past decade, both Alaska and Canada have experienced million-acre fires, while Arizona, California, Montana and Oregon have all experienced the largest forest fires in their recorded history, ranging from 500,000 acres to 740,000 acres. Colorado has also broken records with a 230,000-acre fire. This has a direct impact on our forests and wild areas, as well as on state relief funds and insurance costs.”³⁹

Losses in forest productivity and resilience will have ramifications for primary industries such as logging and forest products and for the human communities depending on them. At a larger scale, losses in forest ecosystem services, from carbon sequestration to

freshwater storage and oxygen production, will have significant impacts on wildlife habitat and human quality of life, as will lost cultural, recreational and aesthetic forest values.

► Shrinking freshwater habitat and water resources

The world is already experiencing fresh water shortages, and a warmer world will have increasing demands for fresh water, even as supplies are likely to diminish.

Many regions of the world depend on mountain glaciers and winter “snowpack” for water resources. Rapid melting rates and warmer weather will strain supplies of water for human needs, agriculture and habitat. All tropical glaciers are expected to be gone in 15 years.⁴⁰ This will have widespread impact on habitats and people that depend on these water supplies, from forests and crops watered by the snows of Mt. Kilimanjaro, to hydropower produced in rivers fed by glaciers in the Peruvian Andes.⁴¹

In the American West, summer water supplies are highly dependent on winter precipitation. Earlier snowmelt means more water is released earlier in the season, which can coincide with rains and produce spring flooding. Less snow held in the mountains means less water in the hotter, drier months. Research shows that the West has enjoyed unusually high levels of precipitation in the last century. The recent drought conditions may be closer to “normal.” The likelihood of shrinking seasonal and long-term water supplies coupled with the region’s growing population requires adaptive strategies—and sooner rather than later. As temperatures and evaporation rates rise, the West will need to consider aggressive conservation strategies to meet human needs and maintain fish and wildlife habitat.⁴²

Cold-water fish species, such as trout and salmon, already affected by loss of habitat from dams and degraded water quality, face additional stress from rising temperatures and shrinking freshwater habitat. “Climate models cannot yet project the most important oceanic conditions for salmon, notes the U.S. National Assessment of Climate Change, “but the likely effects on their freshwater habitat all appear unfavorable. These include: increased winter flooding, reduced summer and fall flows, rising stream and estuary

temperatures, and the possibility that earlier snowmelt and peak spring streamflow will deliver juveniles to the ocean before there is adequate food for them. “Climate change is consequently very likely to hamper efforts to restore already depleted salmon stocks, and to stress presently healthy stocks.”⁴³

Other parts of the world depend on surface and groundwater sources that are more seasonably stable, but which will also be influenced by warmer conditions and changes in precipitation patterns. Nearly one-fifth of the world’s fresh surface water is held in the Great Lakes Basin. While projections show increased precipitation and cloud cover over much of the region, only about one percent of the Great Lakes water supply is refreshed by precipitation each year. Warmer weather will increase water temperatures and evaporation, and lake levels are expected to drop.

Lake levels are cyclical within historic climate patterns, but in 2007, after a prolonged drought, Lake Superior was measured at a level “lower than most people can remember – just above record lows set 80 years ago.”⁴⁴ The low lake levels have hurt commercial shipping, which can’t carry as much cargo, and left some recreational marinas high and dry.

Other large freshwater systems are also sensitive to precipitation and temperature influences. The same drought conditions that are affecting Lake Superior and its shippers have had a similar effect on Mississippi River water levels and the barge industry in 2005 and 2006.⁴⁵ The current drought presents a preview of conditions that may be more common in the region as temperatures rise.

Waterfowl habitat, from prairie potholes, to inland wetlands, to freshwater coastal marshes, is likely to shrink from increased evaporation and less reliable stream flows. Coastal wetlands in marine habitats face saltwater intrusion, and in some cases, total inundation from rising sea levels.

The nation’s largest freshwater wetland, Everglades National Park, supplies the drinking water for 5 million people in South Florida. It is also one of the nation’s most threatened

habitats. In Congressional testimony, Park Superintendent Dan B. Kimball noted that without restoration of natural freshwater flows to act as a saltwater barrier, “Sea level rise would likely push salt water into the Everglades and threaten the viability of South Florida’s drinking water supply.”⁴⁶

From mountain streams to local ponds, to the depths of the Lake Superior, freshwater habitat provides vital resources to humanity, and is among the most important and threatened habitat on earth. The Millennium Ecosystem Assessment states: “The number of species on the planet is declining. Over the past few hundred years, humans have increased the species extinction rate by as much as 1,000 times over background rates typical over the planet’s history (*medium certainty*). Some 10–30% of mammal, bird, and amphibian species are currently threatened with extinction (*medium to high certainty*). Freshwater ecosystems tend to have the highest proportion of species threatened with extinction.”⁴⁷

► **Re-imagining land and resource management**

As we move into a period of extreme uncertainty for ecological stability, we will need the capacity to learn as we go. Scientists, resource managers and policy makers will need research and monitoring tools that will help them assess conditions and trends and synthesize adaptive strategies through an iterative process.⁴⁸ The other key lesson from extreme uncertainty is that our strategies will need to maximize conditions for optimal survival, resilience, and conserving options for the future.

With ecosystem management dispersed across public and private land ownership, as well as multiple agencies and departments, cross-cutting and integrated strategies will be necessary, but challenging to implement under current governance structures. The President has the opportunity to establish cross-cutting leadership teams at the cabinet level and to clarify roles across agencies on ecosystem-scale initiatives.

Within agencies, traditional assumptions about resource management are being challenged by the scope of climate change. During an April 2007, Congressional hearing

on climate, representatives of the Interior Department testified on the changing context for public lands and natural resource management.⁴⁹ Among their observations:

- Park and Refuge boundaries were originally created to preserve a specific mix of species within specific boundaries, but on-site conservation may not be possible within current, fixed boundaries if species composition is changing and moving.
- There may need to be new constraints on the level of allowable uses on public lands due to the loss of productivity and capacity.
- Overall, global warming means more fragile ecosystems, a greater susceptibility to the outbreaks of attacks by parasites and disease, increased vulnerability to wildland fire and erosion, and an overall reduction in the carrying capacity of the land.
- Federal agencies need better research and monitoring capabilities to stay abreast of changes and anticipate trends. Focal areas included drought, permafrost thawing, snowpack runoff and wildland fire. In addition, the United States Geological Service (USGS) representative expressed the need for “broader, more consistent national coverage of the effects of climate change” and improved models to provide a better picture of local changes.⁵⁰

A concerted, multi-agency partnership will be needed to pursue conservation and management strategies that will protect natural resources, habitat and species in an era of rapid climate change.

In addition to addressing practical challenges for how agencies will need to adapt and function during a time of rapid ecological change, many are questioning the fundamental assumptions in legal and regulatory systems for natural resources management. Do old approaches still serve our needs?

Legal scholar Christina Wood points out: “Global warming is leagues beyond what Humanity has ever faced before.”⁵¹ Scientists warn that, to stave off climate disaster, society must dramatically reduce carbon emissions within the *coming decade*.⁵² Albert

Einstein once said, ‘We cannot solve our problems with the same thinking we used when we created them.’⁵³ The next President of the United States must lead a seismic paradigm shift that creates unwavering governmental obligation to protect the atmosphere and all other natural resources.’⁵⁴

She argues that paradigm shift needs to be away from one where “Agencies portray the environment as a nebulous feature of our world and use permit provisions in environmental statutes to allow massive, unending injury to public resources” where “there is no end in sight to resource destruction.⁵⁵” Instead, she suggests that “Our new leaders can and must reframe government’s *discretion* to destroy Nature into an *obligation* to protect Nature and to ensure Natural Resource Stewardship.⁵⁶”

She describes a “Nature’s Trust” framework, in which “Nature’s Trust principles give force to the economic approach of natural capitalism, which requires businesses to build profits by using Earth’s interest, not the capital.⁵⁷ These principles also crystallize moral accountability: failure to protect Nature’s Endowment amounts to generational theft. Boundless across time, planetary in scope, and holistic in approach, Nature’s Trust principles will define leadership of a new world – a world in which all nations on Earth are united in an urgent defense effort to secure the natural systems on this planet for present and future generations of Humankind.”

Given the scale of ecological threat to the planet and humankind, the next President needs to examine the underpinnings of environmental law and policy and shift to a new framework at an unprecedented scale. The Nature’s Trust concept provides a springboard for a new U.S. paradigm in natural resources policy.

► **Impacts on natural resources from shifting energy strategies**

All energy sources, including renewables, can place new pressures on habitat and environmental quality, although some clearly come with more baggage than others. As

the nation charts a new energy strategy, we must avoid creating new ecological damage in the attempt to stem the impacts of global warming.

- **Coal.** In addition to its major role as a source of greenhouse gasses, coal has a long list of other environmental impacts. These include land and watershed damage from coal mining (including ecologically devastating practices such as mountain top removal), the effects of acid gasses and mercury emissions on aquatic life, forest damage caused by ground-level ozone, consumptive water withdrawals from lakes and streams for steam production, and air pollution that damages human health.
- **Oil.** In simplest terms, when it comes to oil, “every stage in the life cycle from exploration to use can have harmful effects on our health and the environment.”⁵⁸ Environmental impacts include oil spills and slicks from production and shipping accidents, smog and particulate pollution, and of course, carbon dioxide.
- **Natural Gas.** Although natural gas is a fossil fuel, it emits much less nitrogen oxides and carbon dioxide than oil or coal combustion. As with other fossil fuels, however, there are environmental impacts from extraction (drilling on and off shore) and distribution systems (e.g. pipelines and storage facilities.) Incomplete combustion of natural gas can release methane, a damaging greenhouse gas 20 times more powerful than carbon dioxide in trapping heat in the atmosphere. There are promising sources for capturing methane as a fuel source from landfill gasses and animal waste digesters.
- **Nuclear Energy.** While fission itself does not produce carbon emissions, studies indicate that nuclear power is linked to considerable carbon releases over its life-cycle through energy use related to mining, fuel enrichment, transportation, construction and maintenance of nuclear power plants, and the storage of radioactive wastes. Other environmental impacts from nuclear energy include landscape degradation and radioactive contamination from uranium mining and its wastes (as well as health impacts on mine workers), releases of radioactive steam, cooling water and gasses from reactor and waste storage accidents, and the unresolved issue of the “eternal” storage of radioactive wastes.

- **Hydropower.** There are many forms of hydropower, some of which have fewer environmental impacts than massive dams that alter entire watershed ecosystems. Smaller scale projects that incorporate designs to minimize or bypass barriers to spawning and/or those designed to reduce fish mortality (from being caught in water intakes or turbines) may have less impacts on rivers and ecosystem.
- **Marine Energy.** A variety of approaches are being developed to harness the energy of waves, tides, and currents. Depending on design and siting, these projects may pose some risks for fish or marine habitat, but may have less visual impact than wind energy.⁵⁹
- **Biofuels.** Heavy reliance on crop-based biofuels is likely to affect habitat and biodiversity in agricultural regions and aquatic systems, especially if new acreage—currently fallow or in conservation reserve—is brought into corn or soybean cultivation. Loss of pastureland, woodlots, and fallow acreage may alter or destroy existing habitat. Moreover, shifting these lands to traditional cultivation will increase sedimentation and aquatic dead zones.
- **Wind Power.** Careful planning to site towers outside of migration corridors and feeding grounds can dramatically reduce bird mortality associated with wind farms, although bat mortality is still an unresolved challenge. While careful siting and design can also address many (but not all) aesthetic concerns, there is still a concern that the infrastructure and facilities for wind power result in significant loss of habitat, especially when constructed in areas that are otherwise relatively undisturbed.

U.S. Regional Overview Ecological Projections from Global Warming

Summary Findings from Climate Change Impacts on the United States, U.S Global Change Research Program⁶⁰

	Projections	Implications
NORTHEAST	More extreme weather, warmer winters	
	<ul style="list-style-type: none"> • Stresses on bays, estuaries, wetlands from sea-level rise • Reduced snow pack in ski areas • Muted fall colors, more insects, more ozone • Loss of beachfront property from erosion/intrusion • Fewer trout, maples; lobsters move north; less flyway habitat 	<ul style="list-style-type: none"> • Losses in: biodiversity; coastal fish species habitat; recreational economy; traditions; quality of life • Changing forest composition • Extreme weather disruptions
SOUTHEAST	More extreme weather, saltwater intrusion	

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	<ul style="list-style-type: none"> Continued saltwater intrusion of coastal forests Potential shift from conifer to hardwood forests Shift in productivity to northern parts of the region Continued loss of coastal wetlands and barrier islands from rising sea levels and extreme weather 	<ul style="list-style-type: none"> Coastal flooding and erosion Bald cypress, live oak, sabal palm loss in coastal areas Reduced fisheries from lost coastal marshes, submerged grass beds
MIDWEST	Warmer winters, hot summers, more evaporation	
	<ul style="list-style-type: none"> Increased evaporation surpassing increasing precipitation Lower lake and river levels; loss of wetland habitat Warmer water, more algae; Fewer cold water fish (e.g., trout) Less soil moisture; more forest fires More infestation, disease, dead trees; loss of much of conifer range 	<ul style="list-style-type: none"> Lake, barge shipping problems Loss of wetlands filtration More invasive species Less forest productivity, habitat Lost recreation Less carbon storage
PLAINS	Increased weather extremes and evaporation	
	<ul style="list-style-type: none"> Increased heat stress events and weather extremes Increased evaporation surpassing increasing precipitation Increased tendency toward drought in Sand Hills region Possible increase in invasive species Opportunities to store carbon in soil organic matter 	<ul style="list-style-type: none"> Increased stress on people and livestock Increased competition for finite fresh water supplies
WEST	Less snowpack, drier summers	
	<ul style="list-style-type: none"> Increased precipitation in some areas; increased drought in others Loss of alpine ecosystems in some regions 	<ul style="list-style-type: none"> Increased competition for water for agriculture, cities, power generation, recreation, etc. Increased likelihood of forest fires, pest damage in forests

NORTHWEST	Wetter winters, drier summers	
	<ul style="list-style-type: none"> More variable precipitation patterns; more rain, less snowpack Increased coastal erosion from rising seas More stresses on forests from summer droughts and pests Less reliable summer streamflows 	<ul style="list-style-type: none"> More stress on salmon Less forest productivity Coastal property damage
ISLANDS	Rising seas, higher risks	
	<ul style="list-style-type: none"> Rising sea-levels; potential freshwater shortages Increased risk from extreme weather (floods, landslides, storms) 	<ul style="list-style-type: none"> Increased public safety risks Increased extinctions in Hawaii
ALASKA	Thawing, Melting, Fires, and Pests	
	<ul style="list-style-type: none"> Coastal erosion; loss of sea ice Thawing of permafrost; changes in soil moisture and forest cover Dramatic increases in forest pests 	<ul style="list-style-type: none"> Increased stresses on subsistence livelihoods Shifts in species; more fires

Guiding Strategies for Adaptation

In addition to reducing and reversing anthropogenic greenhouse gas emissions, the nation's strategies to protect natural resources should include these:

- **Reduce other environmental stresses on natural systems** to maximize health and resilience.
- **Increase natural connectivity** and minimize obstacles for adaptive “migration” to anticipate and create maximum opportunity for successful range shifts in forest and other ecosystems, etc.
- **Minimize extinction** by creating habitat havens when possible for species already under stress, developing “ark projects” for endangered and threatened species.
- **Develop research and monitoring capacity** to better evaluate, understand and manage global and regional impacts on habitat and ecosystems from global warming.
- **Promote technology transfer**, by growing the capacity for the U.S. to develop and export research, conservation strategies and technologies to protect habitat and ecosystem services throughout the world.
- **Anticipate losses and major shifts in ecosystems**, ecosystem services and impacts on human health and well-being, and enhance adaptive capacity via management, technology, infrastructure, institutions, monitoring and new R&D
- **Anticipate extreme events** in natural resource management (floods, coastal erosion, fires, drought, etc.).
- **Avoid creating more energy-linked environmental problems** with poorly conceived solutions for energy production or carbon sequestration.
- **Minimize extinction** and loss of ecosystem services.
- **Minimize human suffering** and inequitable social and economic burdens on vulnerable populations.
- **Strengthen governance**, and institutional capacity for implementing new multi-agency and public/private partnerships and strategies to manage ecosystems for health and resilience, and to develop rapid response capacity to address ecosystem-scale threats.

- **Maximize conditions for natural sequestration in forests** and other natural landscapes.

¹ Former Vice President Al Gore uses this calculation in the film “An Inconvenient Truth.”

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⁶ Ibid., p. 8.

⁷ Ibid.

⁸ The Impacts of Global Climate Change, Presentation by Rosina Bierbaum, National Leadership Summit on Natural Resources and Climate Change, Wingspread, December 4, 2006. Original sources: on heatwaves, *Science* 8/06/05; on drought, *Journal of Hydrometeorology* 12/04; on floods, *Nature*, 01/31/02)

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