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# United States Department of the Interior

## FISH AND WILDLIFE SERVICE

5275 Leesburg Pike, MS: IRTM  
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IN REPLY REFER TO:  
FWS-2017-00463

March 7, 2017

The United States Fish and Wildlife Service (FWS) Freedom of Information Act (FOIA) office received your (FOIA) request, dated February 22, 2017 and assigned it control number FWS-2017-00463. Please cite this number in any future communications with our office regarding your request. You requested the following:

*“...a digital/electronic copy of the report: Johnson, Kurt A.; Morton, John M.; Anderson, Greer; Babij, Eleanora; Cintron, Gil; Fellows, Valerie; Freifeld, Holly; Hayum, Brian; Jones, LouEllyn; Nagendran, Meenakshi; Piehuta, Joe; Sterne, Charla; Thomas, Peter. 2008. **Four key ideas to guide the Service’s response to climate change: A white paper.** Ad Hoc Climate Change Working Group, U.S. Fish and Wildlife Service, Arlington, VA. 28 pp. Available at: [https://intranet.fws.gov/climatechange/AdHoc\\_Climate\\_White\\_Paper\\_02-08-2008.pdf](https://intranet.fws.gov/climatechange/AdHoc_Climate_White_Paper_02-08-2008.pdf). “*

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We are writing today to respond to your request on behalf of the FWS. We have enclosed one file consisting of 28 pages, which are being released to you in their entirety.

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U.S. Fish and Wildlife Service  
FWS FOIA Officer  
5275 Leesburg Pike  
MS: IRTM  
Falls Church, VA 22041

You also may seek dispute resolution services from our FOIA Public Liaison, Carrie Hyde-Michaels, FWS FOIA Officer, at (703) 358-2291.

Sincerely,

CARRIE HYDE-  
MICHAELS

Digitally signed by  
CARRIE HYDE-MICHAELS  
Date: 2017.03.08  
10:08:16 -05'00'

Carrie Hyde-Michaels  
FWS FOIA Officer

Enclosure



# Four Key Ideas to Guide the Service's Response to Climate Change

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*A White Paper*



Photo: NASA

*Ad Hoc Climate Change Working Group*

*January 5, 2008*



## **Contributors**

**(in alphabetical order after coordinators)**

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## **Disclaimer**

This white paper has been developed by the Climate Change Working Group (CCWG), an ad hoc and informal group of concerned U.S. Fish and Wildlife staff from a broad cross-section of Service Programs and Regions. The Service did not assign the production of this white paper, and it does not represent Service policy on climate change or any other issue. Instead, it represents the views of a cross-section of expertise within the Service that wanted to help the organization begin to thoughtfully consider this challenging issue. We have no expectation as to its use, other than it be considered as the Service moves forward with dialogue and decisions.



# Key Ideas:

## Executive Summary and Recommendations

**1. Accelerated climate change is a reality, and will fundamentally affect how the Service does business in the foreseeable future. To fulfill our mandate to conserve trust resources for this and future generations, the Service must assign the highest priority to addressing climate change, and must undertake this challenge with a sense of urgency.**

- In the shorter term, we recommend the Service undertake significant budget initiatives in the 5-year period FY 09 through FY 13 to emphasize the urgency of addressing global climate change.
- In the longer term, we recommend the formation of a national level climate change office that would serve to coordinate all Service efforts related to climate change. We also recommend the designation of at least one full-time climate change/energy coordinator in each Region.

**2. The Service must develop a comprehensive Strategic Vision at the national and international levels. The Service's Strategic Vision should:**

*2a. emphasize an expansive view of the key concepts of Adaptation and Mitigation.*

- We recommend that the Service incorporate the ideas expressed herein related to Adaptation and Mitigation into a comprehensive national “Strategic Vision for the Fish and Wildlife Service’s Response to Climate Change.” The U.S. Climate Change Program<sup>1</sup> recently recommended that the National Wildlife Refuge System (NWRS) develop a “Strategic Plan for Adaptation to Global Climate Change”; we are extending this recommendation to encompass other divisions of the Service.
- To ensure that implementation of this Strategic Vision is dynamic and adaptive, extending beyond the lifetime of administrations, we recommend the appointment of an independent “Climate Change Biology/Management Think Tank” to carefully consider and develop solutions for key resource management, research, inventory, and monitoring questions related to climate change. This group would be composed primarily of Service staff but might include leading authorities in the Federal government, State government, academia, NGOs, and consortia<sup>2</sup>. The objectives of this Think Tank must include, at minimum, intensive

reviews of case studies and development of demonstration projects. While this Think Tank needs to produce results according to a timeline, it should have an ongoing mandate that span administrations. The Think Tank should consider how to incorporate adaptation and mitigation concepts of climate change explicitly into the DOI guidelines and protocols for “Adaptive Management” and the Service’s “Strategic Habitat Conservation” framework.

- We recommend the Service “lead by example” and setting ambitious objectives for mitigation through energy conservation, reduction of greenhouse gas emissions, and carbon sequestration.

We recommend that Region 4 produce a “Lessons Learned” document on carbon sequestration that could serve as a model or handbook for other Regions of the Service.

*2b. emphasize adaptive management at the landscape level to encompass ecological processes and pathways as well as species and communities.*

- We recommend that the Strategic Habitat Conservation approach embrace consideration of climate change impacts on fish and wildlife populations and habitats.
- To better implement this approach, we further recommend that the Service develop comprehensive risk assessments of fish and wildlife populations and habitats to evaluate their relative vulnerability/resilience to climate change. These assessments need not be stand-alone documents, but could be incorporated into amended recovery plans, Comprehensive Conservation Plans, Species Conservation Action Plans (e.g., for birds and fish), Fish & Wildlife Coordination Act reports, NEPA documents, and other planning documents.

**3. Furthermore, the Service’s Strategic Vision must:**

*3a. emphasize education and communication (both internally and externally).*

- We expect that one of the outcomes of developing a Strategic Vision will be to clarify the Service’s message to its employees and to the public. To continue down that path, we recommend that the Service engage in developing a strong inreach and outreach



education and communication program on climate change and its impacts.

- We recommend that, as a starting point, the Service educate itself about climate change, from the Director's office down. We concur with the Director's recommendation to hold regional Climate Change Workshops in every region. We also recommend that a national forum be held to share results from regional forums, and help develop a national strategic vision. We further recommend that a national coordinator be involved to ensure that the forums are uniform in their presentation of material and use of climate change terminology, and that the results of the forums are shared with other regions in the spirit of information exchange.

*3b. promote new ways of thinking through legislation, policy, guidelines, and terminology.*

- The potential for climate change-related effects to undermine Service's long-term stewardship of trust resources demands a thorough review of the specific policy and guidance, organizational culture and barriers, and material resource limitations to institutional adaptation. Therefore, we recommend a "Climate Change Policy Think Tank" or working group to consider key legislative, policy, and guidance issues related to climate change. The two groups should share some common membership, because the issues under consideration are not mutually exclusive.

*3c. promote training and recruiting to develop a professional staff with the necessary skill sets to effectively address climate change.*

- We recommend that, as part of the upcoming Regional climate change workshops, Regions explicitly evaluate their existing skills sets relative to climate change, and any special skill needs the Region may have in order to respond effectively to climate change.
- We recommend the preparation of training courses and materials on climate change (through NCTC).

*3d. identify and develop technology, including new methods for monitoring and managing climate change effects on fish and wildlife habitats and populations.*

- We recommend that comprehensive species inventories of NWRs (and perhaps other conservation lands), be promoted through special funding.<sup>3</sup> The Service cannot be expected to adapt strategically to climate change impacts without a better sense of in situ biodiversity. We speak almost cavalierly about the impacts of climate change and invasive species on biodiversity without any knowledge of the full

extent of species richness for the lands we manage.

- We strongly recommend developing a national program to inventory and monitor changes in the biological integrity, diversity, and environmental health of the NWRS consistent with the 1997 Refuge Improvement Act and BIDEH policy<sup>4</sup>. Objectives of this program would be scaled to detect changes in flora, fauna, and other metrics at the regional and/or national level. This program would consist of permanent sampling sites, ideally integrated and cost-shared with existing national monitoring programs such as the USDA Forest Inventory & Analysis program or the EPA's EMAP. Data resulting from this proposed I&M program can be used to model spatially-explicit distributions of biota now and into the future as a result of climate change<sup>5</sup>. The Service should work with other DOI land agencies to establish a center for spatial modeling within USGS-BRD; such a center would complement the data that would result from a NWRS I & M program.
- We should continue to support and perhaps expand the funding and/or scope of existing monitoring programs that have proven track records such as the USDA-DOI Remote Automated Weather Station (RAWS) network or the Interagency Monitoring of Protected Visual Environments (IMPROVE) program, as well as phenology and breeding bird monitoring programs.
- We recommend that the "Climate Change Biology/Management Think Tank" specifically address the issues of assisted migration, captive breeding, genetic management, invasive species, water resources, altered disturbance regimes, and wildlife disease. This might logically be approached through focused sub-groups each of which can concentrate on a specific issue.
- Under a separate item, we have specifically recommended that the Climate Change Biology/Management Think Tank" address research needs related to biology and management issues.

*3e. anticipate and address the global impacts of climate change collaboratively with other nations.*

- As the Service further develops expertise on a balanced response to climate change on Service lands and trust species of fish and wildlife, using the key concepts of Adaptation and Mitigation, we recommend that we make this experience available internationally through on-line resources, and education and training programs.
- In order to continue drawing on international expertise for complex analyses and difficult decisions, we recommend exploring a more active Service role in U.S. deliberations at

international forums, including the U.N. Framework Convention on Climate Change<sup>6</sup> and its species and habitat related activities.

**4. Accelerated climate change poses an extraordinary challenge but an unprecedented opportunity to be a “great unifier” of Service land and water resource conservation programs.**

- Climate change provides an enormous opportunity for the Service to re-examine what is “natural” in a world that is rapidly changing, for us to philosophically revisit Aldo Leopold’s land ethic, and thereby promote a more sustainable way of life. It can provide a very clear nexus for how Service divisions can collaborate (i.e., horizontal integration) on a single issue that affects all other mandates and trust resources.

# *1. Accelerated climate change is a reality, and will fundamentally affect how the Service does business in the foreseeable future. To fulfill our mandate to conserve trust resources for this and future generations, the Service must assign the highest priority to addressing climate change, and must undertake this challenge with a sense of urgency.*

*Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level... Observational evidence from all continents and most oceans shows that many natural systems are being affected by regional climate changes, particularly temperature increases... Most of the observed increase in globally-averaged temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic GHG concentrations. It is likely there has been significant anthropogenic warming over the past 50 years averaged over each continent (except Antarctica).*  
-- IPCC 2007<sup>7</sup>

*There is now ample evidence of the ecological impacts of recent climate change, from polar terrestrial to tropical marine environments. The responses of both flora and fauna span an array of ecosystems and organizational hierarchies, from the species to the community levels... Although we are only at an early stage in the projected trends of global warming, ecological responses to recent climate change are already clearly visible.*  
-- Walther et al. 2002<sup>8</sup>

*Climate change is the most severe problem that we are facing today—more serious even than the threat of terrorism.*  
-- Sir David King, Chief Scientist of the United Kingdom

There can be no doubt that the global climate is changing, and changing rapidly in many places (e.g., the Arctic); likewise there is little doubt that anthropogenic activities are a key cause of climate change. The most recent Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change<sup>9</sup> (IPCC), as well as a multitude of additional scientific papers, underscores both the magnitude and urgency of the issue of climate change and its potential impacts on trust resources.

Many U.S. Government agencies have been key players in documenting global climate change, often under the auspices of the U.S. Climate Change Science Program (<http://www.climatechange.gov/>).<sup>10</sup> However, a 2007 report by the Government Accounting Office<sup>11</sup> chastised Federal agencies for failure to develop guidance on managing the impacts of global climate change on Federal land and water resources.

The Department of the Interior (DOI) and the U.S. Fish and Wildlife Service (Service) have initiated preliminary efforts to understand and address climate change, but we've just scratched the surface:

- DOI efforts include the DOI Climate Change Task Force and work being undertaken by DOI agencies other than the Service.
- Current Service efforts are occurring at all levels, including (1) directive by the Director to conduct Regional Climate Change Workshops and Director's "all-employee message" on the Service and Climate Change; (2) the recently-constituted Directorate-level task force on climate change; (3) various Program or Regional efforts (e.g., NWRS report in SAP 4.4<sup>12</sup>, Alaska Climate Change Forum by R7<sup>13</sup>, carbon sequestration work in R4<sup>14</sup>, the Coastal Program Strategic Plan<sup>15</sup>); (4) grassroots efforts by field offices and Service employees, e.g., the ad hoc CCWG that prepared this document.

This White Paper was developed by the Climate Change Working Group (CCWG), an ad hoc, informal group of concerned Service staff representing a broad cross-section of Service Programs and Regions. We have no mandate or charge to produce this report, but together we believe we offer a representative cross-section of expertise within the Service that will be called upon to address climate change, and, therefore, that we have worthwhile insights and opinions to add to the debate. The goal of the White Paper is to articulate

what we believe are key ideas to guide the Service's strategic response to climate change, and to offer some recommendations how to proceed.

To deal with the magnitude and imminence of the threat of global climate change to fish and wildlife resources, Service leadership must assign highest priority to addressing climate change, and must undertake this effort with a sense of urgency. Climate change is not a threat for the distant future. It is occurring now, and life is changing more rapidly than anticipated in many parts of the world, including the United States.

An effective response will require commitment at all levels of the Service. Innovative and forward-thinking approaches will be needed, as well as some informed risk taking. Adaptive management and monitoring will be key ideas; effective communication and information exchange will be critical.

We need a new business model that moves climate change rapidly into base funding where it may serve as a unifying principle promoting coordination (see key idea #3a), collaboration and integration among programs and agencies. This new business model must be based on a longer planning window that can provide sustained funding for monitoring and research. Such efforts would help us understand climate-related effects and would be conducive to adaptive management and a focused conservation approach. Legislation pending in Congress may help address the funding issue in the near future, but we must be ready to use those funds to benefit our trust fish and wildlife resources in the most efficient manner.

- In the shorter term, we recommend the Service undertake significant budget initiatives in the 5-year period FY 09 through FY 13 to emphasize the urgency of addressing global climate change.
- In the longer term, we recommend the formation of a national level climate change office that would serve to coordinate all Service efforts related to climate change. We also recommend the designation of at least one full-time climate change/energy coordinator in each Region.



*A journey of a thousand miles begins with a single step.*  
-- Lao Tsu



## *2. To effectively address climate change, the Service must develop a comprehensive Strategic Vision at the national and international levels.*

### *2a. The Service's Strategic Vision should emphasize an expansive view of the key concepts of Adaptation and Mitigation.*

*There is high confidence that neither adaptation nor mitigation alone can avoid all climate change impacts; however, they can complement each other and together can significantly reduce the risks of climate change.*  
-- IPCC 2007<sup>16</sup>

The Service must rapidly develop a comprehensive strategic vision on climate change. We recognize that in tackling this new challenge the Service work force is already stretched to meet current priorities (WO, RO, and FO levels). A successful strategic vision at the national level must recognize and integrate with existing program/regional priorities while, at the same time, identify areas where priorities may need to shift and outline a strategy to successfully transition to those new priorities.<sup>17</sup>

Any strategic vision on climate change must emphasize the key concepts of Adaptation and Mitigation<sup>18</sup> as defined by the IPCC (we must speak the language of the world climate change community, as exemplified by the IPCC). Education will be another key component (see key idea #3a).

#### **Adaptation**

Adaptation is an adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. In essence, adaptation refers to our response to the impacts of climate change. Adaptation is an essential part of climate policy alongside greenhouse gas mitigation<sup>19</sup>.

The IPCC recognizes various types of adaptation, including anticipatory and reactive adaptation, private and public adaptation, and autonomous and planned adaptation. We believe the Service must be more explicit and strategic about how it chooses to adapt to (i.e., manage) the impacts of climate change on fish & wildlife populations and habitats.

We can work with or against climate change impacts. An example of working with climate change

impacts: Should the Service translocate species at risk to places where they've never occurred before but latitudinal or elevational shifts are moving the climatic envelope to those places? An example of working against climate change impacts: Should the Service contract cloud seeding in systems where precipitation is declining? The former approach manages the system towards a new climate change-induced equilibrium; the latter abates the impact by trying to maintain the current condition despite climate change.

This distinction is more than semantics. An inappropriate response or a series of inconsistent responses may result in large expenditures of funds with a questionable outcome over the long term. For example, wetland restoration on coastal Refuges is generally considered to be a beneficial management goal by the Service. However, the long-term costs of coastal wetland restoration on Refuges that have inadequately considered predicted sea level rise (and extreme storm events) in their design could be exorbitant in the event of catastrophic failure. In contrast to the more conventional approach of maintaining historic conditions, Connecticut's Coastal Program<sup>20</sup> has proposed a new strategy for estuarine restoration, including avoiding risky restoration projects such as low marsh, restoring tidal wetlands adjacent to lands where marine transgression can occur, identifying *refugia* sites (future marine transgression areas) for protection, and seed banks to protect the most threatened plants species.

In the past, management decisions have generally been directed toward maintaining or restoring historic conditions. Adaptation may now mean managing towards less certain future conditions, rather than aiming for historical or current conditions<sup>21</sup>. Managing toward future conditions by necessity involves a degree of uncertainty and reliance on model projections which may involve work outside the scope and definition of current legislation or policy (see key idea #3b). Efforts to reduce uncertainty are important<sup>22</sup>, but uncertainty

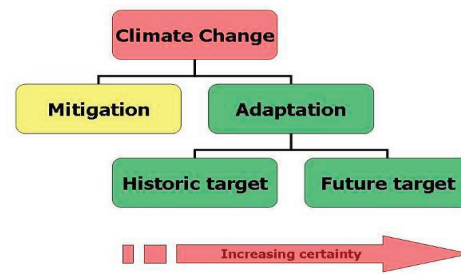
will always remain. This dictates an adaptive management approach, or the adjustment of management actions as the response to previous management is evaluated through monitoring.

Examples of actions that could be taken to promote adaptation to climate change impacts include:

- Establish new reserves and/or corridors that allow for and even promote shifts in species distributions<sup>23</sup> (e.g., incorporate climate change considerations into a dynamic Strategic Habitat Conservation framework<sup>24</sup>).
- Practice dynamic rather than static habitat conservation planning. Dynamic habitat planning means incorporating explicit consideration (projections) of changes in landscape patterns over time in the planning process, and employing an iterative approach to refine projections as new information becomes available. Dynamic habitat planning is particularly important because current climate models are better at simulating climate at a global or regional scale than at small (local) scales on which most plans are based. As models improve and projections are “downscaled”<sup>25</sup> more successfully, this new information will be critical in revising plans and priorities.
- Reduce other anthropogenic stressors as a means of reducing climate change impacts on native biota and habitats. Impacts of anthropogenic stressors, e.g., alien species or habitat fragmentation, may be exacerbated by climate change. The fate of a species or an ecosystem lies in the net effect of all stressors combined. In some cases, it may be easiest to reduce the overall stress on a species or ecosystem by mitigating some of the non-climate stressors, thereby increasing the resilience<sup>26</sup> of the system to climate change.

The best strategic approach may be for us to proceed conservatively at first, managing against climate change impacts in the short term by sustaining or even restoring historic or current

conditions. We would begin managing with climate change as the certainty of climate change impacts and our knowledge of resource resilience to those impacts increase. Ecosystem responses to climate change may not be simple and linear, and changes to markedly different systems may be triggered by small changes if thresholds are exceeded<sup>27</sup>. Conservative approaches (i.e., sustaining or restoring to a current or historical baseline) may allow more accurate identification of key thresholds in nonlinear dynamic systems. Restoration to an historic or baseline condition may reduce stressors and build additional resilience in stressed ecosystems, thereby “buying time” to increase our certainty of the climate change trajectory in an area.



*What is resilience?*<sup>28</sup>

In general terms, resilience can be thought of as the capacity of an ecosystem to absorb shocks (disturbance) while maintaining function. When change occurs, resilience provides the components for renewal and reorganization, so that ecosystem function can be maintained. Vulnerability is the flip side of resilience: when an ecological system loses resilience it becomes vulnerable to change that previously could be absorbed. In a resilient system, change has the potential to create opportunity. In a vulnerable system even small changes may be devastating.

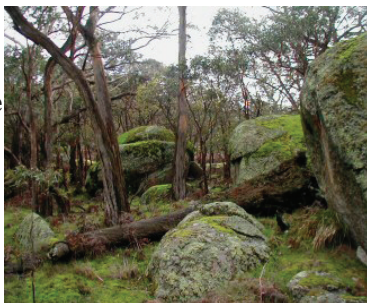
*How can we help maintain/build resilience?*

1. Maintain or enhance biological diversity. Biological diversity appears to enhance the resilience of ecosystems, so the maintenance or enhancement of diversity in a system will contribute to maintaining or increasing its resilience.<sup>29</sup>
2. Reduce non-climate stressors on ecosystems. Pollution, toxics, invasive species, disease outbreaks and catastrophic fires are all ecosystem stressors. By minimizing these other stressors, resilience to climate change can be enhanced.<sup>30</sup>
3. Maintain/create large blocks of habitat by reducing habitat fragmentation, promoting corridors, and habitat restoration where needed, especially to provide connectivity among habitat blocks.

We need to be explicit about the approach we're taking, and why. Approaches will vary depending on the resource or ecosystem affected, the resilience of that resource, and the scale and certainty of predicted climate change effects. As we transition to working with climate change, taking more proactive but also more uncertain approaches in our response to climate change, we can also expect inconsistencies in our collective approach as an agency. A key issue in this debate will be determining when and how to make the transition from managing “against” climate change to managing “with” climate change. However, we fully expect the various programs and regional divisions to eventually move toward a common vision as the realities of climate change become more apparent (see key idea #3b).

Adaptation is a double-edged sword. The potential for malpractice and deliberate abuse exists because of our poor understanding of the natural system, our repeated failure to understand the non-target impacts of management actions, sometimes misplaced priorities, and the occasional political agenda. For example, in the interest of promoting carbon sequestration on private or public lands, the Service could inadvertently promote ecologically-misplaced afforestation or planting quick-growing but exotic vegetation such as *Eucalyptus*. In responding to calls for assisted migration of a listed species, the Service could mistakenly eliminate extant critical habitat prematurely. The Service could naively promote coastal estuarine and barrier island restoration without adequately accounting for extreme storm events (e.g., Katrina) or accelerated sea level rise. Much of our current understanding of communities and their drivers may now be challenged by unexpected results of climate change such as mismatched trophic relationships<sup>31</sup>, changes in the timing and routes of migration, changes in disturbance regimes such as wildfire<sup>32</sup>, and our wholly inadequate knowledge of existing biodiversity.

- We recommend that the Service incorporate these and other ideas related to Adaptation into a comprehensive national “Strategic Vision for the Fish and Wildlife Service’s Response to Climate Change.” The U.S. Climate Change Program<sup>33</sup> recently recommended that the National Wildlife Refuge System (NWRS) develop a “Strategic Plan for Adaptation to Global Climate Change”; we are extending this recommendation to encompass other divisions of the Service.
- To ensure that implementation of this Strategic Vision is dynamic and adaptive, extending beyond the lifetime of administrations, we recommend the appointment of an independent “Climate Change Think Tank” to carefully consider and develop solutions for key resource management, research, inventory, and monitoring questions related to climate change. This group would be composed primarily of Service staff but might include leading authorities in the Federal government, State government, academia, NGOs, and consortia<sup>34</sup>. The objectives of this Think Tank must include, at minimum, intensive reviews of case studies and development of demonstration projects. While this Think Tank needs to produce results according to a timeline, it should have an ongoing mandate that span administrations. The Think Tank should consider how to



incorporate adaptation and mitigation concepts of climate change explicitly into the DOI guidelines and protocols for “Adaptive Management” and the Service’s “Strategic Habitat Conservation” framework.

## Mitigation

Mitigation is human intervention to reduce the sources or enhance the sinks of greenhouse gases (IPCC 2007 definition). The Service’s role in mitigation is two-fold. The first component pertains to how the agency can reduce its own carbon footprint through energy conservation and increased energy efficiency. The second component pertains to conservation actions the Service takes to mitigate climate change.

The Service already has a mandate to reduce energy use in accordance with the National Energy Conservation Policy Act (as amended by the Energy Policy Act of 2005) and two Executive Orders<sup>35</sup>, as well as the President’s Memorandum on Energy and Fuel Conservation of September 26, 2005. The Service’s Energy Team (a national coordinator plus Regional Energy Managers in each Service Region) prepared an FY 2006 Annual Report on Energy Management and Conservation Programs and an FY 2007 Energy Management Implementation Plan. The Energy Policy Act of 2005 established new annual energy reduction goals of 2% per year through FY 2015 for buildings subject to the Act, whereas EO 13123 calls for 35% reduction in FY 2010 for buildings subject to the EO. We recommend that the Service “lead by example” by moving aggressively to achieve or even exceed the goals of EO 13123 for increased building energy efficiencies. Further, we recommend that the Service aggressively pursue an agenda of reducing fuel consumption of its fleet, reducing its carbon footprint associated with travel, and helping “green” our workforce through incentives to reduce the carbon footprint of employees.

The Service has already demonstrated leadership in the use of habitat restoration and management for carbon sequestration. Region 4, in particular, has pioneered a strategic landscape-level approach for implementing carbon sequestration projects, primarily through reforestation. The Region has a Terrestrial Carbon Sequestration Program Coordinator, a specific list of considerations that need to be implemented in order to proceed with a cooperative carbon sequestration project, partnerships with a number of companies and agencies to implement carbon sequestration projects<sup>36</sup>, and a successful track record of project implementation<sup>37</sup>.

The Service is beginning to look at carbon sequestration in other ecosystems such as prairies<sup>38</sup> and wetlands<sup>39</sup>. We need to work with partners (e.g., Ducks Unlimited) to document the carbon sequestration benefits of conserving and restoring these ecosystem types. The issue of “carbon markets” and their possible benefits to Service



activities needs to be explored and communicated among Service Regions.<sup>40</sup>

A major concern that the Service faces is the potential conversion of wildlife habitats in such programs as the Conservation Reserve Program back to agricultural production (corn) or conversion to grass monocultures (switchgrass) to produce crops for biofuel uses<sup>41</sup>. There is a potential to lose significant wildlife habitat this way, and the Service needs to monitor this situation and work with partner agencies, in particular the NRCS, to minimize losses. The Service also needs to evaluate alternative scenarios to produce biomass while at the same time conserving wildlife habitat, such as biofuels derived from low-input high-diversity mixtures of native grassland perennials<sup>42</sup>. We need to ensure that mitigation activities such a biofuels do not compromise wildlife habitats. The Service needs to be cognizant of the potential impact of renewable energy systems such as wind, hydroelectric, and ocean current/tidal on wildlife and wildlife resources.

- As with Adaptation, we recommend that the Service incorporate these and other ideas related to Mitigation into a comprehensive national “Strategic Vision for the Fish and Wildlife Service’s Response to Climate Change.” Further, we recommend that the “Climate Change Think Tank” consider issues related to Mitigation as well as Adaptation.
- We recommend the Service “lead by example” and setting ambitious objectives for mitigation through energy conservation, reduction of greenhouse gas emissions, and carbon sequestration.
- We recommend that Region 4 produce a “Lessons Learned” document on carbon sequestration that could serve as a model or handbook for other Regions of the Service.





*2b. Because climate change may have impacts at multiple and unpredictable spatial scales, the Service's Strategic Vision should emphasize adaptive management at the landscape level to encompass ecological processes and pathways as well as species and communities.*

*Many biological, hydrological, and geological processes are interactively linked in ecosystems. These ecological phenomena normally vary within bounded ranges, but rapid, nonlinear changes to markedly different conditions can be triggered by even small differences if threshold values are exceeded. Intrinsic and extrinsic ecological thresholds can lead to effects that cascade among systems, precluding accurate modeling and prediction of system response to climate change. Understanding and anticipating nonlinear dynamics are important aspects of adaptation planning since responses of biological resources to changes in the physical climate system are not necessarily proportional and sometimes, as in the case of complex ecological systems, inherently nonlinear.*

*-- Burkett et al. 2005<sup>43</sup>*

Dynamic landscape-level conservation through adaptive management provides a framework for conservation of habitats within which actual and projected changes in climate can be factored. Key issues of habitat fragmentation, dispersal/migration corridors, nonlinear changes in ecosystem response, altered disturbance regimes (e.g., increased fire frequency, drought, or storm frequency) and issues of scale (how much is enough?) can be effectively addressed through this framework.

Habitat protection, and, in certain instances, habitat restoration can help reduce the effects of climate change by preserving and enhancing resilient, functional systems which can support biodiversity and fish and wildlife populations in light of future climate change. Overall, restoration helps make species more able to withstand stresses and adapt to changing conditions associated with climate change. Habitat creation, as a component of assisted migration, will also become important as the Service moves towards working with climate change in the future.

Because of limited funding for restoration and creation, future efforts will need to be strategic in their delivery, focusing on scales that are relevant to the types of changes that are likely to occur and specifically on areas that will be able to provide climate refugia and/or corridors for species that are likely to be at risk. Efforts will also need to be collaborative to achieve maximum effectiveness. Collaborative efforts will result in more informed, relevant, and creative solutions for all stakeholders.

**Strategic Habitat Conservation (SHC)<sup>44</sup>**

is the current Service framework for population-based, landscape-level habitat conservation through adaptive management. The SHC framework has been successfully applied in key regions (Lower Mississippi River and Prairie Potholes) and is slated to be expanded to many more geographic areas through a "focal area" approach. Climate change needs to be explicitly factored into implementation of SHC in every area. In addition, the U.S. Climate Change Program<sup>45</sup> recommends that in order to be efficient in managing Refuges in the face of accelerated climate change, the National Wildlife Refuge System (NWRS) needs to develop a "Strategic Plan for Adaptation to Global Climate Change."

Successful landscape-level conservation needs to integrate all Service programs (e.g., migratory birds, refuges, fisheries, ecological services, international conservation, etc.) and issues (e.g., T&E species, pathogens and invasive alien species, rising sea levels, changing hydrology, latitudinal and altitudinal shifts in species distributions) in a comprehensive and coordinated way, and needs to cut across Regional boundaries. One key to success in this cross-cutting approach is to create the avenues to ensure repeated opportunities for open communication.

The Service needs to set priorities for landscape-level conservation actions by conducting thorough and state-of-the-art assessments of species and habitat classifications to evaluate their relative vulnerability/resilience to climate change<sup>46</sup>. Previous assessments of endangerment and/or vulnerability under a stable climate may differ under new trajectories associated with a changing climate, and the uncertainties surrounding these projections need to be assessed<sup>47</sup>. Current and future projections of species distributions are needed<sup>48</sup>. We need to work with the climate and ecological modeling communities to develop downscaled modeling approaches and decision-support tools that are more useful at a landscape level. One such tool that may be quite useful for the Service is the Terrestrial Observation & Prediction System (TOPS) developed by NASA<sup>49</sup>.

Conservation of threatened and endangered species will pose a particular challenge under climate change. The IPCC estimates with *medium confidence* that approximately 20-30% of species

assessed so far are *likely* to be at increased risk of extinction if increases in global average warming exceed 1.5-2.5°C (relative to 1980-1999). As global average temperature increase exceeds about 3.5°C, model projections suggest significant extinctions (40-70% of species assessed) around the globe. Species of additional concern are those that play key roles in ecosystem structure and function. Among these are pollinators, seed dispersers, and species involved in nutrient cycling and energy flow through ecosystems. The species need to be factored in to landscape conservation approaches such as SHC.

- We recommend that the Strategic Habitat Conservation approach embrace consideration of climate change impacts on fish and wildlife populations and habitats.
- To better implement this approach, we further recommend that the Service develop comprehensive risk assessments of fish and wildlife populations and habitats to evaluate their relative vulnerability/resilience to climate change. These assessments need not be stand-alone documents, but could be incorporated into amended recovery plans, Comprehensive Conservation Plans, Species Conservation Action Plans (e.g., for birds and fish), Fish & Wildlife Coordination Act reports, NEPA documents, and other planning documents.



According to the IPCC, some systems, sectors and regions are *likely* to be especially affected by climate change, and therefore may be priorities:

- **Ecosystems:**
  - Terrestrial: tundra; boreal forest and mountain regions because of sensitivity to warming; mediterranean-type ecosystems because of reduction in rainfall; tropical rainforests where precipitation declines (to this we add interior grassland & steppe subject to drought)
  - Coastal: mangroves and salt marshes, due to multiple stresses
  - Marine: coral reefs due to multiple stresses; the sea ice biome because of sensitivity to warming
- **Regions:**
  - Arctic, because of the impacts of high rates of projected warming on natural systems
  - Africa, because of low adaptive capacity and projected climate change impacts
  - Small Islands, where there is high exposure of population and infrastructure to projected climate change impacts
  - Asian and African megadeltas, due to large populations and high exposure to sea level rise, storm surges and river flooding.
- **Water Resources** in some dry regions at mid-latitudes and in the dry tropics, due to changes in rainfall and evapotranspiration, and in areas dependent on snow and ice melt
- **Low-lying Coastal Systems**, due to threat of sea level rise and increased risk from extreme weather events.

### *3. Furthermore, the Service's Strategic Vision must:*

#### *3a. promote education and communication (both internally and externally) in order to overcome barriers to an effective response to climate change.*

*In times of change, learners inherit the Earth, while the learned find themselves beautifully equipped to deal with a world that no longer exists.*

*-- Eric Hoffer*

*Once upon a time, America sheltered an Einstein, went to the moon, and gave the world the laser, the electronic computer, nylons, television, and the cure for polio. Today, we are in the process, albeit unwittingly, of abandoning this leadership role.*

*-- Leon M. Lederman, Nobel Prize winner in Physics*

#### **Education**

Education is a fundamental responsibility of the Service. We must educate ourselves, our colleagues, and the American public about climate change science. We need to communicate what the Service is doing to address climate change through adaptation and mitigation, and educate our constituencies about what they can do to address climate change.

Our first priority starts with educating ourselves about climate change and its actual and potential effects. The recent "all-employee" broadcast presentation by Dr. Burkett is a start, but there is much more to do. Everyone in the Service, from the Director to field biologist, must have a common understanding of climate change and the language of climate change. We all need to speak a common language with regard to climate change in order to communicate effectively and establish credibility; the most accepted "coin of the realm" is the language of the IPCC. Second, we need to have a common understanding of climate change. This can be accomplished by various means, including websites, hard copy primers distributed to all Service employees, additional "all-employee" broadcasts, and training courses at the National Conservation Training Center. The regional climate change forums that the Director has requested would be a big part of this effort. Internal communication

will also be facilitated through list-serves and the Service's intranet site.

We must develop effective communication with our partners in Federal government agencies (both within DOI and outside DOI), State government, local government, NGOs, and private partners. The Service should be a leader on climate change among land management agencies in DOI. We must speak with a consistent message to our partners.

We need to educate our public constituencies about climate change. This ranges from participants in our Partners for Fish and Wildlife program to hunters and fishermen to teachers and school kids. Again, we must speak with a consistent message to our public constituencies. There are numerous educational resources on climate change already available – at a bare minimum, the Service's website on climate change should include scientific information and resources that our employees, partners and public can use.

We feel that is very important to create a comprehensive strategy for communication climate change science to the public, via local media, public hearings, school visits, etc. We should invite national and local communication specialists to help identify the best avenues to disseminate information to media outlets, Congressional staffers, partners, environmental leaders, and educational institutions, and create the tools and products necessary to coordinate our presence in the public eye.

#### **Communication/Information Exchange -**

##### *Building Understanding and Support*

Communication and information exchange – both internal and external to the Service – will be keys to our success. An effective climate change response will have to address reaching out and working with a large community of federal/state/local agencies, public/private sector partners, the public, and the international community. Effective communication with our partners and the public will provide the necessary support for these efforts. We will have greater success when we define our niche in the larger climate change construct. This may involve developing new policy, outreach/ partnering programs, and measurable objectives. We especially need to focus on work with our State partners, by encouraging the incorporation of climate change considerations into State Wildlife Action Plans.

- We expect that one of the outcomes of developing a Strategic Vision will be to clarify the Service's message to its employees and to the public. To continue down that path, we recommend that the Service engage in developing a strong inreach and outreach education and communication program on climate change and its impacts.
- We recommend that, as a starting point, the Service educate itself about climate change, from the Director's office down. We concur with



the Director's recommendation to hold regional Climate Change Workshops in every region. We also recommend that a national forum be held to share results from regional forums, and help develop a national strategic vision. We further recommend that a national coordinator be involved to ensure that the forums are uniform in their presentation of material and use of climate change terminology, and that the results of the forums are shared with other regions in the spirit of information exchange.



### *3b. promote new ways of thinking through legislation, policies, guidelines, and terminology.*

*As one goes through life, one learns that if you don't paddle your own canoe, you don't move.*  
-- Katharine Hepburn

Inherent barriers challenge the ability of the Service to adapt to its evolving understanding of climate change and ecosystem dynamics. The potential for climate change-related effects to undermine the Service's long-term stewardship of trust resources demands a thorough review of policy and guidance, organizational culture, and material resource limitations to institutional adaptation. In addition, it encourages Service leadership to examine their role in the larger US Government policy arena. It may even require use to advocate for amendments to our existing legislation!

#### **Legislation**

Numerous climate change bills are before Congress and one is likely to pass and be enacted into law in the near future. The Service needs to be prepared as an agency to implement those legislative provisions assigned to us. Some legislation under consideration could provide vast sums for wildlife habitat conservation, and, again, we must position ourselves at the forefront of agencies that are able to immediately use this funding for conservation action.

#### **Policy and Guidance**

Although resource managers have many tools to respond to changing conditions at a local level, potential future effects of climate change require additional capacities not currently broadly available or prioritized within the agency. Often managers must focus resources on tactical, near-term priorities, at the expense of longer-term, strategic planning. For example, a 2001 Secretarial Order (SO 3226) directed DOI agencies to consider potential climate change effects in management plans and activities developed for public lands. However, specific guidance on how best to implement this directive is lacking. Cross-program and interagency communication are needed to ensure coordinated approaches to the climate change issue. As a first step, we need to evaluate existing planning documents to determine if and how they address climate change in order to establish a baseline.

Uncertainties about the nature of Service mandates with respect to climate change also lead to differing interpretations of broad resource management authorities and implementation at the management level. Concepts and principles promoted by Service policies and guidance may be too broad, vague, complex, or undefined to support a strategic, long-term approach to conserving trust resources in the face of climate change. Terminology is one case in point. For example, the term "natural" appears in many statutes, (e.g., as natural diversity, natural conditions, natural fire regime) but may not be defined or may be expressed in terms of "historical" conditions, which may or may not be defined. Changes in the distribution and abundance of species in ecosystems are expected as climate change proceeds. We must have a common definition of natural diversity that guides our management into the future as species assemblages and communities change over time.

The Policy on Biological Integrity, Diversity, and Environmental Health (BIDEH), which is a supplemental directive to the statutory charter laid out in the 1997 National Wildlife Refuge System Improvement Act, provides for the maintenance of the composition and function of ecosystems. The term "historic" is often used in a restoration context, but the BIDEH policy uses historic conditions as a benchmark for success - this is problematic. We need to reconsider whether the historic condition is the appropriate reference point for restoration in the context of accelerated climate change<sup>50</sup>. As suggested elsewhere in this text, we will eventually need to manage towards future conditions. This revised temporal reference point would need to be extended into other management domains such as recovery targets for listed species and wetland or prairie restoration.

We need to consider new policies for situations yet to be experienced but anticipated. For example, species translocation (assisted colonization) may be a tool we need to use in the near future. We will need



guidance on the philosophical, ecological, and legal implications of translocating a species to a place it has never occurred before, the circumstances in which we would consider doing this, and how would we actually undertake the effort?<sup>51</sup> Similarly, the Service may need a policy to help us distinguish between conventional notions of exotic, invasive species versus species that are expanding their distribution in response to a changing climate.

### **Agency Leadership**

The Service, in developing a strategic vision on climate change, must look to other bureaus within the Department of the Interior, other US Government agencies, and the many other national and global entities involved in understanding and addressing climate change. Our role must not be passive. As one of the primary stewards of public lands and trust species, and as leaders in their conservation, the Service has a responsibility to lead within DOI in reporting on the changing condition of those resources and the threats to them. Service biologists should be front and center as experts in identifying how to monitor and address those threats.

### **Organizational Culture**

Integrating climate change into the Service's mainstream "way of thinking" may demand re-aligning the Service's organizational structure, policies, regulations etc. While we suspect most managers and offices have the desire to tackle this critical issue, many will find the lack of skills, expertise, and resources to implement such a new large-scale program daunting given budget and staffing limitations.

- The potential for climate change-related effects to undermine Service's long-term stewardship of trust resources demands a thorough review of the specific policy and guidance, organizational culture and barriers, and material resource limitations to institutional adaptation. Therefore, we recommend a "Climate Change Policy Think Tank" to consider key policy and guidance questions related to climate change. The two groups should share some common membership, because the issues under consideration are not mutually exclusive.



*3c. promote training and recruiting to develop a professional staff with the necessary skill sets to effectively address climate change.*

### **Skills**

#### *Building Capacity and Leadership*

The Service is obligated to provide leadership and technical assistance to help guide and coordinate the domestic and international response to climate change impacts on fish and wildlife populations and habitats. Service staff must be prepared to take the lead and/or coordinate climate change planning, recovery, restoration, and management activities.

Because of the highly technical nature of climate change science, we will need staff with skills and tools to provide effective leadership and technical assistance on the issue. Recruiting staff with skill sets that fill these niches, as well as training existing staff in these skills, will enhance our overall ability to provide guidance and leadership. To understand up-to-date climate data may need climatologists and to use these data effectively we will need staff who understand the concept of uncertainty and decision-making in the face of uncertainty. Likewise, we will need staff experienced in the application of adaptive management approaches. Non-traditional natural resource disciplines such as hydrology, coastal zone management, and remote sensing will likely need better representation in the Service's repertoire of expertise. Taking effective advantage of relevant technical expertise in other agencies, NGOs, and academia will be a necessity.

- We recommend that, as part of the upcoming Regional climate change workshops, Regions explicitly evaluate their existing skills sets relative to climate change, and any special skill needs the Region may have in order to respond effectively to climate change.
- We recommend the preparation of training courses and materials on climate change (through NCTC).



*3d. identify and develop new technology, including new methods for monitoring and managing climate change effects on fish and wildlife habitats and populations.*

### **Technology and Management Challenges**

#### *Building Adaptive Capacity*

The Service needs to develop and utilize new tools for integrating climate change in resource management. Key among these are tools that will help decision-making in the face of uncertainty, and improve predictive capability about climate change effects on regional and local scales. These decision-support tools may include climate modeling, remote sensing, GAP analysis, risk assessment, cumulative effects modeling, and population modeling.

The Service also needs to create new or refine existing tools for adapting to climate change: assisted colonization, captive breeding, genetic management, and landscape-level habitat “restoration” on an appropriate geographic and temporal scale, and identification, creation, and conservation of migration corridors. Furthermore, we need better approaches to inventorying and monitoring, and modeling of many types (population models, habitat models, etc.).

#### *Assisted Migration*

Assisted migration is probably the most widely cited tool to address the redistribution of species northward in latitude and upward in elevation. Many existing populations could be trapped in isolated fragments either because migration corridors don't exist, natural and man-made barriers to migration exist, or because the climate envelope changes faster than a species can physiologically or biologically change. Assisted migration is more than translocating species to new areas. This strategic approach may require deliberately creating habitats in places where they've never occurred before, conserving and creating landscape-level migration corridors, identifying *refugia* of vulnerable populations, and using captive breeding and seed banks as “half-way” houses for species that are vulnerable to extinction before new habitats can be established in shifting climatic envelopes. A strategic approach to the growth of the NWRs that is dynamic and considers the effects of climate change would be a critical component of assisted migration<sup>52</sup>.

#### *Captive Breeding*

Our priority, ideally, is to conserve species and natural communities in situ by minimizing or eliminating anthropogenic threats. However, many

ecosystems and habitats for native species already are compromised to the extent that endangered species require intensive *ex situ* management in order to persist. As changes in climate play out at the local level, captive propagation rapidly may become the last option for more imperiled species. Captive propagation is extremely expensive and labor intensive, and so our conventional wisdom is to use it as a “last ditch” strategy; paradoxically, the expense and difficulty of propagation may be greatest when it is undertaken on the verge of extinction. These decisions should not wait until populations reach the “bottleneck” stage; instead, our use of captive propagation should become more proactive, and more selective. Captive breeding could be used as a “half-way” house for vulnerable species which may need assisted migration to yet-to-be-established habitats outside their paleobiological distribution<sup>53</sup>.

#### *Genetic Management*

Two important aspects of genetic management of species at risk are conserving maximum haplotype diversity in wild populations (through connectivity and/or minimizing range reduction) to ensure the greatest potential for adaptive mutation, and managing captive populations so that some semblance of natural selection is maintained<sup>54</sup>, either through carefully managed interbreeding of captive populations or reducing the number of generations in captivity.

*Integrated Inventory & Monitoring* Responding intelligently to climate change will demand a Service-wide, integrated inventory and monitoring (I & M) program. While most research and many I & M initiatives will be collaborative in nature, the Service has an inherent and legal obligation to ensure the well being of the lands we administer and trust resources we conserve. One of the vital roles of the Service is inventory, monitoring, and assessment of populations and habitat. In order to understand what impacts climate change is already having and may have in the future we must continue to expand our efforts in this area. The information gained from these activities will provide vital information for adaptive management and planning efforts. Our goal should be to use monitoring and assessments to (1) identify sensitive ecosystems and critical processes; (2) understand current conditions, including information about existing stressors; and (3) feed information back into management plans and actions. Risk assessments will also be another important tool in helping to identify species and habitats of concern. These data will be the heralds of change and provide us with information that will be critical to a strategic response.

The fundamental impact of climate change to many of our trust resources is the re-distribution of flora and fauna in response to changes in disturbance regimes and climatic envelopes. Because extirpation and extinction, colonization and invasion, and novel species assemblages are expected but unpredictable

future outcome, we need a more holistic approach to inventorying and monitoring biota.

- We recommend that comprehensive species inventories of NWRs (and perhaps other conservation lands), be promoted through special funding.<sup>55</sup> The Service cannot be expected to adapt strategically to climate change impacts without a better sense of in situ biodiversity. We speak almost cavalierly about the impacts of climate change and invasive species on biodiversity without any knowledge of the full extent of species richness for the lands we manage.
- We strongly recommend developing a national program to inventory and monitor changes in the biological integrity, diversity, and environmental health of the NWRS consistent with the 1997 Refuge Improvement Act and BIDEH policy<sup>56</sup>. Objectives of this program would be scaled to detect changes in flora, fauna, and other metrics at the regional and/or national level. This program would consist of permanent sampling sites, ideally integrated and cost-shared with existing national monitoring programs such as the USDA Forest Inventory & Analysis program or the EPA's EMAP<sup>57</sup>. Data resulting from this proposed I&M program can be used to model spatially-explicit distributions of biota now and into the future as a result of climate change<sup>58</sup>. The Service should work with other DOI land agencies to establish a center for spatial modeling within USGS-BRD; such a center would complement the data that would result from a NWRS I&M program.
- We should continue to support and perhaps expand the funding and/or scope of existing monitoring programs that have proven track records such as the USDA-DOI Remote Automated Weather Station (RAWS)<sup>59</sup> network or the Interagency Monitoring of Protected Visual Environments (IMPROVE)<sup>60</sup> program, as well as phenology and breeding bird monitoring programs.

#### *Invasive Species*

One of the major impacts of climate change is the spread and potential impacts of invasive and generally non-native species. As a general rule, invasive species are highly adaptable and have the potential to expand their ranges as habitat conditions in the surrounding areas change, vectors for their spread become more available, and other species become less able to compete due to multiple stressors in their environment. In light of future changes that are predicted, the Service will face many challenges in the management of non-native species. The very definition of non-native may be changed by the migration and spread of species and the overall shift in habitat type distribution. Finding effective solutions to these issues will be important to ensuring that biodiversity is maintained and the



impacts of invasive species do not compound the impacts of climate change. The Invasive Species Forecasting System (ISFS) developed by NASA<sup>61</sup> may be a useful tool for the Service in predicting when and where invasive species will spread.

#### *Water, Water, Water*

Water is an absolutely critical resource for the Service, and water management will become increasingly difficult in the coming decades. For example, the IPCC has concluded the following:

- North America has experienced locally severe economic damage, plus substantial ecosystem, social and cultural disruption from recent weather-related extremes, including hurricanes, other severe storms, floods, droughts, heatwaves and wildfires (very high confidence).
- Coastal communities and habitats will be increasingly stressed by climate change impacts interacting with development and pollution (very high confidence). Sea level is rising along much of the coast, and the rate of and the rate of change will increase in the future, exacerbating the impacts of progressive inundation, storm-surge flooding and shoreline erosion.
- Climate change will constrain North America's over-allocated water resources, increasing competition among agricultural, municipal, industrial and ecological uses (very high confidence).

The Service must continue to increase its understanding of the effects of changing hydrologic cycles on our fish and wildlife trust resources, to develop better predictive capabilities on how hydrology will change<sup>62</sup>, and to develop tools to make more effective decisions about water resource allocation and use in the coming decades. The Service may need to assign higher priority to acquiring water rights to ensure minimum streamflows, etc.

#### *Altered disturbance regimes*

The IPCC concluded that: "Disturbances such as wildfire<sup>63</sup> and insect outbreaks are increasing and are likely to intensify in a warmer future with drier soils and longer growing seasons (very high confidence)." As with water resources, the Service must continue to increase its understanding of the effects of changing disturbance regimes on our fish and wildlife trust resources, to develop better predictive capabilities on how disturbance regimes will change, and to develop tools to make more effective management decisions under these new disturbance regimes.

#### *Disease*

As climate changes, and the human-wildlife interface becomes more blurred, infectious diseases (including zoonoses), will emerge more frequently and in new areas.<sup>64</sup> Climate change will work through changing distribution patterns of disease patterns, changing

wildlife distributions that affect transmission of diseases, altered susceptibility of wildlife to disease because of climate change related stress, and other factors. As with disturbance and water resources, the Service must continue to increase its understanding of the effects of changing disease pattern and prevalence on our fish and wildlife trust resources, to develop better predictive capabilities on how diseases regimes will change, and to develop tools to make more effective management decisions under these new disease regimes.

- We recommend that the "Climate Change Biology/Management Think Tank" specifically address the issues of assisted migration, captive breeding, genetic management, invasive species, water resources, altered disturbance regimes, and wildlife disease. This might logically be approached through focused sub-groups each of which can concentrate on a specific issue.

#### **Research**

##### *Gaining New Information*

The Service will need to improve its own capacity to conduct research on adaptation to and mitigation of climate change. Effective partnering with other Federal agencies, NGOs and academia to conduct this research will be absolutely necessary.

- Under a separate item, we have specifically recommended that the Climate Change Biology/Management Think Tank" address research needs related to biology and management issues.





*3e. Climate change is a global issue. In order to ensure our domestic efforts are effective in addressing the impacts of climate change on international fish and wildlife resources, the Service must anticipate and address the global impacts of climate change collaboratively with other nations.*

*Hope is not what we find in evidence, it's what we become in action.*

*-- Frances Moore Lappe*

The relationship of climate change to species and habitats is complex, yet there are several points on which a scientific consensus has emerged: (1) Species of concern often occupy regions of rapidly increasing human density, and are projected to be under increasing threat as populations shift with global change. (2) Alteration of habitat will exacerbate the causes and consequences of climate change. Regions which are essential to the survival of key species can also be important carbon sinks and serve other essential large-scale ecological functions. (3) As climate changes, and the human-wildlife interface becomes more blurred, infectious diseases (including zoonoses), will emerge more frequently and in new areas.

The Service is in a unique position to lead US Government agencies in assisting the international community to address climate change now and in the future. Our international work harnesses local capacity, societal strengths and resources to strengthen sustainable conservation processes and build climate-resilient ecological and social systems in five strategic conservation regions (Latin America/Caribbean, Mexico, Russia and China, Africa, and South/Southeast Asia), through the Wildlife Without Borders Program, the Multinational Species Conservation Funds, the Division of Management Authority, and the Division of Scientific Authority.

The Migratory Bird Program is a partner in the four major bird initiatives: the North American Waterfowl Management Plan, Waterbird Conservation for the Americas, Partners in Flight, and the U.S. Shorebird Conservation Plan. All of these initiatives support and facilitate bird conservation efforts across international boundaries. In addition, the Division of Bird

Habitat Conservation manages two international grant programs, the Neotropical Migratory Bird Conservation Act and the North American Wetlands Conservation Act. These two programs together support public-private partnerships that carry out projects that promote the long-term conservation of migratory birds and their habitats in the United States, Canada, Mexico, Latin America, and the Caribbean. The goals of the programs include perpetuating healthy populations of migratory birds, providing financial resources for bird conservation initiatives, and fostering international cooperation for such initiatives.

International climate change actions could include:

*Protected Area Management*

Strengthening the role of protected areas as: (a) refuges for biodiversity and as protective systems for natural hazard mitigation; (b) corridors for increasing natural capacity for ecological resilience, system "migration" and adaptation; (c) carbon sinks, and; (d) ecological service providers.

*Resource Management Training*

Building management capacity for mitigation, adaptation, and sustainable use of goods and ecological services from natural systems in a changing social economic and ecological context.

*Civil Society Participation.*

Enhancing key host country agencies' ability to engage civil society in conservation decision-making.

*International Treaty Implementation*

Reinforcing national and inter-governmental ability to implement key agreements such as CITES, the Ramsar Convention, and other international conservation agreements.

Through strong, well-supported International Affairs and Migratory Birds programs, the Service is poised to play a key role in understanding and addressing climate change impacts on species and habitats around the world, in building international cooperation to safeguard U.S. and foreign species from climate change impacts, and in bringing U.S. expertise and resources to international conservation and climate change forums.

- As the Service further develops expertise on a balanced response to climate change on Service lands and trust species of fish and wildlife, using the key concepts of Adaptation and Mitigation, we recommend that we make this experience available internationally through on-line resources, and education and training programs.
- In order to continue drawing on international expertise for complex analyses and difficult decisions, we recommend exploring a more active Service role in U.S. deliberations at international forums, including the U.N. Framework Convention on Climate Change<sup>65</sup> and its species and habitat related activities.

#### 4. Accelerated climate change poses an extraordinary challenge but an unprecedented opportunity to be a “great unifier” of Service land and water resource conservation programs.

*Even if concentrations of radiative forcing agents were to be stabilised, further committed warming and related climate changes would be expected to occur; largely because of time lags associated with processes in the oceans.*

*-- IPCC 2007<sup>66</sup>*

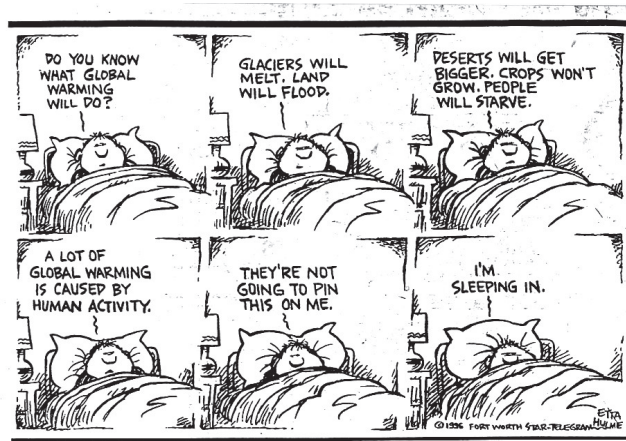
*For myself I am an optimist--it does not seem to be much use being anything else.*

*--Winston Churchill*

Addressing the impacts of accelerated climate change on fish and wildlife poses extraordinary challenges to the Service. Climate change will affect all of us professionally and personally in ways that are still mostly very difficult to predict. It impacts the very mission of our bureau in ways that are certainly new, perhaps foreign, and somehow “unnatural”.

However, it is an enormous opportunity for the Service to re-examine what is “natural” in a world that is not only rapidly changing, but one that has directionality. It will force us to philosophically revisit Aldo Leopold’s land ethic and encourage us to promote a more sustainable way of life. It can provide a very clear nexus for how Service divisions can collaborate (i.e., horizontal integration) on a single issue that affects all other mandates and trust resources.

Climate change will be with us, for all practical purposes, for the “forever.” We need to assign this issue the highest priority and address it with a sense of urgency across all programs and Regions of the Service. At the end of the day, we have a choice to be reactive or proactive in our approach to decision making. Developing a Strategic Vision that is dynamic and incorporates the best of institutionalized Climate Change Think Tanks are big steps toward being proactive in our collective response, and beginning the process of adapting to climate change.



*Ignoring climate change is likely to increasingly result in failure to reach wildlife management objectives.*

*Wildlife managers need to become knowledgeable about climate change, ways to cope with it, and ways to take advantage of it.*

*-- The Wildlife Society (2004)<sup>67</sup>*



**Do not take lightly small good deeds  
believing they can hardly help...**

**For drops of water,  
one by one,  
in time can fill a giant pond.**

*-- attributed, in slightly different form, to the  
Buddha*

# Notes and References:

<sup>1</sup> Julius, S. H., and J. M. West (eds). 2007. Preliminary review of adaptation options for climate-sensitive ecosystems and resources. Synthesis and Assessment Product 4.4, U.S. Climate Change Program. Aug 2007 draft for public comment. 784 pp.

<sup>2</sup> Examples of participants in the Climate Change Biology/Management Think Tank might include representatives from the Federal government (e.g., NPS, USGS, NOAA, NASA, EPA, NCAR, NSIDC), State government (e.g., Western Climate Initiative, California Climate Action Team), academia (e.g., Universities of Illinois, Washington, Colorado, Florida), NGOs (e.g., Pew Center on Global Climate Change, The Nature Conservancy), and consortiums (e.g., Midwestern Regional Climate Center, Joint Institute for the Study of the Atmosphere and Ocean).

<sup>3</sup> Inventories could be conducted by bioblitzs and/or regional inventory teams similar to Rapid Ecological Assessments conducted by The Nature Conservancy and Conservation International.

<sup>4</sup> Meretsky, V. J., R.L. Fischman, J.R. Karr, D.M. Ashe, J.M. Scott, R.F. Noss, and R.L. Schroeder. 2006. New directions in conservation for the National Wildlife Refuge System. *BioScience* 56:135-143.

<sup>5</sup> Magness, D.R., F. Huettmann, and J.M. Morton. In press. Using Random Forest to provide predicted species distribution maps as a metric for ecological inventory & monitoring programs. Chapter in T. Smolinski, M. Milanova & A. Hassanien (eds.). *Applications of Computational Intelligence in Biology: Current Trends and Open Problems*. Springer-Verlag.

<sup>6</sup> <http://unfccc.int/2860.php>

<sup>7</sup> IPCC -- Intergovernmental Panel on Climate Change (IPCC). 2007a. The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, NY. 996 pp.

IPCC. 2007b. Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson (eds.)]. Cambridge University Press, NY. 976 pp.

IPCC. 2007c. Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds.)], Cambridge University Press, NY. XXX pp.

<sup>8</sup> Walther, G-R., E. Post, P. Convey, A. Menzel, C. Parmesan, T. J. C. Beebee, J-M. Fromentin, O. Hoegh-Guldberg, and F. Bairlein. 2002. Ecological responses to recent climate change. *Nature* 416:389-395.

<sup>9</sup> Intergovernmental Panel on Climate Change (IPCC). 2007. Synthesis Report of the IPCC Fourth Assessment Report (AR4).

<sup>10</sup> U.S. Government agencies and funded programs involved with climate change include, but are not limited to: Commerce Department/National Oceanic and Atmospheric Agency (NOAA) (NOAA Climate Office, <http://www.climate.noaa.gov/>)

Energy Department (<http://www.energy.gov/environment/climatechange.htm>) and its Climate Change Prediction Program (<https://ccpp.llnl.gov/>)

Environmental Protection Agency (EPA) (<http://www.epa.gov/climatechange/index.html>); NASA (Goddard Institute for Space Studies, <http://www.giss.nasa.gov/>)(Goddard Space Flight Center, <http://gcmd.nasa.gov/>)

National Center for Atmospheric Research (NCAR, a federally funded research and development center through the National Science Foundation (NSF), <http://www.ncar.ucar.edu/>)

National Snow and Ice Data Center (NSIDC, a part of the Cooperative Institute for Research in Environmental Sciences (CIRES) at the University of Colorado at Boulder, <http://nsidc.org/>)

National Science Foundation (NSF, <http://www.nsf.gov/index.jsp>)



U.S. Forest Service (National Program for Global Change Research, <http://www.fs.fed.us/research/fsgc/national-fsgcrp.shtml>)

U.S. Geological Survey (Earth Surface Dynamics Program's Climate Change Science, <http://geochange.er.usgs.gov/>).

<sup>11</sup> Government Accounting Office. 2007. Climate change: Agencies should develop guidance for addressing the effects on Federal land and water resources. Report to Congressional requestors. GAO-07-863, Washington, D.C. 184 pp. <http://www.gao.gov/new.items/d07863.pdf>

<sup>12</sup> Julius, S. H., and J. M. West (eds). 2007. Preliminary review of adaptation options for climate-sensitive ecosystems and resources. Synthesis and Assessment Product 4.4, U.S. Climate Change Program. August 2007 draft for public comment. 784 pp.

<sup>13</sup> [http://alaska.fws.gov/climate\\_change.htm](http://alaska.fws.gov/climate_change.htm)

<sup>14</sup> <http://www.fws.gov/southeast/carbon/>

<sup>15</sup> <http://ecos.fws.gov/docs/coastal/web/pdf/785.pdf>

<sup>16</sup> **IPCC 2007**

<sup>17</sup> The February 2007 issue of the Harvard Business Review has an article on the problem of implementing a national strategy.

<sup>18</sup> McKibbin, W.J., and P.J. Wilcoxon. 2004. Climate policy and uncertainty: The roles of adaptation versus mitigation. Brookings Discussion Papers in International Economics.

<sup>19</sup> Parmesan, C. 2006. Ecological and evolutionary responses to recent climate change. *Ann. Rev. Ecol. Evol. Syst.* 37:637-669. (**Correct citation?**)

<sup>20</sup> Davis, B., J. Carter, T. Calnan, D. Carter, S. Cooksey, S. Dickson, E. Fisher, S. Goldbeck, J. Hennessey, C. Hernick, T. Howie, Z. Johnson, J. Knisel, G. Lytton, A. McMahon, T. Pratt, B. Rhame, R. Roth, J. Warren, J. Watkins, and J. Weber. 2007. The role of Coastal Zone Management Programs in adaptation to climate change. Final report of the Coastal States Organization Climate Change Work Group. 27 pp.

<sup>21</sup> Choi, Y.D. 2007. Restoration ecology to the future: A call for new paradigm. *Restoration*

*Ecology* 15:351-353. and Harris, J.A., R. J. Hobbs, E. Higgs, and J. Aronson. 2006. Ecological restoration and global climate change. *Restoration Ecology* 14:170-176.

<sup>22</sup> Clark et al. 2001. Ecological forecasts: An emerging imperative. *Science* 293:657-660.

<sup>23</sup> Li, M.-H., N. Krauchi, and S.-P. Gao. 2006. Global warming: Can existing reserves really preserve current levels of biological diversity? *J. Integrative Plant Biology* 48:255-259.

<sup>24</sup> National Ecological Assessment Team. 2006. Strategic habitat conservation. U.S. Fish and Wildlife Service and U.S. Geological Survey, Arlington, VA. 48 pp.

<sup>25</sup> Fowler, H.J., S. Blenkinsop, and C. Tebaldi. 2007. Linking climate change modelling to impacts studies: recent advances in downscaling techniques for hydrological modelling. *International J. of Climatology* 27:1547-1578.

<sup>26</sup> Inkley, D. B., M. G. Anderson, A. R. Blaustein, V. R. Burkett, B. Felzer, B. Griffith, J. Price, and T. L. Root. 2004. Global climate change and wildlife in North America. Wildlife Society Technical Review 04-2. The Wildlife Society, Bethesda, MD, USA. 26 pp.

<sup>27</sup> Burkett, V.R., D.A. Wilcox, R. Stottlemeyer, W. Barrow, D. Fagre, J. Baron, J. Price, J.L. Nielsen, C. D. Allen D.L. Peterson, G. Ruggerone, and T. Doyle. 2005. Nonlinear dynamics in ecosystem response to climatic change: Case studies and policy implications. *Ecological Complexity* 2:357-394.

<sup>28</sup> Folke et al. 2002. Resilience and sustainable development: Building adaptive capacity in a world of transformation.

<sup>29</sup> Elmqvist et al. 2003. Response diversity, ecosystem change, and resilience. *Ecol. Environ.* 1(9):488-494.

<sup>30</sup> Inkley, D. B., M. G. Anderson, A. R. Blaustein, V. R. Burkett, B. Felzer, B. Griffith, J. Price, and T. L. Root. 2004. Global climate change and wildlife in North America. Wildlife Society Technical Review 04-2. The Wildlife Society, Bethesda, Maryland, USA. 26 pp

- <sup>31</sup> Parmesan, C. 2006. Ecological and evolutionary responses to recent climate change. *Ann. Rev. Ecol. Evol. Syst.* 37:637-669. and Parmesan, C., and G. Yohe. 2003. A globally coherent fingerprint of climate change impacts across natural systems. *Nature* 421:37-42.
- <sup>32</sup> Westerling, A.L., H.G. Hidalgo, D.R. Cayan, and T.W. Swetnam. 2006. Warming and earlier spring increase western U.S. forest wildfire activity. *Science* 313:940-943.
- <sup>33</sup> Julius, S. H., and J. M. West (eds). 2007. Preliminary review of adaptation options for climate-sensitive ecosystems and resources. Synthesis and Assessment Product 4.4, U.S. Climate Change Program. Aug 2007 draft for public comment. 784 pp.
- <sup>34</sup> Examples of participants in the Think Tank might include representatives from the Federal government (e.g., NPS, USGS, NOAA, NASA, EPA, NCAR, NSIDC), State government (e.g., Western Climate Initiative, California Climate Action Team), academia (e.g., Universities of Illinois, Washington, Colorado, Florida), NGOs (e.g., Pew Center on Global Climate Change, The Nature Conservancy), and consortiums (e.g., Midwestern Regional Climate Center, Joint Institute for the Study of the Atmosphere and Ocean).
- <sup>35</sup> Executive Order 13123, *Greening the Government Through Efficient Energy Management* and Executive Order 13149, *Greening the Government Through Federal Fleet and Transportation Efficiency*,
- <sup>36</sup> <http://www.fws.gov/southeast/carbon/reforestation.html>
- <sup>37</sup> <http://www.fws.gov/southeast/carbon/casestudies.html> and <http://www.fws.gov/southeast/carbon/TensasRiver.html>
- <sup>38</sup> Tilman, D., J. Hill, and C. Lehman. 2006. Carbon-negative biofuels from low-input high-diversity grassland biomass. *Science* 314:1598-1600.
- <sup>39</sup> Kusler, J. 2006. Common questions: Wetland, climate change, and carbon sequestration. Association of State Wetland Managers, inc. in cooperation with The International Institute for Wetland Science and Public Policy. 27 pp. and Euliss, N. H., Jr., R.A. Gleason, A. Olness, R.L. McDougal, H.R. Murkin, R.D. Robarts, R.A. Bourbonniere, and B.G. Warner. 2006. North American prairie wetlands are important nonforested land-based carbon storage sites. *Science of the Total Environment* 361:179-188.
- <sup>40</sup> For examples, "The Carbon Fund" <http://www.thecarbonfund.org/credits.shtml> and Morris, E. 2007. Western states launch carbon scheme. *Nature* 446:114-115.
- <sup>41</sup> Bies, L. 2006. The biofuels explosion: Is green energy good for wildlife? *Wildlife Society Bulletin* 34: 1203-1205. and Secchi, S., and B.A. Babcock. 2007. Impact of high corn prices on Conservation Reserve Program acreage. *Iowa Ag. Review*, Volume 13 (Spring 2007).
- <sup>42</sup> Tilman, D., J. Hill, and C. Lehman. 2006. Carbon-negative biofuels from low-input high-diversity grassland biomass. *Science* 314:1598-1600.
- <sup>43</sup> Burkett, V.R., D.A. Wilcox, R. Stottlemeyer, W. Barrow, D. Fagre, J. Baron, J. Price, J.L. Nielsen, C. D. Allen D.L. Peterson, G. Ruggerone, and T. Doyle. 2005. Nonlinear dynamics in ecosystem response to climatic change: Case studies and policy implications. *Ecological Complexity* 2:357-394.
- <sup>44</sup> National Ecological Assessment Team. 2006. Strategic habitat conservation. U.S. Fish and Wildlife Service and U.S. Geological Survey, Arlington, VA. 48 pp.
- <sup>45</sup> Julius, S. H., and J. M. West (eds). 2007. Preliminary review of adaptation options for climate-sensitive ecosystems and resources. Synthesis and Assessment Product 4.4, U.S. Climate Change Program. Aug 2007 draft for public comment. 784 pp.
- <sup>46</sup> Johnson, W.C., B.V. Millett, T. Gilmanov, R.A. Voldseth, G.R. Guntenspergen, and D.A. Naugle. DATE. Vulnerability of northern prairie wetlands to climate change. *BioScience* 55:863-872. and Scholze, M., W. Knorr, N.W. Arnell, and I.C. Prentice. 2006. A climate-change risk analysis for world ecosystems. *Proceedings of the National Academy of Sciences* 103 : 13116-13120. and Thomas, C.D., A. Cameron, R.E. Green, M. Bakkenes, L. J. Beaumont, Y.C. Collingham,

- B.F. N. Erasmus, M.F. de Siqueira, A. Grainger, L. Hannah, L. Hughes, B. Huntley, A.S. van Jaarsveld, G.F. Midgley, L. Miles, M.A. Ortega-Huerta, A. T. Peterson, O. L. Phillips, and S.E. Williams. 2004. Extinction risk from climate change. *Nature* 427:145-149.
- <sup>47</sup> Tilman, D., J. Hill, and C. Lehman. 2006. Carbon-negative biofuels from low-input high-diversity grassland biomass. *Science* 314:1598-1600.
- <sup>48</sup> Austin, M. 2006. Species distribution models and ecological theory: A critical assessment and some possible new approaches. *Ecological Modelling* 200: 1-19. and Johnson, C.J. and M.P. Gillingham. 2005. An evaluation of mapped species distribution models used for conservation planning. *Envir. Conservation* 32:117-128.
- <sup>49</sup> <http://ecocast.arc.nasa.gov/content/view/76/133/>
- <sup>50</sup> Choi, Y.D. 2007. Restoration ecology to the future: A call for new paradigm. *Restoration Ecology* 15:351-353. and Harris, J.A., R.J. Hobbs, E. Higgs, and J. Aronson. 2006. Ecological restoration and global climate change. *Restoration Ecology* 14:170-176.
- <sup>51</sup> Hunter, M.L. 2007. Climate change and moving species: Furthering the debate on assisted colonization. *Conservation Biology* 21:1356-1358.
- <sup>52</sup> Hunter, M.L. 2007. Climate change and moving species: Furthering the debate on assisted colonization. *Conservation Biology* 21:1356-1358. and Julius, S. H., and J. M. West (eds). 2007. Preliminary review of adaptation options for climate-sensitive ecosystems and resources. Synthesis and Assessment Product 4.4, U.S. Climate Change Program. Aug 2007 draft for public comment. 784 pp. and Li, M.-H., N. Krauchi, and S.-P. Gao. 2006. Global warming: Can existing reserves really preserve current levels of biological diversity? *J. Integrative Plant Biology* 48:255-259.
- <sup>53</sup> Hunter, M.L. 2007. Climate change and moving species: Furthering the debate on assisted colonization. *Conservation Biology* 21:1356-1358.
- <sup>54</sup> Frankham, R. 2007. Genetic adaptation to captivity in species conservation programs. *Molecular Ecology*. Doi: 10.1111/j.1365-294X.2007.03399.x
- <sup>55</sup> Inventories could be conducted by bioblitzs and/or regional inventory teams similar to Rapid Ecological Assessments conducted by The Nature Conservancy and Conservation International.
- <sup>56</sup> Meretsky, V. J., R.L. Fischman, J.R. Karr, D.M. Ashe, J.M. Scott, R.F. Noss, and R.L. Schroeder. 2006. New directions in conservation for the National Wildlife Refuge System. *BioScience* 56:135-143.
- <sup>57</sup> <http://www.epa.gov/emap/>
- <sup>58</sup> Magness, D.R., F. Huettmann, and J.M. Morton. In press. Using Random Forest to provide predicted species distribution maps as a metric for ecological inventory & monitoring programs. Chapter in T. Smolinski, M. Milanova & A. Hassanien (eds.). *Applications of Computational Intelligence in Biology: Current Trends and Open Problems*. Springer-Verlag.
- <sup>59</sup> <http://www.raws.dri.edu/>
- <sup>60</sup> <http://vista.cira.colostate.edu/improve/>
- <sup>61</sup> <http://bp.gsfc.nasa.gov/>
- <sup>62</sup> Seager et al. 2007. Model projections of an imminent transition to a more arid climate in southwestern North America. *Science* 316: 1181-1184.
- <sup>63</sup> Westerling, A.L., H.G. Hidalgo, D.R. Cayan, and T.W. Swetnam. 2006. Warming and earlier spring increase western U.S. forest wildfire activity. *Science* 313:940-943. and Running, S.W. 2006. Is global warming causing more, larger wildfires? *Science* 313:927-928.
- <sup>64</sup> Jenkins, E.J., V.A. Veitch, S.J. Kutz, E.P. Hoberg, and L. Polley. 2006. Climate change and the epidemiology of protostrongylid nematodes in northern ecosystems: *Parelaphyostromylus odocoilei* and *Protostrongylus stilesi* in Dall's sheep (*Ovis d. dalli*). *Parasitology* 132:387-401. and Harvell et al. 2002. Climate warming and disease risks for terrestrial and marine biota. *Science* 296:2158-2162.
- <sup>65</sup> <http://unfccc.int/2860.php>
- <sup>66</sup> **IPCC 2007**



<sup>67</sup> Inkley, D. B., M. G. Anderson, A. R. Blaustein, V. R. Burkett, B. Felzer, B. Griffith, J. Price, and T. L. Root. 2004. Global climate change and wildlife in North America. Wildlife Society Technical Review 04-2. The Wildlife Society, Bethesda, Maryland, USA. 26 pp.