United States
Environmental Protection
Agency

Office of Research and
Development
Washington, DC 20460

EPA/600/R00/077
September 2000
www.epa.gov/ncerqa

Proceedings

2000 STAR Integrated Assessments of Global Change Progress Review

September 25-27, 2000
Research Triangle Park, North Carolina

NATIONAL CENTER FOR ENVIRONMENTAL RESEARCH

Table of Contents

Introduction v

Vulnerability Assessment of San Joaquin Basin Water Supply, Ecological Resources, and Rural Economy Due to Climate Variability and Extreme Weather Events 1
John Dracup, Richard Howitt, Leslie Grober

Assessment of the Consequences of Climate Change on the South Florida Environment 2
Mark A. Harwell, Wendell P. Cropper, Jr., Jerald S. Ault, John H. Gentile, David Letson, Jiangang Luo, Steven Tosini, John Wang

Integrated Assessment of Climate Change Impact in the Mackinaw River Watershed, Illinois 3
Edwin E. Herricks, J.W. Eheart, Kieran P. Donaghy, Brian Orland

An Integrated Assessment of the Effects of Climate Change on Rocky Mountain National Park and Its Gateway Community 4
N. Thompson Hobbs, Dennis Ojima, John Loomis, Stephan Weiler, David M. Theobald, Alan P. Covich, Jill S. Baron, Thomas J. Stohlgren, Michael B. Coughenour

Infrastructure Systems, Services, and Climate Change: Integrated Impacts and Response Strategies for the Boston Metropolitan Area 6
Paul H. Kirshen, Matthias Ruth

Impact of Climate on the Lower Yakima River Basin 8
Lance Vail, Mike Scott, Kristi Branch, Dennis Dauble, L. Ruby Leung, Mark Wigmosta, Claudio Stockle, Keith Saxton

Introduction

The mission of the United States Environmental Protection Agency (EPA) is to protect public health and to safeguard and improve the natural environment—air, water, and land upon which life depends. Achievement of this mission requires the application of sound science to the assessment of environmental problems and to the evaluation of possible solutions. The National Center for Environmental Research's (NCER) Science to Achieve Results (STAR) Program at EPA is committed to providing the best products in high-priority areas of scientific research through significant support for long-term research.

One high-priority research program identified in the Office of Research and Development's Strategic Plan is Global Change. In support of the Global Change Program, the STAR program issued a Request for Applications (RFA) in 1996 and 1999, which solicited the development and demonstration of integrated assessment methodologies that address the positive and negative consequences of climate change at the regional or local scales.

Annual progress reviews such as this one will allow investigators to interact with one another and discuss progress and findings with EPA and other interested parties. If you have any questions regarding the program, please contact the Program Manager, Bernice L. Smith (smith.bernicel@epa.gov).

Vulnerability Assessment of San Joaquin Basin Water Supply, Ecological Resources, and Rural Economy Due to Climate Variability and Extreme Weather Events

John Dracup [1], Richard Howitt [2], and Leslie Grober [3]

[1] University of California at Berkeley, Berkeley, CA; [2] University of California at Davis, Davis, CA; [3] Central Valley Regional Water Quality Control Board, Sacramento, CA

The main objectives of this collaborative research project are to: (1) assess the vulnerability of water supply, water demand, water quality, ecosystem health, and socioeconomic welfare within the San Joaquin River Basin as a function of climate variability and extreme weather events; and (2) provide guidance in the formulation of effective management strategies to mitigate the range of potential impacts due to climate variability and extreme weather.

This study is updating and advancing previous studies on climate change in California. First, this study is based on new general circulation model (GCM) output from the U.K. Hadley Centre's HadCM2 climate change experiments and new methods in statistical downscaling that convert GCM climate forecasts into local weather forecasts. Second, this study features an integrated impacts analysis of climate change/variability on the resources of the San Joaquin River Basin—previous studies focused only on water resource impacts. Third, a decision support system (DSS) is being produced that will provide assistance to the CALFED Program (a joint California state and federal program designed to resolve water issues in Northern California) in water resource and ecosystem management of the subregion.

The first year of the project has been devoted to assembling the various models that will be used in both the impacts assessment and forecast phases of the project. The model system features seven loosely coupled models: (1) climate downscaling; (2) rainfall/runoff; (3) water supply allocation; (4) agricultural production; (5) water quality; (6) fish ecology; and (7) socioeconomics. The climate downscaling, rainfall/runoff, water supply allocation, and socioeconomics models are fully or near-fully developed; the remaining model components will be completed during year 2. The model system includes the latest integrated modeling tools provided by the United States Geological Survey (i.e., Modular Modeling System [MMS] and Object User Interface [OUI]). These public domain tools feature database-driven integrated modeling frameworks. The MMS tool is suitable for constructing, parameterizing, and running rainfall/runoff models. The OUI tool is a map-based graphical user interface (GUI) that provides a common interface for running models as well as acquiring, browsing, organizing, and selecting spatial and temporal data. All models will be incorporated into the OUI during year 2.

The principal benefit of the work proposed is an improved assessment of the San Joaquin River Basin's vulnerability to climate variability and extreme events. Partnerships with key water and ecosystem managers in the Basin will enable effective utilization of future planning and provide assistance to the CALFED Program.

San Joaquin River Basin managers will be provided with the DSS. These managers will use the DSS to further evaluate the impacts of climate variability and extreme events and to develop approaches for mitigating potential impacts. A user-friendly compact disk toolbox and user manual will be developed as part of this Environmental Protection Agency study. The DSS is being designed with minimal time required for file manipulation to formulate impact response scenarios. The DSS will allow the analyst to assess interventions such as reservoir reoperation, real-time water quality management, and adaptive management of fishery resources in mitigating some of the potential impacts. Training on the resulting DSS system will be provided to planners, operations analysts, and other users.

Assessment of the Consequences of Climate Change on the South Florida Environment

Mark A. Harwell, Wendell P. Cropper, Jr., Jerald S. Ault, John H. Gentile, David Letson, Jiangang Luo, Steven Tosini, and John Wang

Center for Marine and Environmental Analyses, Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami, FL

A partnership of scientists from the University of Miami Center for Marine and Environmental Analyses (CMEA), the South Florida Water Management District (SFWMD), and the United States Geological Survey-Biological Resources Division (USGS-BRD) is exploring the potential effects on ecological and societal systems of South Florida from climate change-induced alterations in the precipitation, temperature, and insolation regime. The South Florida regional environment is dominated by slight differences in elevation, seasonal precipitation, and episodic natural events, such as hurricanes and freezes.

Significant interannual variation exists in precipitation, often leading to major impacts on ecological and societal systems. The human population in the region is approximately 6 million people, all located immediately adjacent to the natural ecosystems and highly dependent on the natural systems for water supply and for the foundation of the economy. Global climate change may significantly affect the timing and amount of precipitation, temperature, and solar radiation, as well as the timing and duration of the wet season in South Florida.

Effects of these potential changes are being assessed on the following physical, ecological, and societal systems: (1) regional surface and groundwater hydrology; (2) freshwater runoff into coastal estuaries and associated salinity changes; (3) seagrass, hardbottom, and mangrove community productivity and distributions; (4) estuarine fish and invertebrate populations; (5) economics of recreational fishing; (6) wetlands hydroperiod in the Everglades; (7) wading bird populations; (8) urban and agricultural water supply; and (9) urban flood control. The research utilizes a suite of state-of-the-science models developed by the co-principal investigators.

A range of precipitation, temperature, and insolation scenarios will be input to the SFWMD hydrological model, providing water level, freshwater runoff, hydroperiod, water supply, and other endpoints. The CMEA Biscayne Bay hydrodynamic model will simulate the salinity regime, and this output will drive the CMEA seagrass-hardbottom-mangrove seascape model to predict ecological responses. The CMEA fish/shrimp trophodynamics model will predict population levels of key species in response to the seascape changes. The USGS-BRD ATLSS model will be used to predict changes in wading bird populations of the Everglades. A set of analytical tools will be used to evaluate economic implications of changes in water supply, flood protection, fishing, and wading birds.

The initial focus of the research has been on modifying and interfacing the models. An initial set of baseline historical weather and water level/canal discharge data have been acquired and entered into the Biscayne Bay hydrodynamical model. That model has been modified to more accurately account for groundwater and sheetflow-surface water inputs, as well as to more accurately represent the boundary conditions of the north and south boundaries of the Bay. Initial calibration and verification runs have been performed to compare the modified, coupled model results with actual historical data for Biscayne Bay salinities.

This study also is exploring the implications of climate change effects on the U.S. Army Corps of Engineers' plan for restructuring the regional water management system. To prepare for those risk analyses, the surface canal, surface sheetflow, and groundwater freshwater input data relevant to the primary water management option for the South Florida Ecosystem Restoration process (R13D4) also have been acquired and entered. Results from this study will have important implications for restoration and sustainability of the regional environment, as well as potential effects on the growth, development, and economy of South Florida.

Integrated Assessment of Climate Change Impact in the Mackinaw River Watershed, Illinois

Edwin E. Herricks, J.W. Eheart, Kieran P. Donaghy, and Brian Orland
University of Illinois at Urbana-Champaign, Urbana/Champaign, IL

The primary objective of this project is to complete an integrated assessment of multiple sector impacts produced by predicted changes in climate using models, standards, and innovative analysis tools. The impact assessment will focus on locations in the Mackinaw River Watershed, IL. Five locations were selected that provide sector dominance, defined sector competition, or general sector competition.

The specific objectives are to: (1) develop sector-specific responses to climate change; (2) identify relationships between and among sectors at each site and among all sites; (3) apply the impact analysis paradigm to identify and quantify local impacts produced by climate change; (4) identify mechanisms that produce an adaptive response to climate change while developing sector/system resilience to climate change impact; and (5) integrate project results with a Web-based decision support interface available at the University of Illinois.

This project will identify and quantify the consequences of climate change/variability on human and natural systems in the Mackinaw River Basin. The Mackinaw River Watershed, approximately 3,100 km^2 (1,200 mi^2) in size, is one of the highest quality ecosystems in Illinois. Water quality is rated as excellent, but threatened. Identified threats include agricultural and urban centers. It has been the focus of recent, integrated management activity, including major involvement of the Nature Conservancy, the Illinois Department of Natural Resources, and local watershed groups.

A focus on the sensitivity and vulnerability of local human and natural systems to climate change, and the adaptive mechanisms that operate in response to impact threats was achieved by an extensive, sector-specific interview process followed by local focus group sessions in various areas of the watershed. These sessions provided a foundation for DSS development and supported the identification of impacts. The impact assessment paradigm used local setting information for Mackinaw River Watershed systems (e.g., human environment) and sectors (e.g., agricultural, municipal) that operate in, or have influence on, the local setting. For identified sectors, an "elemental" analysis identified response to climate change phenomena. Initial analysis priority was given to direct effect assessment developed from focus group responses, although identification of chains of effect that are understood and quantified, or supported by existing models, also have been identified. Sector-specific analysis will be completed, evaluating elemental response to five categories of climate change phenomena. The analysis will develop site and sector response spectra, which will support a consequence and severity determination for an impact assessment.

Initial vertical integration is based on specific climate system changes and layers of cross-cutting analysis that are defined by impact type. The following impact types are identified: (1) socioeconomic, (2) environmental, and (3) water resources (both quality and quantity). A second approach establishes single sector impacts as having the highest priority for resolution and then evaluates other sector responses based on criteria selected for the dominant sector. For example, placing agriculture as dominant would change how impacts can be viewed for aquatic ecosystems, water resources, or municipal operations. This analysis is ongoing.

The research has three concurrent phases that address separate work activities but are highly interconnected. Phase I will: (1) identify climate change phenomena; (2) identify, for selected locations in the Mackinaw River Watershed, a sector-by-sector response to climate variability; and (3) identify the expected change in sector elements, considered singly, and aggregated within and across sectors. This phase was initiated with sector interviews and focus group summaries.

Phase II will identify the local impact of climate change with particular emphasis on economic, environmental, and social impact aggregations, where impact first will be assessed at the element/sector level, then analyzed for sector pairs and multiple sector integration. Work on this phase continues with the identification of models that support impact analysis and are compatible with the developing DSS.

Phase III will: (1) implement a Web-based system to support involvement from local collaborators, and (2) provide an innovative use of information technology to involve local community elements in impact analysis. This phase of the research emphasizes the development of DSS elements and technology.

This research will identify the local impact of climate change on a typical watershed in the Midwest that faces a range of consequences from climate change. The systematic accounting for element, sector, and system level responses, starting at the local level, will provide an essential compliment to existing downscaling of GCC models. The horizontal and vertical integration will provide important, sector-specific information essential to the future management of climate change effects. This research also features an innovative use of information technology—the development of a decision support interface that will provide a valuable adjunct to ongoing community-based management programs in the Mackinaw River Watershed. These results will be of importance to local, state, and federal water resources planners and legislators in deciding how best to cope with uncertain anticipated climate changes in the Midwest.

An Integrated Assessment of the Effects of Climate Change on Rocky Mountain National Park and Its Gateway Community

N. Thompson Hobbs, Dennis Ojima, John Loomis, Stephan Weiler, David M. Theobald, Alan P. Covich, Jill S. Baron, Thomas J. Stohlgren, and Michael B. Coughenour
Colorado State University, Fort Collins, CO

Gateway communities are concentrations of human population and commerce in close proximity to conservation areas. This research is an effort to understand how climate influences human and natural systems in Rocky Mountain National Park and its gateway community, Estes Park, CO.

Objectives during the first year included: (1) assembling historic weather records for the development of climate scenarios; (2) assessing potential climate effects of climate change on human and natural systems by relating historic variation in weather to wildlife population dynamics, visitor behavior, and local economic performance; (3) parameterizing and tuning simulation models to support projections of climate effects and their interaction with local land-use change; and (4) conducting a stakeholder workshop to provide feedback on the first year's assessment and to guide future research.

Detailed time series of population data for terrestrial (elk, ptarmigan) and aquatic vertebrates were obtained and related to historic variation in weather. Summer precipitation was negatively related to breeding density of ptarmigan, accounting for 36 percent of annual variation. Ptarmigan population growth rates were negatively affected by the number of days with minimum temperature below 0° C. Rates of survival and recruitment in the elk population were influenced by average winter temperatures and by precipitation during summer. Population models based on these relationships and driven by climate scenarios derived from Hadley and Canadian Climate Center (CCC) projections are being used to evaluate the population-level consequences of climate change for wildlife in the park.

Weather database data and records of monthly visitation during the last 11 years were used to estimate a simple regression model of monthly visitation as a function of five variables that serve as proxies for major climatic and demographic influences on visitation. The simple model explains nearly all (88%) of the variation in monthly visitation over this 11-year time period. Model results suggest that 1 cm of additional snow on the ground at Bear Lake reduces monthly visitation by 386 visits. One degree Celsius higher temperature in Estes Park increases visits by 18,457 each month.

The IMPLAN input-output model was used to project consequences of changes in visitation for the local economy (see Figure 1). Climate change estimated from the CCC and Hadley General Circulation Model (GCM) show a 333,540 to 193,000 visitor increase, respectively, for the 1996 base year. These additional visitors were introduced along with their postulated spending into the IMPLAN model to determine the local impact on output, employment, and income. The "warmer" CCC scenario would result in more than $33 million (10%) in increased local output, 822 (13%) new jobs, and more than $13 million (10%) of additional income. The Hadley GCM would yield more than $19 million (6%) in increased local output, 477 (7%) new jobs, and more than $13 million (6%) of additional income.

The SAVANNA ecosystem model has been parameterized and tuned to examine the effects of climate and land-use change on terrestrial systems within the park. Similar work is proceeding toward understanding climate effects on aquatic systems using the Regional Hydro-Ecological Simulator System.

A 1-day stakeholder workshop was conducted during May 2000, and was attended by citizens representing diverse viewpoints and interests in the Estes Park community. The workshop reviewed initial progress and made suggestions for focusing this research. Priorities emerging from the workshop included: (1) understanding climate effects on the distribution and abundance of the elk population and the potential for conflict with landowners outside the park; (2) projecting climate impacts on riparian systems; (3) understanding the tradeoffs between potential climate-induced enhancements of economic activity resulting from increased visitation and potential reductions in local residents' quality-of-life; and (4) understanding climate effects on wildfire risks.

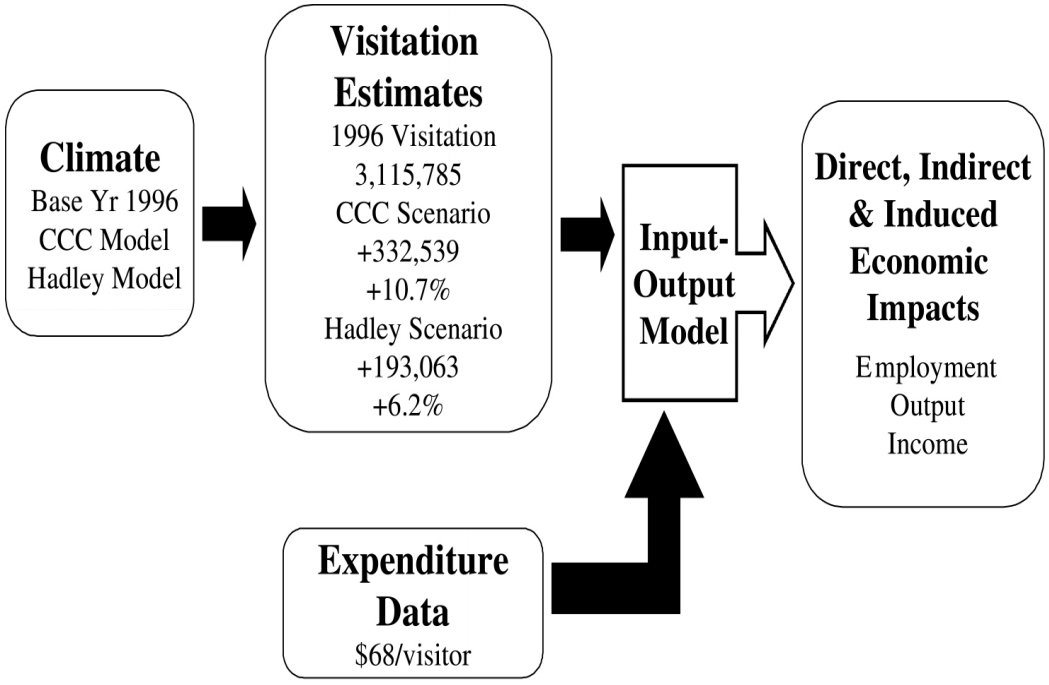

Figure 1. Effect of climate on tourism and local economic activity.

Infrastructure Systems, Services, and Climate Change: Integrated Impacts and Response Strategies for the Boston Metropolitan Area

Paul H. Kirshen [1] ***and Matthias Ruth*** [2]
[1] *Tufts University, Medford, MA;* [2] *University of Maryland, College Park, MD*

The services provided by infrastructure systems include flood control; water supply; drainage; wastewater management; solid and hazardous waste management; energy; transportation; providing constructed facilities for residential, commercial, and industrial activities; communication; and recreation. The socioeconomic and environmental services they provide are essential—without them, the U.S. economy could not function and many human and environmental systems would collapse. This is particularly the case in metropolitan areas.

The objectives of the Climate's Long-Term Impacts on Metro Boston (CLIMB) Project include:

1. Documentation and analysis of the state of present infrastructure systems and the socioeconomic and eenvironmental services provided by them in the Boston Metropolitan Area (BMA) using various indicators to identify their contribution to the quality-of-life in the region. The BMA includes the major cities of Boston and Cambridge and 99 other municipalities within approximately 20 miles of Boston. Land use varies from urban to farms and open space.

2. Determination of the integrated direct and indirect impacts of climate change, socioeconomic, and technology scenarios on the future evolution of infrastructure systems and services (ISS) and the regional quality-of-life over time.

3. Identification and importance of policies and short- and long-term research needs for the provision of infrastructure services that will meet stakeholder needs over time given the uncertainties of climate and other changes.

4. Collaboration with the Metropolitan Area Planning Council (MAPC), our local partner, to ensure that stakeholders are involved, their concerns are addressed, the project results are effectively communicated to them and the public at large, and to begin engaging stakeholders in the process of preparing for potential climate change.

The approach includes: (1) working with stakeholders and experts to understand the multiple driving forces behind ISS in the BMA and the vertical and horizontal interrelationships of ISS demands and impacts; (2) building a dynamic analytical modeling tool that incorporates this understanding and uses indicators to organize data, model socioeconomic and environmental dynamics and interrelated impacts of ISS, and aid in communication of project results—this requires quantitative analysis of the impacts of climate change upon present infrastructure; (3) working with stakeholders to execute the model with climate change, socioeconomic, and technology scenarios to achieve the research objectives; and (4) communicating with the help of the MAPC to stakeholders and the general public throughout the project.

The research will improve the risk management of the impacts on infrastructure from future uncertain climate, socioeconomic, environmental, and technology changes by showing possible impacts and driving forces behind those impacts and their sensitivities, working with stakeholders to develop short- and long-term resilient policies and programs to mitigate and adapt to impacts, and empowering stakeholders and the general public.

The most significant finding to date is the consensus of the CLIMB Infrastructure Workshop held on March 24, 2000, that the overall impacts of long-term climate change on Metro Boston's infrastructure systems and services could be severe. The workshop brought together infrastructure managers, representing over 35 different organizations, and CLIMB researchers to determine key impacts for consideration. While many of the infrastructure managers were not knowledgeable about climate change issues before the workshop, all contributed and expressed a desire to continue to participate.

Some of the additional impacts to consider that were suggested by the infrastructure managers in discussion groups include:

1. Increased scouring of bridge piers and coastal zone erosion.

2. Chronic as well as extreme impacts on constructed facilities.

3. Effects of higher groundwater elevations on underground utilities and tanks.

4. A larger number of power producers and suppliers from outside the region may help buffer potential impacts of climate change on the region's energy sector—assuming that the energy infrastructure and energy markets outside the region are not similarly affected as in Metro Boston. Understanding their ability to supplement power generation in the region may be key to assessing climate impacts.

5. Very little decentralization of energy supply has occurred in Massachusetts and as a consequence, the majority of the population in Metro Boston continues to rely on centralized power generation. With increased deregulation, decentralization may follow.

6. The need to keep infrastructure out of larger coastal and urban floodplains may require population shifts that may be inconsistent with some of the goals of controlling urban sprawl.

7. Climate change impacts on coastal waters also will impact human health.

8. Even though the region's largest water supplier may not be vulnerable to climate change, it may become vulnerable if local systems incur shortages.

9. Changes in cold water habitats and fisheries could change the operation of water management systems.

10. Any losses in system water pressure could result in more bacteria and less fire-fighting capacity in water supply systems.

11. Major impacts on transportation and communication systems are the indirect cost consequences.

Impact of Climate on the Lower Yakima River Basin

Lance Vail [1], Mike Scott [1], Kristi Branch [1], Dennis Dauble [1], L. Ruby Leung [1], Mark Wigmosta [1], Claudio Stockle [2], and Keith Saxton [2]

[1] Battelle Pacific Northwest Division, Richland, WA; [2] Washington State University, Pullman, WA

The objective of this project is to develop and demonstrate a framework to assess the localized impact of climate change and climate variability on a diverse set of interdependent interests, including: agriculture, surface water and groundwater supply, surface water and groundwater quality, air quality, fisheries, and economics. The goal of this project is not to develop any specific new process models, but to adapt existing models to ensure that the linkages between the various models are appropriately represented.

A diverse team of experts will develop an integrated assessment framework by using a software system engineering approach. This framework will quantify tradeoffs between different interests while simultaneously considering the generation and propagation of assessment uncertainties. The framework also will assess the efficacy and tradeoffs associated with adaptation alternatives, such as cropping schemes and reservoir operations. The framework will be demonstrated on the Lower Yakima River Basin in central Washington State. The assessment results and tradeoffs will be made available to the stakeholders via public meetings of the Tri-County Water Resource Agency (TCWRA) and the Internet. The effectiveness of the framework in facilitating communication with the stakeholders will be evaluated cooperatively with the TCWRA.

The framework and assessment results will be published in the printed literature and posted on the Internet. This framework will be transferable to other local-scale impact assessments throughout the United States. The assessment results and assessment framework will contribute to the U.S. National Assessment. Additionally, all global and regional climate simulations generated for this study will be archived at the appropriate spatial and temporal resolutions that could contribute towards other studies supporting the U.S. National Assessment.

This project was recently funded; therefore, there are no results to be reported at this time.