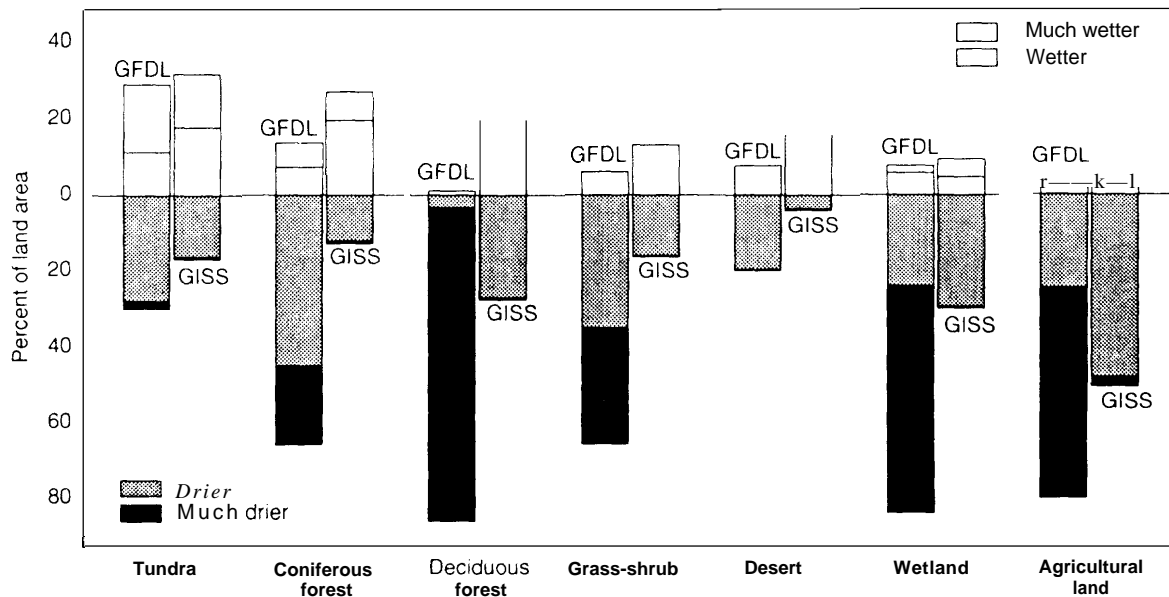


Figure 2-13—Soil-Moisture Changes Under the GFDL and GISS Climate Change Scenarios, by Land-Use and Cover Type



NOTE: Bars above the zero axis represent the percent of land-use area predicted to become wetter; bars below the axis show the percent of land area becoming drier. Drying or wetting is calculated from the change in the ratio of actual evapotranspiration (AET) to potential evapotranspiration (PET). No change is reported if the index changed (up or down) by less than 0.025; wetter = 0.25 to 0.05; much wetter = >0.05; drier = -0.25 to -0.05; much drier = <-0.05. GFDL = Geophysical Fluid Dynamics Laboratory, GISS = Goddard Institute for Space Studies.

SOURCE: P.N. Halpin, "Ecosystems at Risk to Potential Climate Change," contractor report prepared for the Office of Technology Assessment, June 1993.

vulnerability and adaptability of the various resources and the potential management strategies and policies that might assist adaptation.

## CHAPTER 2 REFERENCES

1. Albrecht, B.A., "The Effect of Uncertainty in the Representation of Cloud Processes in Climate Models on Climate Change Prediction" in: *Effects of Scientific Uncertainties on the Accuracy of Global Climate Change Predictions: A Survey of Recent Literature*, M.E. Fernau and D.W. South (eds.), U.S. Department of Energy (DOE) Internal Report, Argonne National Laboratory, Environmental Assessment and Information Sciences Division, Technology and Environmental Policy Section (Argonne, IL: DOE, October 1991).
2. Arp, W.J., and B.G. Drake, "Increased Photosynthetic Capacity of *Scirpus olneyi* After 4 Years of Exposure to Elevated CO<sub>2</sub>," *Plant, Cell, and Environment*, vol. 14, No. 9, 1991, pp. 1003-6.
3. Assel, R. A., "Impact of Global Warming on Great Lakes Ice Cycles," in: *The Potential Effects of Global Climate Change on the United States, Appendix A: Water Resources*, EPA-23&05-89-050, J.B. Smith and D. Tirpak (eds.) (Washington, DC: U.S. Environmental Protection Agency, June 1989).
4. Ausubel, J.H., "Does Climate Still Matter?" *Nature*, vol. 350, 1991, pp. 649-52.
5. Ausubel, J.H., "A Second Look at the Impacts of Climate Change," *American Scientist*, vol. 79, 1991, pp. 210-21.
6. Balling, R.C., Jr., "The Global Temperature Data," *Research & Exploration*, vol. 9, No. 2, Spring 1993, pp. 201-07.
7. Bazzaz, F.A., "The Response of Natural Ecosystems to the Rising Global CO<sub>2</sub> Levels," *Annual Review of Ecology and Systematic*, vol. 21, 1990, pp. 167-90.
8. Bazzaz, F.A., and E.D. Fajer, "Plant Life in a CO<sub>2</sub>-Rich World," *Scientific American*, vol. 226, No. 1, January 1992, pp. 68-74.
9. Bean, M.J., "Waterfowl and Climate Change: A Glimpse into the Twenty-First Century," *Orion Nature Quarterly*, Spring 1989, pp. 22-27.

### Box 2-F--Major Assessments of Climate Change Impacts

Three major assessments by national and international organizations have addressed the potential impacts of climate change: the U.S. Environmental Protection Agency's (EPA's) 1989 report, *The Potential Effects of Climate Change* (94), the three-volume climate change series issued by the Intergovernmental Panel on Climate Change in 1990 (42, 43, 44, and the 1992 supplement (45)), and a 1991 report by the National Academy of Sciences, *Policy Implications of Greenhouse Warming* (22), and its 1992 supplement. These reports focus on different aspects of climate change. Taken together, they lay the foundations for OTA's assessment of the adaptability and vulnerability of systems to climate change, and their findings are cited throughout this chapter!

The EPA Report--In 1987, Congress requested that EPA study "the potential health and environmental effects of climate change including, but not... limited to, the potential impacts on agriculture, forests, wetlands, human health, rivers, lakes, estuaries, as well as societal impacts." To respond, EPA conducted a massive 2-year effort, hiring more than a hundred contractors to model potential effects on each system, and contracting out several regional case studies to integrate how all impacts might interact in different regions. The results **were** synthesized in a 400-page report accompanied by 11 appendixes of contractor papers.

EPA used regional predictions of temperature and precipitation generated by four major general circulation models (GCMs) to examine the sensitivities of managed and unmanaged systems and to evaluate regional effects. The climate predictions were distributed to contractors, who then incorporated the results into their own models for crop growth, forest productivity, farm-level decisionmaking, etc., to predict the potential effects on particular systems and in particular regions.

EPA found that unmanaged systems such as coastal wetlands, parks, and forests "may be unable to adapt quickly to rapid warming." Effects could include a reduced range for many tree species, changes in forest composition, a decline in cold-water fish and shellfish (although some warm-water species could benefit), an increase in species extinction, loss of coastal wetlands, and an increase in salinization of estuaries. Such impacts could begin in 30 to 80 years. Climate changes may heighten the effects of other stresses (such as pollution, increased radiation accompanying stratospheric ozone depletion, pests and pathogens, and fire). For example, climate-induced stress may make large regions of forests more susceptible to other stresses, such as fire, pests, disease outbreaks, wind damage, and air pollution. Changes in forest species and productivity could lead to secondary effects such as increased soil runoff and erosion, reduced aquifer recharge, reduced biodiversity, and changes in wildlife habitat and recreational opportunities. Species extinctions could increase (and biological diversity could decline), especially in areas where roads, agriculture, and urban development block or restrict migration pathways or habitat, and in areas that harbor heat-or drought-sensitive species. Some forested land could become grassland. As communities and ecosystems are displaced by climate change, it may be necessary to expand scientific knowledge on the practice of ecosystem restoration, so that Communities can be rebuilt in degraded sites or relocated to new areas where they have not existed in the past (94) (see also vol. 2, boxes 4-A and 5-M).

Overall, EPA found that managed systems such as water resources and agriculture are more capable than natural systems of withstanding climate change. However, problems may still arise as humans attempt to adapt to the changes to these systems brought about by climate **change**. Agricultural yields might be reduced, but productivity could shift northward so that overall production could probably meet domestic needs, with some possible reductions in exports. Farmers might have to change their practices, such as beginning or increasing irrigation, which might increase conflicts over water use. If climate change leads to reduced stream flows, water quality may suffer because less water will be available for diluting or flushing pollutants and dissipating heat; these

---

<sup>1</sup> All three reports were based on the assumption that there would be no major changes in climate variability.

changes could affect fish and wildlife populations. The effects on agriculture might vary considerably over regions, with declines, for example, in crop acreage in the Great Plains potentially offset by increased acreage in the Great Lakes States.

Quality of life may not suffer much in areas where, for example, forests shift from one species to another, and where the shifts are gradual; however, in areas where forests die out altogether (such as may occur in some parts of California), people would face severe environmental and land-use effects. Recreation relies on relatively healthy forests; rapid changes that caused stressed or declining forests would likely reduce recreational opportunities and demand.

The IPCC Report--The intergovernmental Panel on Climate Change (IPCC) is an international group of hundreds of scientists from more than 50 countries established in 1988 by the World Meteorological Organization and the United Nations Environment Program. The IPCC setup three working groups: Working Group I to assess the scientific basis for how human activities affect the climate; Working Group II to study the potential impacts of climate change worldwide; and Working Group III to formulate possible policy responses. The results were published in the three-volume *Climate Change* report in 1990 (The IPCC Scientific Assessment, The IPCC Impacts Assessment, and The IPCC Response Strategies). The working groups continue to meet, and issue occasional updates to the 1990 reports.

The scientific assessment predicted that under a "business-as-usual" scenario (characterized by continued reliance on coal-intensive energy sources and only modest efficiency increases), the global average temperature would increase at a rate of 0.5°F (0.3°C) per decade, with a likely increase of 2 °F (1 °C) over current levels by 2025 and 5.4 °F (3 °C) before the end of the next century. The impact assessment used this business-as-usual prediction for increasing temperature (with accompanying estimates that equivalent atmospheric CO<sub>2</sub> concentrations<sup>2</sup> would double by 2025 to 2050 and sea level would rise about 1 foot (0.3 meter) by 2030) to predict potential impacts on systems including natural terrestrial ecosystems, agriculture, and forestry.

IPCC suggested that climate change could shift climatic zones several hundred miles toward the poles over the next 50 years, requiring natural terrestrial ecosystems to either migrate or adapt to a new climate regime. The rate of change will determine the degree of impacts: some species might be able to keep up with change, but some could become extinct, thus reducing global biodiversity. Ecosystems are unlikely to move as units, but will develop new structures as species abundance and distribution are altered. Most at risk are systems with limited options for adaptability (montane, alpine, and polar areas, island and coastal communities, remnant vegetation, heritage sites or reserves, and areas already under stress). Sealevel rise and ocean warming will affect fisheries, potentially reducing habitat for several commercially important species. Coastal wetlands maybe inundated by rising seas and forced to migrate inward, though in many areas, this may not be possible. inland wetland areas may come under increased pressure for agricultural use. As for managed systems, forests may become more susceptible to parasites, and losses from fires will increase. It is unclear whether global agricultural productivity would increase or decrease overall, but many regions are likely to experience shifts or losses in production (for example, a decline in cereal and horticultural production in the southern United States), which will alter trade patterns. Impacts will differ considerably from region to region, as will the socioeconomic effects. Water availability will likely increase in some areas and decrease in others, but regional details are not yet known. There may also be a change in drought risk, which could seriously affect agriculture at both the regional and global levels.

The NAS Report--The National Academy of Sciences (NAS) convened three different scientific panels to conduct preliminary analyses of climate change effects, mitigation strategies, and adaptation strategies. Each panel drafted a report that described their analyses and conclusions. A fourth "synthesis" panel drew on the work of the other three panels to formulate a policy report, which was published in April 1991.

---

<sup>2</sup> The cumulative warming effect of all greenhouse gases is equivalent to a doubled CO<sub>2</sub> concentration.

### Box 2-F-Major Assessments of Climate Change Impacts--(Continued)

The NAS panels assumed greenhouse warming in the range of 2 to 9°F (1 to 5°C), but did not give a specific time frame of reference. Based on this scenario, NAS classified natural resource systems and human activities into one of three categories: low sensitivity to climate change within the given range; sensitive but adaptable at a cost; and sensitive with questionable ability to adjust or adapt. NAS concluded that built systems generally fit into the first or second categories, and managed crop or timber lands fit into the second.

Water resources are quite sensitive to climate because runoff is the "small difference between the larger quantities of precipitation and evaporation," and runoff "fluctuates relatively more" than either precipitation or evaporation. Changes in runoff will have adverse impacts only when water supply no longer matches water demand for use and consumption. In the United States, water supply and demand are now closely matched in the Great Basin, Missouri, and California water regions, so these areas maybe particularly vulnerable to decreases in precipitation (and conversely, they would reap large benefits should precipitation increase). Activities such as irrigation are also vulnerable to decreased precipitation because irrigation is most common in areas where precipitation is already light and evaporation is high. Unless climate changes quickly relative to demographic changes that affect water demand, however, the NAS report concludes, "the overall impact of climate change is unlikely to be substantially more serious than that of the vagaries of the current climate" (21).

In contrast, NAS suggested that unmanaged ecosystems--the "natural landscape" and marine ecosystems--respond relatively slowly to climate change and that their ability to adapt is questionable and "problematic."

SOURCE: Office of Technology Assessment, 1993.

10. Blumberg, A.F., and D.M. Di Toro, "The Effects of Climate Warming on Lake Erie Water Quality," in: *The Potential Effects of Global Climate Change on the United States, Appendix A: Water Resources, EPA-230-05-89-050*, J.B. Smith and D. Tirpak (eds.) (Washington, DC: U.S. Environmental Protection Agency, June 1989).
11. Botkin, D. B., and R.A. Nisbet, "Projecting the Effects of Climate Change on Biological Diversity in Forests," in: *Global Warming and Biological Diversity*, R.L. Peters and T.E. Lovejoy (eds.) (New Haven, CT: Yale University Press, 1992).
12. Botkin, D.B., R.A. Nisbet, and T.E. Reynales, "Effects of Climate Change of Forests of the Great Lakes States," in: *The Potential Effects of Global Climate Change on the United States, Appendix D: Forests, EPA-230-95-89-054*, J.B. Smith and D. Tirpak (eds.) (Washington, DC: U.S. Environmental Protection Agency, June 1989).
13. Brady, N.C., *The Nature and Properties of Soils*, 9th Ed. (New York NY: MacMillan Publishing 1984), 750 pp.
14. Brewer, R., *The Science of Ecology* (Philadelphia: Saunders College publishing, 1988).
15. Broecker, W. S., "Unpleasant Surprises in the Greenhouse?" *Nature*, vol. 328, 1987, pp. 123-26.
16. Browne, M.W., "Report Says Carbon Dioxide Rise May Hurt Plants," *New York Times*, Sept. 18, 1992, p. A14.
17. Burns, R. M., and B.H. Honkala, "Silvics of North American Conifers," vol. I, *Agriculture Handbook 654* (Washington DC: U.S. Department of Agriculture, Forest Service, 1990).
18. Chambers, J.R., "U.S. Coastal Habitat Degradation and Fishery Declines," in: *Transactions of the North American Wildlife and Natural Resources Conference* (Washington, DC: The Wildlife Management Institute, in press).
19. Clark, J. S., C.D. Reid, and G. Derda, *Sensitivity of Major North American Terrestrial Biomes to Global Change, draft report* prepared for the Electric Power Research Institute, 1992,
20. Clark, W.C., "Scale Relationships in the Interactions of Climate, Ecosystems, and Societies," in: *Forecasting in the Social and Natural Sciences*, K.C. Land and S.H. Schneider (eds.) (Boston, MA: D. Reidel Publishing Co., 1987), pp. 337-78.
21. Committee on Science, Engineering, and Public Policy, Panel on Policy Implications of Greenhouse Warming, National Academy of Sciences, National Academy of Engineering, Institute of Medicine, *Policy Implications of Greenhouse Warming: Mitigation, Adaptation, and the Science Base* (Washington DC: National Academy Press, 1992).
22. Cooper, C.F., "Sensitivities of Western U.S. Ecosystems to Climate Change," contractor report prepared for the Office of Technology Assessment, August 1992.
23. COX, G.W., "Review of Draft Report on Vulnerabilities of Western U.S. Ecosystems to Climate Change: Biodiversity and Wildlife Issues," draft contractor paper prepared for Office of Technology Assessment July 1992.

24. Croley, T.E., II, and H.C. Hartmann, "Effects of Climate Changes on the Laurentian Great Lakes Levels," in: *The Potential Effects of Global Climate Change on The United States, Appendix A: Water Resources, EPA-230-05-89-050*, J.B. Smith and D. Tirpak (eds.) (Washington, DC: U.S. Environmental Protection Agency, June 1989).
25. Davis, O.K., "Ancient Analogs for Greenhouse Warming of Central California," in: *The Potential Effects of Global Climate Change on the United States, Appendix D: Forests, EPA-23@95-89-054*, J.B. Smith and D. Tirpak (eds.) (Washington, DC: U.S. Environmental Protection Agency, June 1989).
26. Dawson, W.R., "physiological Responses cAnimals to Higher Temperatures," in: *Global Warming and Biological Diversity*, R.L. Peters and T.E. Lovejoy (eds.) (New Haven, CT: Yale University Press, 1992).
27. Drake, B. G., "Effect of Elevated CO<sub>2</sub> on Chesapeake Bay Wetlands," *Responses of Vegetation to Carbon Dioxide, in: Ecosystem and Whole Plant Responses*, U.S. Department of Energy (DOE), Office of Energy Research, Carbon Dioxide Research Division (Washington, DC: DOE, April-November 1988).
28. Drake, B.G., Research Scientist, Smithsonian Environmental Research Center, testimony before the Senate Committee on Commerce, Science, and Transportation Hearing on Global Change Research: *Global Warming* and the Biosphere, Apr. 9, 1992.
29. Emanuel, W.R., H.H. Shugart, and M.P. Stevenson, "Climatic Change and the Broad-Scale Distribution of Terrestrial Ecosystem Complexes," *Climate Change*, vol. 7, 1985, pp. 29-43.
30. Frederick, K., and P. Gleik, "Water Resources and Climate Change," in: *Greenhouse Warming: Abatement and Adaptation*, N. Rosenberg, W. Easterling, P. Crosson, and J. Darmstadter (eds.) (Washington DC: Resources for the Future, 1988).
31. Giantz M.H., "The Use of Analogies in Forecasting Ecological and Societal Responses to Global Warming," *Environment*, vol. 33, December 1991, pp. 11-15, 27-33.
32. Grulke, N.E., G.H. Riechers, W.C. Oechel, U. Hjelm, and C. Jaeger, "Carbon Balance in Tussock Tundra Under Ambient and Elevated Atmospheric CO<sub>2</sub>," *Oecologia*, VOL 83, 1990, pp. 485-494.
33. Hains, D.K., and C.F. Hains, "Impacts of Global Warming on Runoff in the Upper Chattahoochee River Basin," in: *The Potential Effects of Global Climate Change on the United States, Appendix A: Water Resources, EPA-230-05-89-050*, J.B. Smith and D. Tirpak (eds.) (Washington DC: U.S. Environmental Protection Agency, June 1989).
34. Halpin, P.N., "Ecosystems at Risk to Potential Climate Change," contractor report prepared for the Office of Technology, June 1993.
35. Hammond, A.L., "Ecosystem Analysis: Biome Approach to Environmental Science," *Science*, vol. 175, 1972, pp. 46-48.
36. Hansen, A.J., T.A. Spies, F.J. Swanson, and J.L. Ohmann, "Conserving Biodiversity in Managed Forests," *Bioscience*, vol. 41, 1991, pp. 382-92.
37. Hansen, J., W. Rossow, and I. Pung, "Long-Term Monitoring of Global Climate Forcings and Feedbacks," in: *NASA Goddard Institute for Space Studies Conference Publication*, New York, 1992.
38. Heimann, M., "Modeling the Global Carbon Cycle," paper presented at the First Demetra Meeting on Climate Friability and Global Change, Chianciano Terme, Italy, Oct. 28-Nov. 3, 1991.
39. Holdridge, L.R., *Life Zone Ecology* (San Jose, Costa Rica: Tropical Science Center, 1977).
40. Hopkins, A.D., *Bioclimatics: A Science of Life and Climate Relations*, U.S. Department of Agriculture (USDA) Miscellaneous Publication 280 (Washington, DC: USDA, 1938).
41. Mao, S.B., "The Aerial Fertilization Effect of CO<sub>2</sub> and Its Implications for Global Carbon Cycling and Maximum Greenhouse Warming," *Bulletin of the American Meteorological Society*, vol. 72, No. 7, July 1991, pp. 62-65.
42. Intergovernmental Panel on Climate Change (IPCC), World Meteorological Organization, and United Nations Environment Program, *Climate Change: The IPCC Impacts Assessment*, report prepared for IPCC by Working Group II, W.J. McG. Tegart, G.W. Sheldon, and D.C. Griffith (eds.) (Canberra, Australia: Australian Government publishing Service, 1990).
43. Intergovernmental Panel on Climate Change (IPCC), World Meteorological organization and United Nations Environment Program, *Climate Change: The IPCC Response Strategies*, report prepared for IPCC by Working Group III, 1990.
44. Intergovernmental Panel on Climate Change (IPCC), World Meteorological Organization, and United Nations Environment Program, *Climate Change: The IPCC Scientific Assessment*, report prepared for IPCC by Working Group I, J.T. Houghton, G.J. Jenkins, and J.J. Ephraums (eds.) (Cambridge, England: Cambridge University Press, 1990).
45. Intergovernmental Panel on Climate Change, World Meteorological Organization, and United Nations Environment Program, *Climate Change 1992: The Supplementary Report to the IPCC Scientific Assessment*, report prepared for IPCC by Working Group I, J.T. Houghton, B.A. Callander, and S.K. Varney (eds.) (Cambridge, England: Cambridge University Press, 1992).
46. Izrael, Y.A., and S.M. Semenov, "Ecological Standards Setting: Methodology and Practical Issues: Problems of Ecological Monitoring and Ecosystems Modeling," *Leningrad, Gidrometeoizdat*, vol. 13 (in press).
47. Kareiva, P.M., J.G. Kingsolver, and R.B. Huey (eds.), *Biotic Interactions and Global Change* (Sunderland, MA: Simmer Associates, Inc., 1993).
48. Karl, T.R., "Missing Pieces of the Puzzle," *Research & Exploration*, vol. 9, No. 2, Spring 1993, pp. 234-49.
49. Kellogg, W., and Z. Zhou, "Sensitivity of Soil Moisture to Doubling of Carbon Dioxide in Climate Model Experiments Part I: North America," *Journal of Climate*, VOL 1, No. 4, April 1988.
50. Körner, D., and J.A. Amone, "Responses to Elevated Carbon Dioxide in Artificial Tropical Ecosystems," *Science*, vol. 257, Sept. 18, 1992, pp. 1672-75.
51. Krutilla, J. V., "Conservation Reconsider@" *American Economic Review*, vol. 57, No. 4, September 1967, pp. 777-86.

52. Lawren, B., "NET LOSS," *National Wildlife*, vol. 30, October/November, 1992, pp. 47-50,52.
53. Lettenmaier, D.P., T.Y. Gan, and D.R. Dawdy, "Interpretation of Hydrologic Effects of Climate Change in the Sacramento\*Joaquin River Basin, California," in: *The Potential Effects of Global Climate Change on the United States*, Appendix A: *Water Resources*, EPA-230-05-894150, J.B. Smith and D. Tirpak (eds.) (Washington, DC: U.S. Environmental Protection Agency, June 1989).
54. Lindzen, R. S., "Some Coolness Concerning Global warming," *Bulletin of the American Meteorological Society*, vol. 71, 1990, pp. 288-290.
55. Lorius, C., J. Jouzel, D. Raynaud, J. Hansen, and H. Le Treut, "The IceCore Record: Climate Sensitivity and Future Greenhouse Warming," *Nature*, vol. 347, 1990, pp. 139-145.
56. hhhImaqJ.D., "AM%@ Global Climate Change: When Will We Have Better Evidence?" in: *Climate Change and Energy Policy*, L. Rosen and R. Glasser (eds.), Los Alamos National Laboratory, LA-UR-92-502 (New York, NY: American Institute of Physics, 1992), pp. 17-31.
57. Manabe, S., and R.T. Wetherald, "Reduction in Summer Soil Wetness Induced by an Increase in Atmospheric Carbon Dioxide," *Science*, vol. 232, 1986, pp. 626-78.
58. Mattson, W.J., and R.A. Haak, "The Role of Drought in Outbreaks of Plant-Eating Insects," *Bioscience*, vol. 37, No. 2, February 1987, pp. 110-18.
59. McCormick, M.J., "Potential Climate Changes to the Lake Michigan Thermal Structure," in: *The Potential Effects of Global Climate Change on the United States*, Appendix A: *Water Resources*, EPA-230-05-89-050, J.B. Smith and D. Tirpak (eds.) (Washington, DC: U.S. Environmental Protection Agency, June 1989).
60. Michaels, P.M., "The Greenhouse Conflagration Clinton/Gore and Global Warning," 'lecture at The Cato Institute, Washington DC, Dec. 14, 1992.
61. Michaels, P.M., *Sound and Fury: The Science and Politics of Global Warming* (Washington, DC: The Cato Institute, 1992).
62. Miller, B.A., and W.G. Brock, "Potential Impacts of Climate Change on the Tennessee Wiley Authority Reservoir System," in: *The Potential Effects of Global Climate Change on the United States*, Appendix A: *Water Resources*, EPA-230-05-89-050, J.B. Smith and D. Tirpak (eds.) (Washington, DC: U.S. Environmental Protection Agency, June 1989).
63. Moreau, D.H., "It Will Be a Long Wait for Proof," paper presented at the Southeast Climate Symposium: *Changing Climate and Water Resources*, Charleston SC, Oct. 27-29, 1992.
64. National Science Foundation "Soil-Warming Experiments in Global Change Research," report of a workshop held in Woods Hole, MA, Sept. 27-28, 1991.
65. Norby, R.J., E.G. O'Neil, and R.J. Luxmoore, "Effects of Atmospheric CO<sub>2</sub> Enrichment on the Growth and Mineral Nutrition of *Quercus alba* Seedlings in Nutrient Poor Soil," *Plant physiology*, vol. 82, 1986, pp. 83-89.
66. Oechel, W.C., "Effects of Anticipated Changes in Global Climate and Atmospheric CO<sub>2</sub> on Western Ecosystems: Chaparral and Associated Forest Ecosystems," draft contractor paper for Office of Technology Assessment, July 1992.
67. Oechel, W.C., "Responses of Alaskan Biological and Social Systems to Climate Change: A Scenario," contractor paper prepared for Office of Technology Assessment, Jan. 11, 1993.
68. Oechel, W.C., and W.D. Billings, "Effects of Global Change on the Carbon Balance of Arctic Plants and Ecosystems," in: *Arctic Ecosystems in a Changing Climate: An Ecophysiological Perspective*, F.S. Chapin III, R.L. Jefferies, J. Svoboda, J.R. Reynolds, and G.R. Shaver (eds.) (San Diego, CA: Academic Press, 1992), pp. 139-68.
69. Oechel, W.C., and B.R. Strain, "Native Species Responses to Increased Carbon Dioxide Concentration" in: *Direct Effects of Increasing Carbon Dioxide on Vegetation*, DOWER-(X238, B.R. strain and J.D. cure (eds.) (Washington, DC: U.S. Department of Energy, December 1985).
70. Overpeck, J.T., and P.J. Bartlein, "Assessing the Response of vegetation to Future climate change: Ecological Response Surfaces and Paleocological Model Validation," in: *The Potential Effects of Global Climate Change on the United States*, Appendix D: *Forests*, EEA-23095-89-054, J.B. Smith and D. Tirpak (eds.) (Washington, DC: U.S. Environmental Protection Agency, June 1989).
71. Parker, BB., National Oceanic and Atmospheric Administration (NOM), Ocean and Lake Levels Division, Office of ocean and Earth Sciences, National Ocean Service, NOAA, "The Use of Long Historical Sea Level Records in the Study of Climate and Global Change," paper presented at Marine Technology Society '92, Washington DC, Oct. 19-21, 1992.
72. Perry, D.A., "Landscape Pattern and Forest Pests," *Northwest Environmental Journal*, vol. 4, No. 213, 1988.
73. Perry, M., "The Potential Effect of climate change on Agriculture and Land Use," *Advances in Ecological Research*, vol. 22, 1992, pp. 63-91.
74. Peters, R.L., and J.D.S. Darling, "The Greenhouse Effect and Nature Reserves," *Bioscience*, December 1985, pp. 707-17.
75. Pitt, D.E., "Data Leave Little Doubt That Fish Are in Peril," *The New York Times*, Aug. 3, 1993, p. C4.
76. Ray, G.C., B.P. Hayden, A.J. Bulger, Jr., and M.G. McCormick-Ray, "Effects of Global Warming on the Biodiversity of Coastal-Marine Zones," in: *Global Warming and Biological Diversity*, R.L. Peters and T.E. Lovejoy (eds.) (New Haven, CT: Yale University Press, 1992), pp. 91-104.
77. Ray, G.C., M.G. McCormick-Ray, and F.M. Potter, *Global Climate Change and the Coastal Zone: Evaluation of Impacts on Marine Fisheries and Biodiversity of the U.S.*, contractor report prepared for the Office of Technology Assessment, February 1993.
78. Rind, D., R. Goldberg, J. Hansen, C. Rosenzweig, and R. Ruedy, "Potential Evapotranspiration and the Likelihood of Future Drought," *Journal of Geophysical Research*, vol. 95, No. D7, June 20, 1990, p. 10,001.
79. Rind, D., C. Rosenzweig, and R. Goldberg, "Modelling the Hydrological Cycle in Assessments of climate Change," *Nature*, vol. 358, 1992, pp. 119-122.
80. Schneider, S., P. Gleick, and L. Meams, "prospects for Climate Change," in: *Climate Change and U.S. Water Resources*, P. Waggoner (ed.) (New York John Wiley and Sons, 1990), pp. 41-73.

81. Schneider, S.H., **L. Mearns**, and **P.H. Gleick**, "Climate-Change Scenarios for Impact **Assessment**," in: *G106uI Warming and Biological Diversity*, **R.L. Peters** and **T.E. Lovejoy** (eds.) (New Haven, CT: Yale University Press, 1992), pp. 38-55.
82. Sheer, **D.P.**, and **D. Randall**, "Methods for Evaluating the Potential Impacts of Global Climate Change: **Case Studies of the State of California and Atlanta, Georgia**," in: *The Potential Effects of Global Climate Change on the United States, Appendix A: Water Resources*, **EPA-230-05-89-050, J.B. Smith** and **D. Tirpak** (eds.) (Washington, DC: U.S. Environmental Protection Agency, June 1989).
83. **Smith**, W. H., "United States Forest Response and Vulnerability to Climate Change," contractor report prepared for the Office of **Technology Assessment** May 1992.
84. **Spencer**, R.W., and **J.R. Christy**, "Precise Monitoring of Global **Temperature Trends from Satellites**," *Science*, vol. **247**, **1990**, pp. 1558-62.
85. **Titus**, J.G., cd., *Greenhouse Effect, Sea Level Rise, and Coastal Wetlands*, **EPA-230-05-86013** (Washington DC: U.S. Environmental protection Agency, July 1988).
86. **Topping**, J. C., Jr., and **J.P. Bond**, *The Potential Impact of Climate Change on Fisheries and Wildlife in North America*, report of the Climate Institute to the U.S. Environmental Protection Agency, May 1988.
87. **Tracy**, C.R., "Ecological Responses of Animals to Climate," in: *Global Warming and Biological Diversity*, **R.L. Peters** and **T.E. Lovejoy** (eds.) (New Haven, CT: Yale University Press, 1992).
88. U.S. Congress, **Office of Technology Assessment (OTA)**, *Changing by Degrees: Steps to Reduce Greenhouse Gases*, **OTA-0482** (Washington, DC: U.S. Government printing Office, February 1991).
89. U.S. Congress, **Office of Technology Assessment (OTA)**, *Forest Service Planning: Accommodating Uses, Producing Outputs, and Sustaining Ecosystems*, **OTA-F-505** (Washington, DC: U.S. Government Printing Office, February 1992).
90. U.S. Congress, **Office of Technology Assessment (OTA)**, *Harmful Non-Indigenous Species in the United States* (Washington, DC: Government printing Office, 1993).
91. U.S. Department of **Commerce**, National Oceanic and Atmospheric Administration (NOM), National Marine Fisheries **Service (NMFS)**, *Our Living Oceans: The First Annual Report on the Status of the U.S. Living Marine Resources*, **NOAA Technical Memo, NMFS-F/SPO-1**, 1991.
92. U.S. Department of Energy (DOE), **Argonne National Laboratory**, Environmental Assessment and Information Sciences **Division, Technology and Environmental Policy Section**, *Effects of Scientific Uncertainties on the Accuracy of Global Climate Change Predictions: A Survey of Recent Literature*, U.S. DOE internal report, **M.E. Fernau** and **D.W. South** (eds.) (Argonne, IL: DOE, October 1991).
93. U.S. Department of Energy (DOE), **Office of Energy Research**, Office of Basic Energy Sciences, **Carbon Dioxide Research Division**, *Direct Effects of Increasing Carbon Dioxide on Vegetation*, **DOE/ER-0238, B.R. Strain** and **J.D. Cure** (eds.) (Washington, DC: U.S. DOE, December 1985).
94. U.S. Environmental protection Agency (EPA), *The Potential Effects of Global Climate Change on the United States*, **EPA-23&05 -89-050, J.B. Smith** and **D. Tirpak** (eds.) (Washington DC: U.S. EPA, December 1989).
95. U.S. Environmental Protection Agency (**EPA**), *The Potential Effects of Global Climate Change on the United States, Appendix A: Water Resources*, **EPA-23 0-05-89-050, J.B. Smith** and **D. Tirpak** (MIs.) (Washington, DC: U.S. EPA, June 1989).
96. U.S. Environmental Protection Agency (EPA), *The Potential Effects of Global Climate Change on the United States, Appendix D: Forests*, **EPA-230-95-89-054, J.B. Smith** and **D. Tirpak** (eds.) (Washington, DC: U.S. EPA, June 1989).
97. **Urban**, D.L., and **H.H. Shugart**, "Forest Response to Climatic Change: A Simulation Study for Southeastern Forests," in: *The Potential Effects Of Global Climate Change On The United States, Appendix D: Forests*, **EPA-23 0-95-89-054, J.B. Smith** and **D. Tirpak** (eds.) (Washington DC: U.S. Environmental Protection Agency, June 1989).
98. **Warren**, S.R., *Coastal Wetland Vulnerabilities to Climate Change*, contractor report prepared for **Office of Technology Assessment** July 30, 1992.
99. **Warrick**, R.A., **R. Gifford**, and **M.L. Parry**, "CO<sub>2</sub>, Climatic Change and Agriculture," in: *The Greenhouse Effect, Climatic Change and Ecosystems*, **B. Bolin** et al. (eds.), **SCOPE 29** (New York, NY: John Wiley and Sons, 1986).
100. **Webb**, T., III, "Past Changes in Vegetation and Climate: Lessons for the Future," in: *Global Warming and Biological Diversity*, **R.L. Peters** and **T.E. Lovejoy** (eds.) (New Haven, CT: Yale University press, 1992), pp. 59-75.
101. **Willard**, D. E., and **L.D. Kosmond**, *A Watershed-Ecosystem Approach to Land and Water Use Planning and Management*, contractor report prepared for the **Office of Technology Assessment**, Aug. 28, 1992.
102. **Willard**, D.E., et al., *Wetland Vulnerabilities to Climate Change*, contractor report prepared for the **Office of Technology Assessment**, Aug. 18, 1992.
103. **Williams**, P.B., "The Impacts of Climate Change on the Salinity of San Francisco Bay," in: *The Potential Effects of Global Climate Change on the United States, Appendix A: Wafer Resources*, **EPA-230-05-89-050, J.B. Smith** and **D. Tirpak** (eds.) (Washington, DC: U.S. Environmental Protection Agency, June 1989).
104. **Woodman**, J.N., and **C.S. Furiness**, "Potential Effects of Climate Change on U.S. Forests: Case Studies of California and the Southeast," in: *The Potential Effects of Global Climate Change on the United States, Appendix D: Forests*, **EPA-23(L 95-89-054, J.B. Smith** and **D. Tirpak** (eds.) (Washington, DC: U.S. Environmental Protection Agency, June 1989).
105. **Wyman**+ **R.L.**, "Multiple Threats to Wildlife: Climate Change, Acid Precipitation and Habitat Fragmentation" in: *Global Climate Change and Life on Earth*, **R.L. Wyman** (ed.) (New York, NY: Routledge, Chapman, & Hall, 1991), pp. 134-55.

106. **Zabinski**, C., and M-B. Davis, "Hind **Times** Ahead for **Great Lakes Forests**: A **Climate** Threshold **Model Predicts Responses** to **CO<sub>2</sub>-Induced** Climate Change,' m: *The Potential Effects of Global Climate Change on the United States, Appendix D: Forests*, **EPA-230-95-89-054**, **J.B. Smith** and **D. Tirpak (eds.)** (Washington DC: U.S. **Environmental** Protection Agency, **June** 1989).
107. **Ziska, L.H., B.G. Drake**, and **S. Chamberlain**, "Long-Term Photosynthetic Response in Single **Leaves** of a **C<sub>3</sub>** and **C<sub>4</sub>** Salt Marsh Species Grown at Elevated Atmospheric **CO<sub>2</sub>** in Situ,' *Oecologia*, vol. 83, 1990, pp. 469-72.