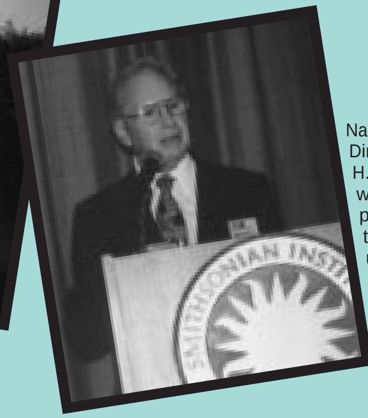
U.S. Interior Secretary Bruce Babbitt (left) and EPA Assistant Administrator David Gardiner chat during a conference break.



National Zoo Director Michael H. Robinson welcomed participants to the conference's unique and appropriate venue, the National Zoo.

SCIENTISTS AND POLICYMAKERS EXPLORE POTENTIAL IMPACTS OF CLIMATE CHANGE ON WILDLIFE

Global warming could have serious consequences for wildlife, ranging from species migration to species extinction. Wild things as diverse as marine invertebrates, fish, waterfowl, butterflies, and Baltimore orioles may be at risk from climate change. Where is the evidence? What are the solutions? These questions and others were considered at a conference on climate change and its potential impacts on wildlife, held by the U.S. Environmental Protection Agency on October 7-8, 1998, at the National Zoo in Washington, D.C.

The conference was convened to provide the public with the most up-to-date scientific information on the impacts of climate change on wildlife. The goal was to increase awareness and understanding among policymakers, wildlife and outdoor enthusiasts, researchers, members of the media, and other interested members of the public.

Welcoming participants to the meeting, National Zoo Director Michael H. Robinson conveyed a theme that was echoed during the entire conference—namely, the fragility of ecosystems and the environment—and emphasized the importance of a "bio-literate" citizenry to ensure the survival of a habitable planet.

David Gardiner, assistant administrator at EPA, seconded Robinson's concern for an informed public. "The more we learn about the future of wildlife, the better we will understand our own," he said.

Nineteen organizations and agencies co-sponsored the conference, which was attended by more than 125 people from 19 states, Canada, Great Britain, and Peru. Attendees included representatives from federal government agencies; academic institutions; nonprofit environmental and wildlife organizations; and others.

In his keynote address, U.S. Secretary of the Interior Bruce Babbitt sounded an optimistic

Continued on page 2

IS CLIMATE CHANGING WHERE THE WILD THINGS ARE?©

A report on an October 7-8, 1998, conference sponsored by the EPA Office of Policy, Office of Economy and Environment, at the

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Continued from page 1

note. Science and public policy are winning the battle on global warming, he said, adding: "The scientific consensus has been increasingly translated into public understanding of irreducible facts." Babbitt maintained that it is becoming difficult to deny the importance of climate change.

During an overview of the global warming debate, Stephen H. Schneider, professor in the Department of Biological Science at Stanford University, emphasized the vulnerability of natural ecosystems to climate change. "When we start moving species around and fragmenting habitats, the impacts may not be reversible. This problem may not be so easy to fix once it gets going."

Stuart Pimm, professor in the Department of Ecology and Evolutionary Biology at the University of Tennessee, Knoxville, discussed the potential ramifications of a changing climate on wildlife. He said that 80 percent of the world's plants and animals live in tropical rainforests; minor changes to such fragile ecosystems could have "a big effect on where the wild things are."

> "Climate change rarely is going to be acting on its own. It will be acting in conjunction with a variety of other stresses that we will be putting on ecosystems and the species in them."
>
> **THOMAS E. LOVEJOY**
> Counselor to the Secretary for Biodiversity and Environmental Affairs
> Smithsonian Institution

Scientists from around the country presented their research findings. Although the animals studied ranged from invertebrates to birds, the conclusions were much the same—changes in climate already may be having an effect on wildlife. Questions and concerns raised by the audience focused on the need to collect this evidence and present it to the public.

Thomas Lovejoy, the Smithsonian Institution's counselor to the Secretary for Biodiversity and Environmental Affairs and the originator of the public television series *Nature*, discussed the scientific evidence presented at the conference. "We are talking about an experiment on a planetary scale with nowhere else to go if we don't like the consequences," he said. Like Secretary Babbitt, Lovejoy noted that climate change has turned from a possibility into a very real occurrence. "Based on the evidence presented at the conference," he added, "we can actually say that some impacts are happening."

Closing the conference, David Gardiner asserted that the public must have answers to five basic questions before they will be ready to act on global warming. After posing the questions, Gardiner provided possible answers.

1. Is global warming a problem? A significant amount of evidence says that it is.

2. Does it require me to act now? The evidence points to rapidly occurring changes.

3. If we need to act, what do we need to do? We need to address global warming differently than we do other environmental problems and focus on solutions that will succeed in the long-term.

4. Will our actions be affordable? We have to think of the costs of not acting. And we have a long history of overestimating how much it costs to protect the environment.

5. Will the action be fair? It's a difficult question, but we're very committed to ensuring that developing countries are participating in efforts to reduce greenhouse gas emissions in a meaningful way. In fact, the EPA has worked with more than 50 countries around the world to help them reduce their emissions. ■

SECRETARY BABBITT SPEAKS OUT ON CLIMATE CHANGE

The debate over global warming is changing, according to Secretary of the Interior Bruce Babbitt. "Science and policy are winning," he said. In his keynote address, Babbitt maintained that those who previously denied the existence of global warming are losing ground. "The rate at which we are putting carbon dioxide into the atmosphere is clearly documented," Babbitt added. "The laws of physics and chemistry which translate that into warming of the atmosphere are irrefutable."

To illustrate his point, Babbitt discussed the retreat of glaciers. "I was out at Glacier National Park last summer," he said. "It's increasingly hard to understand why it's called Glacier National Park, because the glaciers are getting hard to find." Babbitt told the audience that he went for a hike in the park and along the way encountered signs that each marked where a glacier had once been 70 or 80 years ago. By the end of the hike, he finally reached the retreating glacier and found another sign that read, "Congratulations, you're here in time. This glacier will be gone in 2030."

Although Babbitt pointed out that glacial retreat is not by itself direct evidence of global warming, he said that it is one example of a greater trend. He added that, as ecosystems change, we won't be able to alter national park locations to go to new locations. "We can't move Yellowstone north to make up for the habitat migration."

Secretary Babbitt also addressed other regional effects of climate change. He said that the sand dunes in Nebraska, the Alaskan tundra forests, New England salmon runs, and the West Antarctic Ice Sheet are at risk or already have been compromised as a result of temperature changes.

According to Babbitt, the Nebraskan sand dunes have been stabilized because of precipitation, but a drought "could unleash the Sahara." Some of Alaska's taiga forests have become "drunken" forests as the permafrost thaws beneath them. "The trees are askew in all directions," Babbitt noted. And salmon runs in New England probably have been affected by area-wide temperature changes and their impact on the food web. Finally, a collapse of the West Antarctic Ice Sheet could raise sea levels worldwide by 5 meters.

Interior Secretary Bruce Babbitt said that public opinion is key to the success of national efforts to address climate change.

Such profound changes may have a devastating effect on wildlife. Babbitt took issue with those who say that species extinction is just "part of the geological record." He emphasized that the number of affected species could be high. "While wildlife are extremely adaptive," Babbitt said, "one thing they can't take is this worldwide, sudden change." ■

SIGNAL AND NOISE

Is climate change affecting wildlife? To answer that question, wildlife researchers must first determine whether effects can be detected above the "noise" of natural variability, said Stephen H. Schneider, professor in the Department of Biological Science at Stanford University. The next step is to attribute causes to the effects.

Climatologists are going through the same process of detection and attribution to determine the extent to which humans are responsible for global climate change over the past century.

"Each individual piece of evidence is assailable," Schneider explained. But he said that the combined results of many studies, and their overall concordance with the theory of climate change, suggest that the observed trends in climate are unlikely to be random acts of nature. The same argument, applied to wildlife studies, suggests that wildlife indeed may already be responding to climate change. "The signal is starting to emerge from the noise," Schneider said.

Good scientific assessment must separate what is very well known and highly probable from what is speculative, Schneider noted. He stressed that researchers should assess the probabilities of various potential outcomes and admonished the audience to be wary of those who claim to "know" how much the climate will change in the next century. "People who talk in terms of ranges and probabilities are much more likely to be credible," he said.

According to Schneider, the natural average rate of climate change to which species have adapted is on the order of 1˚C per 1,000 years. But human-induced global warming could cause the climate to change much more rapidly—perhaps as fast as 1˚C per 100 years. "The really tough problem is that as species move around, different species will move at different rates, so communities will become disaggregated."

Stanford University professor Stephen H. Schneider said that future climate change is "unlikely to be trivial" for wildlife.

Schneider recommended that wildlife researchers try to determine the range of natural variability in wildlife populations by looking at past changes and then find out what may be causing current patterns of change. "The catch is that it will take a long time to do that," he said. "We're performing this experiment on us and all other living creatures, and we're not going to have definitive scientific answers in time. We're left with a value judgment about whether we want to slow it down." ■

IS CLIMATE CHANGING WHERE THE WILD THINGS ARE?©

reports the results of a conference sponsored by the U.S. Environmental Protection Agency that took place on October 7-8, 1998, in Washington, DC.

Karen Gibbons, U.S. Environmental Protection Agency, 401 M St., SW (2171), Washington, DC 20460 and Norah Davis, Waste Policy Institute, 2111 Wilson Blvd., Suite 600, Arlington, VA 22201.

Stuart L. Pimm (second from left), of the University of Tennessee, pointed out how climate change could exacerbate the global loss of biodiversity.

WHERE THE WILD THINGS ARE

Climate change will add an additional stress on top of the many existing threats to biological diversity, said Stuart L. Pimm, professor in the Department of Ecology and Evolutionary Biology at the University of Tennessee, Knoxville.

Pimm noted that 80 percent of the world's plants and animals live in tropical moist forests. At current rates of deforestation, he said, those species will be lost by the middle of the next century. Even if we manage to save 5 percent of the world's tropical rainforests, we will likely save only about 50 percent of the species. "And that's without global change," he added.

Climate change may exacerbate such threats to biodiversity. Pimm described how overdrained wetlands such as the Everglades are left "extraordinarily vulnerable" to fires, particularly during dry years. In some areas, drought is a potential impact of climate change. "Small increases in fire frequencies can have a huge impact on the wildlife that lives in these areas."

Rainforest deforestation is very much affected by climate, Pimm said. The rate of forest cleared is much greater in drier years, due to the greater amount of burning. "A little bit warmer, a little bit drier, and the area of forest that we clear goes up three times. A small change in the climate of the world's tropical forests will have a huge impact in how long those forests will last."

Species with very small geographical ranges, such as birds in the Atlantic coastal forests of Brazil, are "overwhelmingly threatened" with extinction, Pimm said. In the Andean chain from Bolivia to Mexico, such species are disproportionately concentrated within narrow elevational limits.

The narrower the species' elevational range, the more likely it is to be "completely evicted from house and home by a given change in climate," Pimm explained. Climatic shifts will move vegetational bands up and down mountains.

"Places like the Andes, where we haven't yet driven many species to extinction, are the areas where species have tiny geographical ranges and will be disproportionately threatened by climate change," Pimm said. "This is where species are born, and it's the destruction of these 'nurseries' that represents the added threat of global change."

EARLY BIRDS GET THE WARM

Climate change may be affecting the geographical ranges and migration patterns of North American birds, according to Terry L. Root, professor at the University of Michigan's School of Natural Resources. Of 47 species whose spring arrival dates were recorded in the Upper Peninsula of Michigan between 1965 and 1994, Root found that four expanded their ranges northward during that period and 15 advanced their arrival dates by one to eight weeks.

Twenty-seven species showed no significant change in arrival time, and only one species, the hermit thrush, arrived later.

Root also found what she called a "striking association" over the 30-year study period between the arrival of some migrants and the thawing of lake ice. The ice-out date is a "very good indicator of the weather itself," Root said. She discovered that short-, medium-, and long-distance migrants all arrived earlier in the spring, a result that supports the theory that migratory birds are responding to a large-scale change in climate, rather than local weather effects.

Root pointed to a study by Humphrey Crick and colleagues (*Nature* 1997, vol. 388, p. 526), who found that egg-laying dates of British birds were earlier by an average of 19 days in 1995 than they were in 1971. The results are similar to Root's findings for North American birds.

"Is this something to be concerned about?" Root asked. "It depends on what the species are." If species move their ranges north at differential rates, it may lead to the "tearing apart" of ecological communities. It also could lead to birds arriving in their spring breeding grounds before key food sources are available.

University of Michigan professor Terry L. Root described how a warmer climate may be changing migration patterns in birds.

SEA CHANGE

Since 1975, populations of chinstrap penguins on the western Antarctic Peninsula have increased while Adélie penguins have declined. William Fraser, professor in the Polar Oceans Research Group at Montana State University, explained that climate change may be the reason.

Chinstraps and Adélies are ecologically similar species that inhabit similar ranges. During the breeding season, both are very dependent on krill. "If you have two krill predators breeding in the same area, why should the populations show different trends?" Fraser asked.

Montana State University professor William Fraser (left) reported on population changes in Adélie and chinstrap penguins in the western Antarctic peninsula.

Fraser and his colleagues found that the difference could be explained by changes in the extent of winter sea ice. In winter, Adélie penguins feed by diving through cracks in the sea ice to catch krill. Fraser found that fewer Adélies survive during winters of low sea ice because suitable feeding sites may be too scarce or distant. Chinstrap survival increases in warm winters because they feed in the open water.

Fifty years ago, according to Fraser, heavy sea ice occurred in roughly four out of every five years. Today, it occurs in only one or two out of every five years. "The frequency of cold years is decreasing, which should favor chinstraps and not favor Adélies."

Fraser also found that an apparent increase in snowfall, possibly connected with global warming, may be harming Adélies. The colonies of Adélies on the colder southwest sides of islands have become exposed to heavier, longer lasting snow cover that tends to remain well into the summer. These populations experience high rates of extinction. When snow melts after spring blizzards, nest sites become flooded. The presence of snow also tends to delay nesting, leading to chicks that are lighter than their counterparts in other colonies because their peak growth period no longer coincides with the greatest abundance of krill. Chinstraps normally breed nearly three weeks later than Adélies, allowing them to avoid the impacts of increased snowfall.

Fraser also described the findings of his colleague Richard Veit of The College of Staten Island, who documented a 90 percent reduction in the population of sooty shearwaters over the last 25 years. An estimated 5 million of these pelagic birds foraged in the California ocean current in the early 1970s. Their decline is correlated with an increase in sea surface temperatures and a coincident 80 percent decrease in the food available to shearwaters.

"Climate warming through a variety of mechanisms appears to disrupt the requirements of evolved life history strategies," Fraser said. "Once you disrupt those patterns, you begin to get changes in populations, communities, and finally entire ecosystems." ■

Camille Parmesan, of the University of California, Santa Barbara, reported that many European and North American butterflies are shifting their ranges northward.

BUTTERFLIES IN PERIL

At least one species of butterfly in North America and more species in Europe are shifting their ranges northward, according to Camille Parmesan, a researcher with the National Center for Ecological Analysis and Synthesis at the University of California, Santa Barbara. The shifts in species' ranges over the past century match temperature increases recorded during the same period, and thus could be related to climate change.

In North America, Parmesan said, populations of Edith's Checkerspot butterfly whose habitats have not yet been affected by development and other changes in land use have shifted their range northward by about 92 kilometers (and 124 meters upward in alpine regions) over the last century. Over the same time, the geographic lines of identical mean

Continued on page 6

Continued from page 5

temperatures (isotherms) have shifted northward and upward by about 105 kilometers in this area. The observed warming trend may be sufficient to explain the shift in this butterfly's distribution.

In a study of 40 butterfly species in Europe, Parmesan found that 75 percent of the species for which data were available at their southern and northern range limits had shifted their range northward over the past century. Europe as a whole warmed by 0.4°C during the study period, with northern countries warming faster than those in the south.

EPA's Bill White said that the Kyoto Protocol is a cost-effective and commonsense approach to a serious problem.

Human land use changes, such as urbanization, agriculture, or the clearcutting of forests and replanting with monoculture tree plantations, may prevent some species from expanding their ranges northward as the climate warms, Parmesan said. "Species have very limited options as to where they can go to find good habitat." She noted that one endangered subspecies of Edith's Checkerspot is being squeezed from the north by urban development in southern California while at the same time squeezed from the southern part of its range in Mexico by climate change. "I really doubt that this subspecies will be able to make it," she said.

Parmesan also noted that an increase in atmospheric carbon dioxide may affect insects and their predators more directly. As CO_2 increases, the carbon-to-nitrogen ratio in plants increases, reducing their nutritional value. According to studies cited by Parmesan, insects may have to eat more plant tissue in order to survive, and also may become smaller, lay fewer eggs, and suffer population declines. "Insects are the foodstuff for many other animals," Parmesan said. "You'll have a cascading effect" through entire ecosystems if insect populations decline. ■

Al McGartland, director of EPA's Office of Economy and Environment, served as conference moderator.

KYOTO: A GOOD FIRST STEP

"Because the effects of global warming are so serious and so costly, we believe that not acting with what we know would be irresponsible," said Bill White, senior advisor on climate change to Administrator Carol Browner at EPA. "That's why we agreed to the Kyoto Protocol."

White added that the treaty embodies two out of three major objectives called for by the Clinton Administration. First, it has sound targets and timetables for reducing emissions of the world's major industrialized nations, and second, it contains flexible market-based mechanisms for achieving those targets. The third objective, the meaningful participation of developing countries, is one that the Administration is working hard to achieve.

The timeframe for emissions reductions, 2008-2012, is the result of U.S. initiatives, as are the differentiated targets for developed countries. Additionally, U.S. efforts ensured that the Kyoto Protocol will cover all six major greenhouse gases and include carbon sinks. The addition of carbon sinks was particularly important, he said, "because it not only reduces the costs of fighting global warming, but it also provides potentially an added incentive for critical conservation efforts around the world."

Another provision, emissions trading, also will help the United States and other developed nations meet their targets more cheaply. In EPA's experience with domestic emissions trading under the acid rain program, the costs of reducing emissions have been less than half of the original estimates.

Under the protocol, the U.S. must reduce its greenhouse gas emissions to 7 percent below 1990 levels by 2008-2012. The timetable for emissions reductions will help "cushion the transition" and minimize any adverse effects on businesses and workers, White said. "This is important to maintain public support going forward."

White addressed the importance of the Clean Development Mechanism (CDM), which he said will build a bridge between developed and developing countries. The CDM allows companies in the developed world to invest in projects in developing countries and get credit for them toward their own greenhouse gas emission targets. "While the Kyoto Protocol doesn't meet our requirements for developing countries," White said, "the CDM is an important opportunity to engage developing nations in reducing emissions."

The flexibility mechanisms in the protocol are not aimed solely at reducing cost, according to White. Without those measures, he said, "we cannot achieve the early success that's critical to meeting the long-term challenge of climate change, and we will have little hope of meeting the even deeper emissions cuts that may be called for in the future."

White emphasized that although the treaty is in the best interest of the United States, it is still a work in progress. "But we're talking about a cost-effective, commonsense approach to a very serious problem."

SHIFTING CONSEQUENCES

"We often assume that species can adapt to a changing climate by shifting their distribution," said Thomas Martin, professor at the University of Montana and assistant director of the Biological Resources Division, Montana Cooperative Wildlife Research Unit, U.S. Geological Survey. "But in fact these shifts may have a whole series of other consequences and ramifications that may impinge on populations."

Martin demonstrated that two species of birds located at a high-elevation site in north-central Arizona respond quite differently to changes in rainfall. Virginia's warblers, which normally are most common in relatively dry areas at higher altitudes, move downslope in dry years. In wet years, orange-crowned warblers, which prefer the moist environment of lower elevations, move upslope. But although the Virginia's warblers survive well at lower altitudes, the orange-crowned does poorly when forced upslope, due apparently to increased predation and the narrow humidity requirements of its eggs. Decreases in breeding success will cause populations to decline over the long term.

Martin found similar climatic effects in other bird species, including fluctuations in activity levels and energy expenditures in response to changes in rainfall. "Many of these species have clear habitat preferences," he said. "As they shift out of these adaptive zones, they don't do very well."

Thomas Martin (left), of the University of Montana, in conversation with conference co-organizer Hector Galbraith, of Stratus Consulting, Inc. Martin's research focuses on how climate change may cause shifts in microhabitat use by birds.

Moving northward in response to climate change may not be a good solution, Martin said, because species could end up in areas populated by competitors and predators that they have not previously encountered.

"Plants won't be able to shift as fast as animals can," Martin added. "Animals may end up moving into habitat types to which they aren't necessarily adapted."

UCSB researcher Raphael Sagarin described changes in intertidal invertebrate populations along the California coast.

"STRANGE THINGS ARE GOING ON"

Changes are underway in populations of marine invertebrates in Monterey Bay, California, according to Raphael Sagarin, of the Department of Ecology, Evolution, and Marine Biology, at the University of California, Santa Barbara.

At Hopkins Marine Station, near the southern end of Monterey Bay, most invertebrate populations in the intertidal zone have changed significantly since an initial census was taken in 1930. Sagarin found that most species with southerly geographic ranges became more abundant, while those with more northerly ranges declined. "Cosmopolitan" species, those with wide geographic ranges, were evenly split between those that increased and those that decreased in abundance.

During the 60-year period between the surveys, sea surface temperatures in the region increased by an average of 1˚C. The years immediately preceding Sagarin's census were warmer than the years preceding the 1930 study.

Sagarin concluded that climate warming appeared to be the most likely explanation for the phenomenon. He first examined alternative hypotheses such as El Niño, changes in predators, sampling error, pollution and other anthropogenic effects, and changes in the substrate where the invertebrates were found.

However, he warned, "This study is only correlational: it shows a climatological change and a biological change. We see a connection, but we haven't discovered the mechanism connecting them."

Sagarin noted that although the evidence is not yet strong enough to show a clear cause-and-effect relationship, "We know that strange things are going on."

FISH STORY

Freshwater fish are very sensitive to changes in water temperature, according to John Magnuson, professor in the Department of Zoology and director of the Center for Limnology at the University of Wisconsin.

In addition, he said, the aquatic systems that support fish respond "directly and strongly" to climatic changes. Lakes in many parts of the world are experiencing decreasing periods of ice cover as the climate warms. Changes in climate also affect water temperature. Climate models project that lakes will become warmer and that the period of thermal stratification in summer will become longer as the climate changes.

John Magnuson, of the University of Wisconsin, said that some freshwater fish could suffer extirpations and extinctions in a warmer climate.

Magnuson noted that fish physiology and development are tightly linked to temperature as well as to indirect effects of climate such as changes in runoff patterns, nutrient inputs to lakes, changes in the flooding of wetlands, and the introduction of new species as waters warm. Many fish prefer to live within only a 4˚C range in temperature.

When water temperature warms, he said, lake fish can move deeper to cooler water, or populations can shift northward—if watersheds are connected. Stream and river fish can swim upstream toward cooler water in mountainous regions. Populations may survive, but habitat will be lost in some areas. "There would be extirpations and extinctions at southern boundaries of fishes' ranges," Magnuson said.

In lakes, warm-water fish are projected to thrive as the climate changes, while cool-water fish species would show little effect and cold-water fish would decline. Warmer water temperatures and the longer period of summer stratification would allow more oxygen to be depleted from the deep water. Cold-water fish that normally spend the summers in deep water would no longer be able to survive there.

Fish will be able to redistribute themselves only in connected watersheds, Magnuson noted. As a result, people may have to start physically moving fish northward in some areas. This could create new problems: "If you move a species to a new area, it may be more thermally adapted but will now compete with the existing fish, which are already stressed" by climate change.

DUCKS IN DANGER

Climate change could imperil key nesting habitats for North American waterfowl, according to Lisa Sorenson, research assistant professor in the Department of Biology at Boston University.

Each spring, millions of waterfowl return to breed in the Prairie Pothole region, an area of shallow wetlands and gently rolling hills in the north central U.S. Although the potholes represent only 10 percent of North American waterfowl breeding habitat in the area, researchers estimate that 50 to 80 percent of the continent's ducks are produced there. In addition, the region provides important migration habitat for waterfowl that breed farther to the north.

Sorenson, whose research focused on the U.S. portion of the region, said that climate change is expected to lead to a greater frequency and severity of drought in the Prairie Potholes. By the year 2020, with a projected temperature increase of 1.5˚C, and an average precipitation increase of 5 percent, the average conditions would tend toward mild drought, reducing the number of pothole wetlands available in the breeding season by 23 percent. The number of ducks settling to breed would drop by 32 percent. By 2050, the average number of ponds would decrease by 54 percent, and ducks would decline by 58 percent. Dabbling ducks would be more affected than diving ducks.

Although Sorenson stressed that the numbers are uncertain, she added, "We do believe that the general trend shown by the predictions is valid, and that the potential magnitude of the change in duck and wetland numbers is noteworthy and alarming."

Sorenson noted that the projected reduction in ducks in the pothole region represents only a change in settling pattern, not necessarily a reduction in populations. Ducks could move north to breed if necessary. But studies suggest that ducks breeding farther north may have lower productivity, and northern wetlands also may be vulnerable to increased drought under climate change.

Boston University's Lisa Sorenson described how an increase in droughts could threaten key U.S. waterfowl nesting habitats.

THE COST OF LOSING BIRDS

Jeff Price, of the American Bird Conservancy, said that a decline in warblers surprisingly could lead to timber die-offs in southern boreal forests.

Birds perform a number of major ecological functions, said Jeff Price, director of the Important Bird Areas Program, American Bird Conservancy. Birds serve as plant pollinators, seed dispersers, and play an especially important role in pest control.

"Some species of birds eat 300 insects a day," Price noted. "One pair of evening grosbeaks may devour 25,000 to 50,000 caterpillars in the time it takes to raise one brood."

Price said that three species of warblers—the Cape May, Bay-breasted, and Tennessee warbler—specialize in feeding on spruce budworms, an important pest species on spruce and balsam fir in the southern boreal forests of Canada and the United States. Spruce budworms normally are present in small numbers, but during outbreaks their densities may reach nine million larvae per acre and they annually defoliate 5.7 million acres in the eastern United States. Spruce budworms are the No. 1 cause of lost timber production in Canada, according to Price.

"Birds eat up to 84 percent of budworm larvae when the larvae populations are low," Price said. But climate change is projected to reduce the range of many warblers, including those that prey on spruce budworms. Even a 0.5˚C warming could reduce warbler populations in southern boreal forests, according to model projections.

Changes already are underway in these bird species. Over the last 23 years, Price said, Bay-breasted and Cape May warblers have shifted their ranges northward by an average of 100 kilometers. The same northward shift has been observed in 43 percent of North American wood warblers.

Price said that climate change would make forests more vulnerable to outbreaks, as fewer spring frosts would create conditions favorable to budworms. "If you then remove the birds, you'll see a greater likelihood of more severe outbreaks, longer and larger outbreaks, greater loss of timber, and more fire frequency," he added. He predicted that the result could be "a rapid conversion of southern boreal forest to brushland and grassland."

Climate changes may drive other species northward as well. Price's research suggests that the Baltimore oriole may no longer be seen in Baltimore by the end of the next century, and the state bird of Massachusetts, the black-capped chickadee, could be extirpated from the state. ■

CALLING THE SHOTS

"We need to push our boats out," urged Norman Myers. "If we believe that global warming is going to be exceedingly bad news, we should be prepared to say so."

Myers, a senior fellow at the World Wildlife Fund, implored scientists and environmental activists to speak out and share their research and findings with the public. "Sometimes, being cautious can amount to a form of recklessness."

He added that the extinction of a single species is different from any other environmental problem we face. "We can restore topsoil," he said. "We can allow the ozone layer to fix itself up. But when a species is gone, it's gone for good."

Myers emphasized the fragility of ecological "hotspots," areas that feature an exceptional number of species and also face exceptional threats. Many of them are tropical forests. According to Myers, hotspots contain over half of the planet's plant species and 25 percent of all animal species. He predicted that as a result of global warming, hotspots could lose 50,000 plant species and as many as 1

Continued on page 10

Norman Myers, of the World Wildlife Fund, called for scientists and activists to speak out about global warming.

Continued from page 9

million animal species. Hotspots include the Upper Guinea Pass in West Africa, the Atlantic Coastal Forest in Brazil, and the Sundarbans in Bangladesh, to name a few. The Sundarbans is a mangrove forest and diverse ecosystem. "With a half-meter rise in sea level, Bangladesh would lose the Sundarbans and the largest remaining tiger population living on earth."

Myers added that sea level rise will cause problems for other wildlife populations that live in coastal areas, such as fish in coral reefs and wetlands. "Coral reef ecosystems will effectively drown, and coastal wetlands will be dramatically affected." In addition, he claimed, "global warming could cause 250 million people to be washed out of their homes."

Repeating a theme that sounded throughout the conference, Myers cautioned that one environmental impact can compound another in synergistic ways. For example, he said forest ecosystems stressed by logging and slash-and-burn cultivation will be less resilient, "making them a lot more susceptible to global warming when it comes along."

Myers warned that policymakers are likely to listen to absence of evidence about a problem and perceive that to be evidence of the absence of a problem. "Our silence can send a very resounding message, indeed," he said. The risks of major impacts on natural ecosystems should encourage us to take action on climate change now, despite the scientific uncertainties. "It is better to be roughly right than exactly wrong," Myers concluded.

BRINGING IT TOGETHER

Drawing on lessons learned from his colleagues' research, Stuart Pimm said that wildlife workers should bear in mind three issues: the nature of change, the rate of change, and the interaction between global warming and other environmental concerns. "Most of the consequences of global climate change will be small," said Pimm, "but then there will be a very few catastrophic and economically damaging changes." Concerning rates of change, Pimm mentioned that in the past, climate changed as much as 1 degree per 1,000 years. Today we're looking at potential changes of 1 degree per century.

Pimm added that global warming may alter food webs and yield "counterintuitive effects." For example, he said, when a predator is removed from a food web, the prey that it feeds on will increase 50 percent of the time and decrease 50 percent of the time. "If you take away an enemy, half the time you'll realize that the enemy is your friend."

Pimm also stressed the need for scientists to compile existing evidence of climate change impacts on wildlife. Information that currently is scattered and fragmentary could, if properly synthesized, present "tight and compelling" evidence. "The data set contains all kinds of animals, including reptiles, amphibians, and even flowering plants," he said. He urged scientists to compare impacts across different timescales, since some biological changes that take place on a two- to three-year timescale are diametrically opposite to those that take place over longer periods.

For more information about the conference, visit the U.S. Environmental Protection Agency's global warming conference website at: **www.epa.gov/globalwarming/conferences/.**

In addition, EPA publishes a number of fact sheets about global warming and energy conservation. Call EPA's Fax-On-Demand Service (202-260-2860) or access EPA's global warming website at **www.epa.gov/globalwarming.**

WHAT CAN BE DONE?

"We have heard a lot of insights into the effects of climate change on various aspects of the animal kingdom," said Thomas Lovejoy, as he opened a panel on possible solutions and adaptation strategies for wildlife. "Now it's time to address the very pragmatic question of what can be done."

According to Norman Myers, we should embark upon large-scale reforestation projects on formerly forested lands, especially considering the rapid rate of tree growth in some locations. "In some places, such as the humid tropics, you could plant a seedling and jump aside," he joked. Myers noted that every 1 million square kilometers of land planted with fast-growing trees can absorb 1 gigaton of carbon per year. "It wouldn't fix the problem by a long, long way," he emphasized, "but it would be a measure to reduce the problem, and it would also have other benefits." Myers added that, although tree plantations may be "biotic deserts," they could relieve the exploitation pressure on the world's remaining natural forests.

Continued on page 12

Tom Lovejoy, of the Smithsonian, moderated the concluding panel on next steps.

Adam Markham (second from left), of the World Wildlife Fund, was one of the speakers on the conference's concluding panel. Joining him were (l-r) Norman Myers, Stuart Pimm, and Al McGartland. Not shown: Terry Root and Thomas Lovejoy.

THE AUDIENCE REACTION

Audience reaction at the conference was wide-ranging.

"Certainly from a conservation standpoint, I'm very concerned about the combined effects of climate change with habitat destruction and other issues that are facing wildlife. My belief is that we need to be on top of the issues and need to present that information to the public."

REG HOYT
Senior Vice President for Conservation and Science
Zoological Society of Philadelphia

"If climate changes too dramatically for wildlife populations to adapt or to have the flexibility of moving, that's when we will run into problems."

TED MASHIMA
Projects Director
National Association of Physicians for the Environment

"My concern is that adding one more anthropogenic problem, such as global warming, could hurt biodiversity."

BONNIE BURGESS
Project Manager, Water Resources
League of Women Voters

"We are very interested in issues that affect fish, and as a group we are trying to get more involved in issues such as climate change."

JUDY LEHMBERG
Representative
Federation of Fly Fishers

"We have to get more information on what the impacts are. If this conference helps strengthen the science, it'll be important.

MIKE LENNARTZ
Wildlife Fish and Water Management
U.S. Forest Service

"There are lots of compelling stories about the impacts of global warming, but the difficulty is, what will we do about it?"

RON LACOSS
Environmental Studies Teacher
Landon School, Maryland

Continued from page 11

Al McGartland, director of EPA's Office of Economy and Environment, said that the use of renewable energy must grow dramatically if we are to stabilize atmospheric concentrations of greenhouse gases. "We have to think about R&D and other solutions," he said. McGartland also emphasized the need to better communicate the risks of climate change to decisionmakers and the public, both domestically and in developing countries.

Adam Markham, director of energy and climate policy at the World Wildlife Fund, said that much more support is needed to fund research on the impacts of climate change on wildlife. "But the primary response must be to reduce emissions," he said. According to Markham, immediate action is needed and appears to be supported by the American public. He cited a recent WWF poll on climate change, which found that 70 percent of Americans believe that climate change is a serious problem, while 66 percent say we should take action even if scientists haven't reached full consensus on climate change.

However, Markham said, climate change is not at the top of the public's environmental agenda. To him, this indicates a need for new efforts to build a sense of urgency about global warming. Furthermore, he added, even the wildlife conservation community hasn't taken climate change seriously enough. "We have to try to communicate to conservationists that climate change requires them to think in the longer term, and we have to have a vision of conservation that looks at ecosystems in the sense of their processes and complexity, rather than just a species-based approach."

Terry Root focused on the need for wildlife researchers to understand the potential surprises and "nonlinearities"—large, exponential changes that may occur in response to an environmental impact—which may be in store as the climate changes.

Researchers also must consider the importance of abiotic (nonliving) factors in ecology, Root said. "We have a paradigm in ecology which says that biotic interactions are the primary aspects shaping our world," she said. "But abiotic interactions are at least as important." Shifts in climate, for example, may have an equal or greater effect on species as predation and competition do.

Finally, Stuart Pimm and Thomas Lovejoy discussed the importance and complexity of the Kyoto Protocol's Clean Development Mechanism. Lovejoy noted that the CDM not only would address climate change, but also it may confer "wonderful benefits for biodiversity conservation" by allowing a single piece of forest to generate multiple streams of income. Examples include income from carbon sequestration, ecotourism, and non-timber forest products industries. In this way, forests could be worth more standing than cut down for timber or agriculture. ■

CONFERENCE SPEAKERS

The Honorable Bruce Babbitt, Secretary of the Interior

William Fraser, Ph.D., Professor, Polar Oceans Research Group, Montana State University

David Gardiner, Assistant Administrator, Office of Policy, U.S. Environmental Protection Agency

John Magnuson, Ph.D., Professor, Department of Zoology and Director, Center for Limnology, University of Wisconsin

Adam Markham, Director of Energy and Climate Policy, World Wildlife Fund

Thomas Martin, Ph.D., Professor, University of Montana and Assistant Director, Biological Resources Division, Montana Cooperative Wildlife Research Unit, U.S. Geological Survey

Norman Myers, CMG, Senior Fellow, World Wildlife Fund

Camille Parmesan, Ph.D., Researcher, National Center for Ecological Analysis and Synthesis, University of California, Santa Barbara

Stuart L. Pimm, Ph.D., Professor, Department of Ecology and Evolutionary Biology, University of Tennessee, Knoxville

Jeff Price, Ph.D., Director, Important Bird Areas Program, American Bird Conservancy

Michael H. Robinson, Ph.D., Director, National Zoological Park

Terry L. Root, Ph.D., Professor, School of Natural Resources and Environment, University of Michigan

Raphael Sagarin, Department of Ecology, Evolution, and Marine Biology, University of California, Santa Barbara

Stephen H. Schneider, Ph.D., Professor, Department of Biological Science, Stanford University

Lisa Sorenson, Ph.D., Research Assistant Professor, Department of Biology, Boston University

Bill White, Senior Advisor to the Administrator for Climate Change, U.S. Environmental Protection Agency

MODERATORS:

Thomas E. Lovejoy, Ph.D., Counselor to the Secretary for Biodiversity and Environmental Affairs, Smithsonian Institution

Al McGartland, Ph.D., Office Director, Office of Economy and Environment, U.S. Environmental Protection Agency