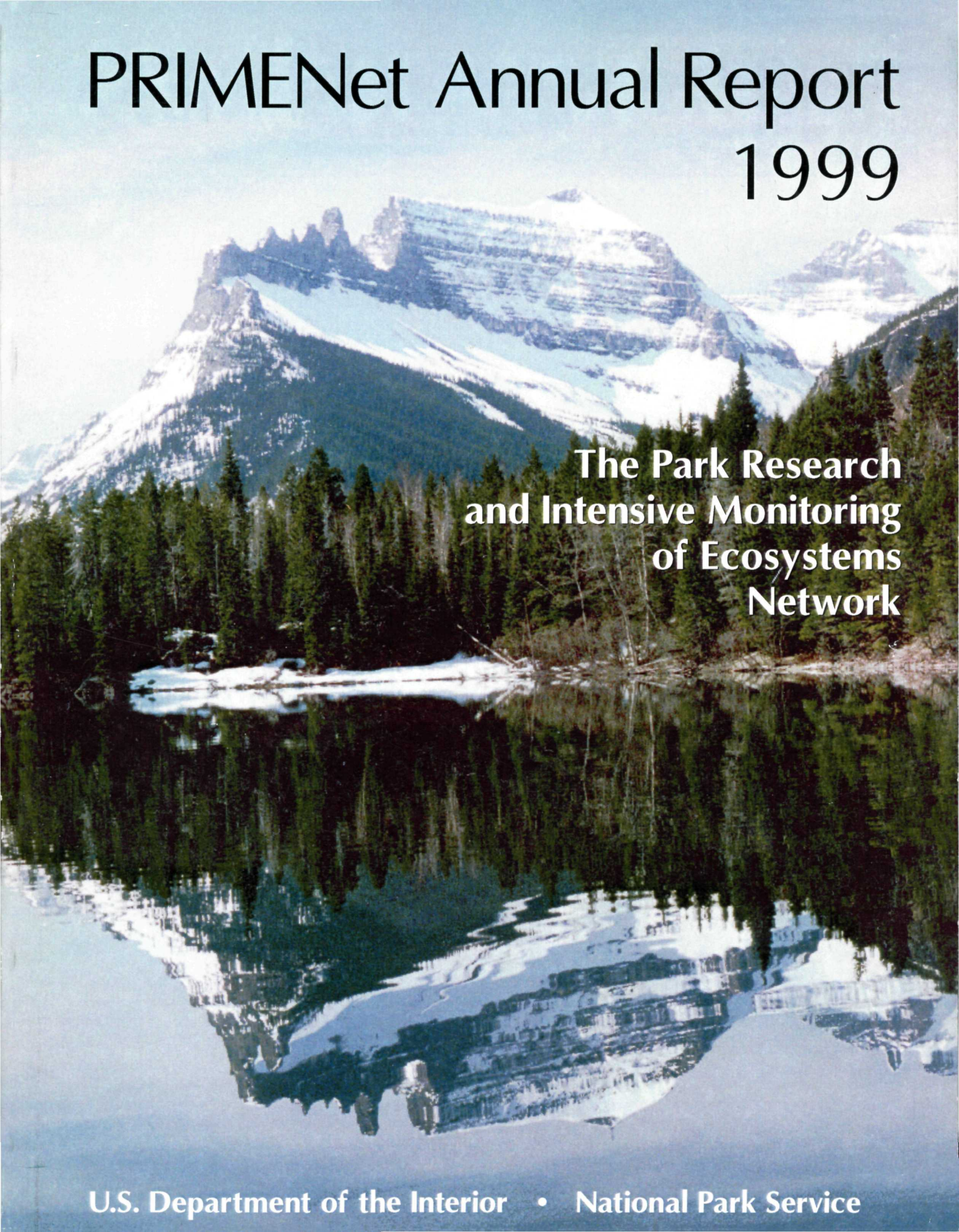
PRIMENet Annual Report 1999



The Park Research and Intensive Monitoring of Ecosystems Network

U.S. Department of the Interior • National Park Service

COVER: Photograph of Glacier National Park, Montana by Erik Hauge, retired NPS-Air Resources Division.

PRIMENet

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First Annual Report 1999

U. S. Department of the Interior
National Park Service

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Figures and Tables

Acknowledgements

NPS contributors to this report include: Kristi Heuer, Kathy Tonnessen, John Ray, David Joseph, Roger Hoffman, Dale Breitenfeld, and Jeff Selleck. EPA contributors include Bill Hogsett (EPA-Corvallis) and Jack Shreffler (EPA-RTP). We acknowledge the assistance of the University of Georgia, NADP/NTN, CASTNet, Air Resource Specialists, Inc., and IMPROVE staff and contractors who organized the data sets. Thanks to all the park contacts who provided useful input to the report.

Executive Summary

The Environmental Protection Agency (EPA) and the National Park Service (NPS) agreed to jointly conduct the Park Research and Intensive Monitoring of Ecosystems Network (PRIMENet) in 1996. The purpose of this network is to link environmental stressors and ecosystem responses in fourteen class I parks that have been selected as PRIMENet index sites.

The environmental stressors that are being monitored at PRIMENet sites include ultraviolet (UV) radiation, air quality and deposition, toxic contaminants, and climate. The EPA contributed funds and expertise to establish ground-level monitoring of UV radiation at all PRIMENet parks. The last of the UV monitors was installed in Hawaii Volcanoes National Park in February 1999. The Air Resources Division of the NPS has operated an air quality monitoring network for visibility, gaseous pollutants (e.g., ozone and sulfur dioxide), atmospheric deposition, and meteorological measurements since 1978. The data acquired from these sites allow intersite comparisons that address temporal and spatial variability among different environments. The EPA is also screening twelve of the PRIMENet parks for toxic contaminants that accumulate in various media, including water, sediments, plant tissue, and fish.

The effects of these atmospheric stressors on natural ecosystems are being evaluated by research projects funded by PRIMENet. The areas of research include; (1) the effects of UV radiation, nitrogen, and ozone on natural ecosystems, and (2) the extrapolation of point environmental measurements to larger landscapes. Research is also being focused on amphibian populations, with projects addressing monitoring protocols, contaminant gradients, and UV dosimetry. Project summaries are included in Section III of this document and final reports by the investigators are expected in FY 2001.

The EPA and the NPS are committed to continue the long-term monitoring of atmospheric stressors at the PRIMENet parks, however, there is no continued funding for research grants beyond 2001. In the future, other EPA, NPS, and USGS programs may provide the opportunity for research funding at these index sites.

I. PRIMENet:
The Park Research and Intensive Monitoring of Ecosystems Network

In 1996 the U.S. Environmental Protection Agency and the National Park Service agreed to jointly conduct the Park Research and Intensive Monitoring of Ecosystems Network, PRIMENet, in fourteen class I parks in the U.S. This network of monitoring and research locations uses the park units as "outdoor laboratories," where environmental changes are monitored through time in relatively undisturbed sites.

PRIMENet parks include: Acadia, Big Bend, Canyonlands, Denali, Everglades, Great Smoky Mountains, Glacier, Hawaii Volcanoes, Olympic, Rocky Mountain, Shenandoah, Sequoia/Kings Canyon, Theodore Roosevelt, and Virgin Islands National Parks. Current information on the program can be obtained at http://www.nature.nps.gov/ard/prime.

What is PRIMENet?

The Park Research and Intensive Monitoring of Ecosystems Network is the first major network to be jointly funded by the U.S. Environmental Protection Agency (EPA) and the National Park Service (NPS) to address the linkages between environmental stressors and ecosystem responses. This approach to evaluating ecosystem health was recommended by the National Research Council in their review of the EPA's research program (1, 2). The concept of index site monitoring is also being developed by the Committee on Environment and Natural Resources, which is an interagency effort to merge existing federally-funded environmental monitoring and research programs (3). As part of this cooperative effort, the EPA has contributed funds and expertise to do UV radiation monitoring, while the NPS has contributed air quality monitoring at the PRIMENet parks. Both agencies contribute to research activities at these sites. Management of the project is a shared responsibility. The PRIMENet Oversight Committee consists of both EPA and NPS scientists (see Appendix C).

PRIMENet represents an ambitious attempt to co-locate monitoring and research activities funded by multiple Federal agencies in national parks to examine long-term trends in regional and global stressors and ecosystem responses. This cooperative program between EPA and NPS will undoubtedly expand to include other research entities, including the U.S. Department of Agriculture (USDA) Forest Service, the U.S. Geological Survey (USGS), the National Oceanic and Atmospheric Administration (NOAA), the National Science Foundation's Long Term Ecological Research Program, and numerous university researchers. This effort demonstrates that resources can be pooled to (1) provide useful monitoring and research data to all participating agencies, (2) incorporate research ideas and activities of academia to answer policy and regulatory questions concerning the effects of man's activities on natural ecosystems, and (3) use national parks to examine trends in global and regional environmental stressors and the responses of natural systems and populations.

Figure 1. U.S. Map of PRIMENet Site Locations.

History of the Network

The EPA and NPS signed the interagency agreement (IAG) to cooperate on PRIMENet in September 1996. This agreement was renewed for an additional three years, effective October 1, 1999. Under the current IAG, we agreed to establish 14 sites where major environmental stressors would be monitored. The parks selected are class I areas which are protected under the Clean Air Act Amendments of 1977 (4), and represent a range of ecosystem types. The fourteen parks are shown in Figure 1.

The last of the UV monitors was installed in Hawaii Volcanoes National Park (NP) in February 1999. The monitors installed are known as Brewer spectrophotometers, and are the same instruments used at sites throughout Canada and Europe (5). They can detect not only the total amount of UV radiation but also the amounts for different wavelength bands within the spectrum. This is useful because different wavelength bands may pose different risks. These instruments can also be used to calculate total column ozone, the atmospheric parameter that shields the earth's surface from UV-B radiation. At all sites we are measuring a standard set of air quality and meteorological parameters, including visibility (in selected locations), ozone, wet and dry deposition, and climate (air temperature, soil temperature, wind speed and direction, and humidity).

Research on the effects of these atmospheric stressors on natural ecosystems has begun in the areas of: (1) effects of UV-B on resources, with

emphasis on amphibians, (2) effects of ozone on native vegetation, (3) effects of nitrogen deposition on terrestrial and aquatic systems, (4) the extrapolation of point environmental measurements to larger landscapes, using modeling and statistical techniques, and (5) the accumulation of organic contaminants in ecosystem components. Research needs for the parks were based on inputs from the PRIMENet park representatives (see Appendix A). Research projects were selected through a competitive process, with projects being selected for two-years of funding beginning in August 1998. Some projects in these parks are sponsored by other agencies, such as the USGS, which make use of the monitoring data and infrastructure that the PRIMENet sites provide (see Appendix E).

Annual meetings have been organized to allow for exchange of information among the sponsoring agencies, the PRIMENet researchers, and the park representatives. The first annual PRIMENet meeting was held in Estes Park, Colorado, in November 1997. In November 1998, the second annual PRIMENet meeting convened in Marin County, California.

Focus on UV Monitoring

The purpose of ground-level monitoring of UV radiation in parks is twofold: (a) to determine spatial and temporal trends in UV reaching the ground at different elevations and in different environments, and (b) to provide an estimate of the exposure of park resources to UV-B to determine dose-response relationships. It is widely documented that stratospheric ozone has been reduced due to the release of chlorofluorocarbons into the atmosphere. It is also known that this reduction in total column ozone has resulted in increasing amounts of UV-B reaching the surface, with the largest changes being observed in the polar regions (6). There is evidence that these higher levels of UV-B radiation can be detrimental to human health and biological resources (7, 8). Resources that have been identified as sensitive to increased UV-B include amphibians, aridland reptiles, and marine and freshwater plant and animal populations. In human populations, increases in UV-B are linked to higher incidence of skin cancer, cataracts, and immune system disorders.

To increase our knowledge of the trends in this stressor and the possible consequences to natural resources, PRIMENet focuses both research and monitoring activities on this issue. In addition to the UV monitors placed in the national parks, the EPA has an existing, complementary network of UV monitors in urban areas. These include Boston, Massachusetts; Boulder, Colorado; Gaithersburg, Maryland; Research Triangle Park, North Carolina; Atlanta, Georgia; Riverside, California; and Albuquerque, New Mexico. The urban monitors are used primarily to assess human exposure to UV-B radiation. In addition to EPA, several other federal agencies are monitoring UV radiation, including the USDA, NOAA, the Department of Energy, the National Science Foundation and the Smithsonian. There are co-located UV instruments in both Big Bend and Everglades NPs, where the USDA is currently operating their "shadow band" instruments. A common web site for information on these UV networks can be found at http://www.arl.noaa.gov/research/programs/uv.html. These agencies are coordinating activities through the "U.S. Interagency UV-Monitoring Network Plan" prepared under the auspices of the

President's Committee on Environment and Natural Resources.

The contractor in charge of PRIMENet UV operations is the University of Georgia. The NPS coordinates the site operators and NOAA assists in the quality assurance and audit program. Overall project management is headed by the EPA-Global Change Program at the National Exposure Research Lab in Research Triangle Park, North Carolina.

Monitoring Other Environmental Stressors

Air Quality and Deposition Monitoring

The Air Resources Division (ARD) of the NPS has operated an air quality monitoring network for visibility, gaseous pollutants (e.g., ozone and sulfur dioxide), and wet and dry deposition since 1978. Prior to this, little to no monitoring had been conducted in parks. Currently, the NPS conducts visibility optical monitoring at selected PRIMENet parks using either a transmissometer or nephelometer. This optical monitoring is complemented at IMPROVE network sites (Interagency Monitoring of Protected Visual Environments) by fine particle sampling. This network of particle monitoring sites will add 108 sites this year in parks and wilderness areas to allow for verification of targets established under the regional haze regulations. The NPS monitors ground-level ozone in park units, using EPA-approved methods, with data being entered in the EPA's Aerometric Information and Retrieval System (AIRS). At these monitoring sites, meteorological data are also collected to allow for interpretation of atmospheric concentration data. As part of the National Atmospheric Deposition Program/National Trends Network (NADP/NTN) and the Clean Air Status and Trends Network (CASTNet), wetfall chemistry and atmospheric concentration of gases and particles are being monitored at a number of park units. These are just a subset of the larger national networks, which can be analyzed for spatial and temporal trends in deposition. For information on the NPS air monitoring networks, refer to the web site at http://www.nature.nps.gov/ard/gas. To get more accurate deposition loading data for high-elevation ecosystems in the Rocky Mountains, the NPS is cooperating with the USGS-Water Resources Division in a long-term snowpack chemistry survey at 62 sites.

These routine, long-term monitoring data are being supplemented by special studies at some of the PRIMENet parks. The NPS-ARD has just completed four years of enhanced monitoring for ozone and its precursors (nitrogen oxides and volatile organic compounds) at three locations with high ozone levels (Great Smoky Mountains, Mammoth Cave and Shenandoah NPs) to better understand the causes of these high levels, which are damaging native vegetation in the parks. The NPS is participating with the air regulatory agencies of the U.S. and Mexico in a special field study to assess visibility impairment at Big Bend NP in Texas, and to identify the seasonal sources of particles causing that air quality impact. These types of intensive air quality studies will assist with interpretation of the long-term monitoring data.

Contaminant Monitoring

Researchers from EPA-Las Vegas are using twelve PRIMENet sites to screen for toxic contaminants that may have accumulated in

various media, including water, sediments, plant tissue and fish. These contaminants include pesticide residues and by-products, many which are known endocrine mimics or endocrine disrupting compounds (EDCs). These EDCs have been implicated in effects on human and wildlife health, including disruption of reproductive potential. Analyses from the twelve parks sampled during summer 1998 should be available by summer 1999.

Mercury (Hg) is the trace metal contaminant of particular concern with respect to effects on human health and food-chain effects in wildlife populations. Currently, 27 states and a number of Canadian provinces have issued fish consumption advisories that warn consumers about mercury-contaminated fish and shellfish (9). Sources of air-borne Hg include power plant and incinerator emissions and natural fluxes from ecosystems. Mercury is currently being monitored in wet deposition at two PRIMENet parks, Everglades and Acadia NPs. These parks are part of the Mercury Deposition Network (MDN). Data collected at these parks are available at the web site http://nadp.sws.uiuc/mdn.

Effects Research

In summer 1998, the selection of PRIMENet research projects was completed. The research categories included: (1) effects of UV-B, nitrogen and ozone on natural ecosystems, and (2) extrapolation of point environmental measurements to larger landscapes. Following a rigorous peer review and agency-relevance review process, six projects were selected for funding. Oversight of the cooperative agreements with university researchers and IAGs with federal agency researchers is the responsibility of EPA-National Health and Environmental Effects Research Lab, Corvallis, Oregon. Summaries of these projects are included in Section III. At each study site, field research will occur during years 1999 and 2000, with final reports expected in FY 2001.

Another topic area for research is a focus on amphibian populations. In FY 1997 PRIMENet funded USGS-Biological Resources Division (BRD) researchers to develop amphibian monitoring protocols at Shenandoah, Great Smoky Mountains, and Big Bend NPs. They are now extending this research program to include work along a contaminant gradient at Acadia NP. In January 1999, the EPA and NPS sponsored an amphibian workshop in Duluth, Minnesota to plan a two-year effort that combines UV dosimetry with amphibian metapopulation analysis. Summaries of these projects are also included in Section III of this report.

II. Monitoring Data at PRIMENet Sites: Air Quality, UV and Climate

The value in the PRIMENet monitoring program is the long-term nature of the data sets collected, and the spatial comparison of common physical and chemical variables across many sites. Data sets at PRIMENet sites include visibility, ozone, wet and dry deposition, UV radiation, and climate. In subsequent years we will be able to compare all fourteen sites and begin to perform temporal trend analysis.

Visibility

Twelve of the fourteen PRIMENet parks are or have been part of the Interagency Monitoring of Protected Visual Environments (IMPROVE) network. Acadia, Big Bend, Canyonlands, Denali, Everglades, Glacier, Great Smoky Mountains, Rocky Mountain, and Shenandoah NPs have monitored visibility according to the IMPROVE protocol since the network's inception in March 1988. Sequoia/Kings Canyon NP initiated visibility monitoring in September 1992, while visibility data collection at Hawaii Volcanoes NP occurred only between March 1988 and April 1993. Virgin Islands NP has measured fine mass with a simplified IMPROVE fine particle monitor since October 1990, and became a fully complemented site in 1997. Olympic and Theodore Roosevelt NPs are scheduled to begin visibility monitoring by year 2000. Monitoring site information and dates of operation are summarized in Appendix D.

A fully complemented IMPROVE protocol visibility site employs three types of monitors—photographic, optical, and aerosol. Photographic monitoring documents the condition of a scene in a park several times a day using a 35mm camera. Optical monitoring directly measures the light extinction coefficient with transmissometers or the light scattering coefficient with nephelometers. The light extinction coefficient is a measure of the attenuation of light per unit distance caused by the scattering and absorption of gases and particles in the atmosphere. The scattering coefficient has a similar definition except absorption is not included. Aerosol monitoring is based on fine (PM-2.5) and coarse (PM-10) particle sampling and sample analysis. The aerosol sampler uses four independent modules to collect four simultaneous samples: three PM-2.5 samples on Teflon, nylon and quartz filters, and one PM-10 sample on a Teflon filter. The PM-2.5 filters are analyzed for mass, chemical elements, ions, organics and elemental carbon, and optical absorption. The PM-10 filter is analyzed for mass only. The concentrations of the various aerosol constituents are used to estimate their contributions to the light extinction coefficient. These "reconstructed" extinctions are briefly summarized below. A detailed discussion of the IMPROVE network, its monitoring protocols, and data analysis is found in Sisler (10). IMPROVE aerosol and optical data sets are available at ftp://alta_vista.cira.colostate.edu.

The 1991-1997 average reconstructed extinction at eleven PRIMENet sites is plotted in Figure 2. (The mean extinction for Hawaii Volcanoes and Sequoia/Kings Canyon NPs is computed based on March 1988-February 1992, and January 1993-December 1997 data, respectively). Virgin Islands NP extinction is not plotted

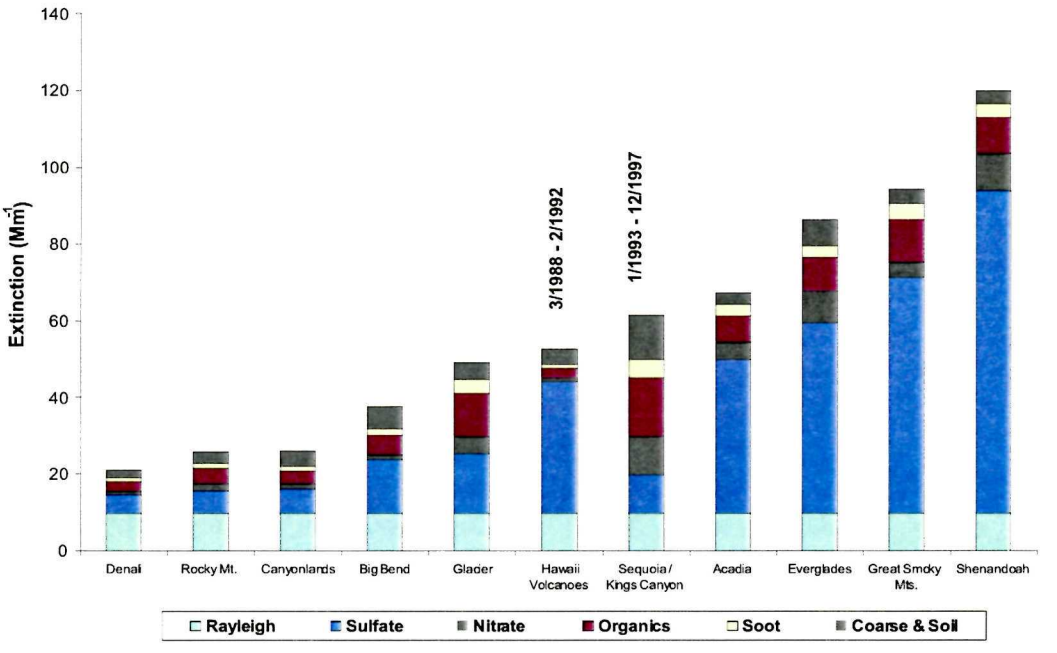

Figure 2. Average Reconstructed Extinction at PRIMENet Sites from 1991 to 1997.

because only one of the four IMPROVE particle sampling modules was employed up until 1997, making an accurate estimate of extinction difficult. The total reconstructed extinctions at these eleven sites vary from 20 to 120 inverse megameters (Mm^{-1}), a factor of six difference. These extinction values correspond to standard visual ranges of 186 km for Denali NP and 33 km for Shenandoah NP. Denali NP fine particle concentrations and total extinction are generally the lowest of all those observed in the IMPROVE network. Rocky Mountain and Canyonlands NPs have low total reconstructed extinctions of about 26 $M m^{-1}$ (150 km visual range). The PRIMENet IMPROVE sites exhibit the well-documented, strong spatial gradient in visibility between eastern and western U.S. monitoring stations.

The light extinction (and visibility reduction) at IMPROVE sites is typically explained by the following atmospheric constituents: fine particles of sulfates, nitrates, organic carbon, light absorbing carbon (soot), and soil, coarse particles, and atmospheric gas molecules like O_2 and N_2 which scatter light (Rayleigh scattering). Rayleigh scattering does vary somewhat with elevation but often it is assigned a constant contribution to extinction of 10 Mm^{-1}. Figure 2 illustrates that Rayleigh scattering accounts for a greater percentage of the total extinction at the cleaner sites like Denali and Canyonlands NPs than at lower visibility

eastern sites like Acadia, Everglades, Great Smoky Mountains, and Shenandoah NPs.

In the east, sulfates are usually the greatest contributor to extinction and visibility impairment. Sulfates contribute 57 to 69 percent of the total extinction in the four eastern sites displayed in Figure 2. At Denali, Rocky Mountain, and Canyonlands NPs sulfates account for less than one fourth of the total extinction. Sulfate extinction at Shenandoah NP (83.8 Mm^{-1}) is nearly fifteen times greater than that at Rocky Mountain NP (5.7 Mm^{-1}). Sulfate particles are typically formed in the atmosphere from the conversion of sulfur dioxide gas emitted from large anthropogenic sources such as fossil-fuel fired power plants. However, the monitor at Hawaii Volcanoes NP undoubtedly recorded the influence of the nearby large natural sources of volcanic sulfur emissions.

The next largest chemical contributors to visibility impairment at most PRIMENet sites are organic carbon and light absorbing carbon (soot) which have their origins in vegetative burning and urban emissions. Nitrates present a smaller contribution to extinction at all PRIMENet sites with the exception of Sequoia/Kings Canyon NP where the sulfate, nitrate and Rayleigh extinctions are all each on the average about 10 Mm^{-1}. Nitrates are often formed in the atmosphere from precursor gaseous nitrogen oxides emitted from industrial and urban sources. Fine soil and larger coarse particles have a relatively large contribution to the extinction budget at Sequoia/Kings Canyon NP. This soil and coarse particle contribution is about two to six times larger than the corresponding ones measured at the other PRIMENet sites. Soil and coarse particles can result from unpaved roads, wind blown dust, and industrial sources.

Sisler and Malm (11) investigated trends in annual reconstructed visibility and fine particles at IMPROVE monitoring sites over the nine-year period 1988-1996. The 30 IMPROVE sites analyzed included eight of the following PRIMENet parks: Acadia, Big Bend, Canyonlands, Denali, Glacier, Great Smoky Mountains, Rocky Mountain, and Shenandoah NPs. For the worst visibility days, their analysis indicated a statistically significant ($p<0.10$) improving trend in reconstructed visibility at Canyonlands, Denali, and Glacier NPs and statistically insignificant changes at the other five PRIMENet IMPROVE sites. With respect to the average visibility days, Acadia, Canyonlands, Denali, Glacier, Rocky Mountain, and Shenandoah NPs showed statistically significant ($p<0.05$ or $p<0.10$) improving reconstructed visibility trends. No statistically significant trend was discernable at Big Bend and Great Smoky Mountains NPs. Finally, the trend analysis for the best visibility days indicated statistically significant ($p<0.05$) improvements in reconstructed visibility at Acadia, Canyonlands, Denali and Rocky Mountain NPs. Changes at the other four parks were judged to be statistically insignificant.

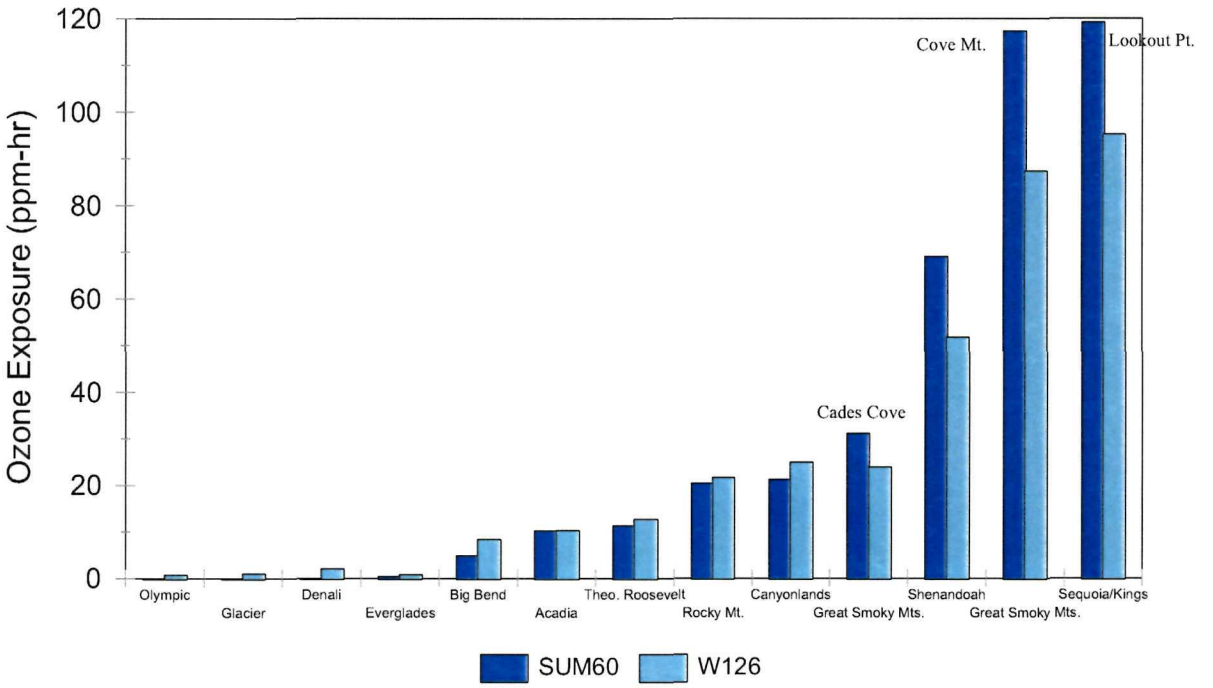

Figure 3. Ozone Exposures at PRIMENet Sites for the 1997 growing season.

Ozone

All of the PRIMENet sites currently monitor ground-level ozone, with the exception of Hawaii Volcanoes NP. The installation of an ozone monitor at Hawaii is scheduled for July 1999. For site information and operation dates of the monitors see Appendix D.

Two summation methods have been used to describe how cumulative ozone exposure relates to effects on vegetation during the growing-season, May through September. The SUM60 statistic is a sum of all hourly ozone concentrations equal to or exceeding 60 parts per billion (ppb). A second method called W126 is a sum of all hourly ozone concentrations where the concentration is weighted by a function that gives a greater emphasis to concentrations above 60 ppb. This method is described by Lefohn et al. (12).

Figure 3 shows the SUM60 and W126 statistics for each of the PRIMENet sites during the 1997 growing-season. Only one year of data is presented because the operation dates of each monitor were highly variable and these indices are difficult to average in a meaningful way. The disadvantage of presenting one year of data is that interannual variation is ignored. However, these spatial patterns tend to remain consistent from year to year.

Ozone injury to sensitive vegetation can occur above 25 ppm-hr for a three-month average of SUM60 and has been documented in Sequoia/Kings Canyon,

Great Smoky Mountains, and Shenandoah new 8-hour National Ambient Air Quality Standard (NAAQS) which is subject to court remand. The standard is based on human health effects and is set at 80 ppb ozone averaged over three years. Parks with large elevation gradients are particularly susceptible to ozone exposure. High elevation sites report 2-3 times more ozone than low elevations. This is illustrated by the two sites in Great Smoky Mountains NP, where the difference between Cades Cove (CC) at 564 m and Cove Mountain (CM) at 1243 m is a SUM60 factor of four. Ozone exposure at Olympic, Glacier, Denali, and Everglades NPs was very low in 1997.

Atmospheric Deposition

Wetfall

Eleven of the fourteen PRIMENet park sites have had National Atmospheric Deposition Program/National Trends Network (NADP/NTN) precipitation collectors since 1984. These parks include; Acadia, Big Bend, Denali, Everglades, Glacier, Great Smoky Mountains, Olympic, Rocky Mountain (Beaver Meadows - BM), Rocky Mountain (Loch Vale - LV), Shenandoah, Sequoia/Kings Canyon and Theodore Roosevelt NPs. Canyonlands and Virgin Islands NPs were added to the network in 1998, and Hawaii Volcanoes NP is expected to join in July 1999. See Appendix D for a listing of the locations, elevations, and operation dates of the NADP/NTN samplers.

Figure 4 shows a summary of the precipitation data for concentrations of nitrate and sulfate averaged over a 14-year period. It is organized to show the parks with the lowest to highest concentrations of NPs. These parks are likely to exceed the nitrate in wetfall, with paired bars indicating sulfate concentrations. The error bars indicate standard deviations of the means. The lowest volume-weighted mean concentrations of nitrate were recorded at Olympic and Denali NPs. High concentrations of nitrate (values above 15 $\mu eq\ l^{-1}$) were measured in Rocky Mountain-BM, Great Smoky Mountains, Theodore Roosevelt, Shenandoah, Acadia and Big Bend NPs. Concentrations of sulfate had a wider range in values than nitrate. Again, the lowest concentrations of sulfate were recorded in samples collected at Olympic and Denali NPs, with very high concentrations (values above 30 $\mu eq\ l^{-1}$) for Acadia, Shenandoah and Great Smoky Mountains NPs. The sulfate to nitrate ratios approach one at the two sites in Rocky Mountain and at Glacier NP. Only Sequoia/Kings Canyon and Rocky Mountain (BM) NPs showed nitrate in excess of sulfate.

These spatial patterns in deposition among the park sites reflect the influence of sulfur emissions in the eastern part of the United States, and the ubiquitous nature of nitrogen emissions throughout the U.S., except at purported "background" sites as Olympic and Denali NPs. However, it is important to note that the trend analysis for Olympic NP indicates a significant increase in nitrate concentrations over the period 1985-1993. For a summary of this trend analysis for nitrate and sulfate concentrations in precipitation at selected PRIMENet parks, see Lynch et al. (13).

The data summarized in Figure 4 are expressed as volume-weighted concentrations of nitrate and sulfate. This convention was used because it allows the comparison of sites with different amounts of annual precipitation. However, from the

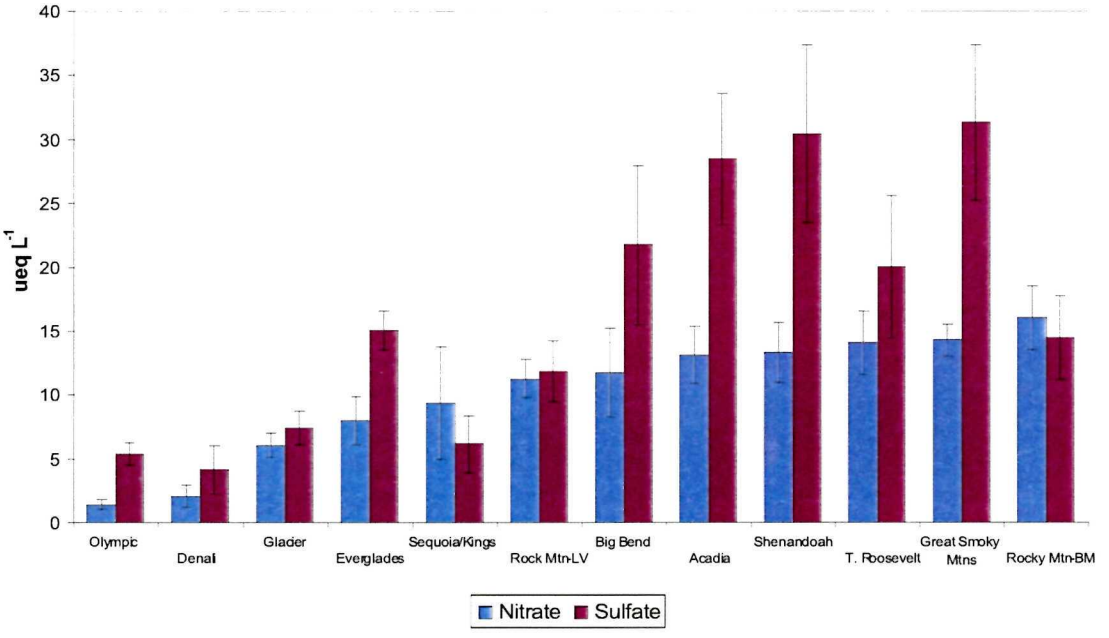

Figure 4. Average Annual Concentrations of Nitrate and Sulfate in Precipitation from 1984 to 1997.

ecosystem perspective, it is most important to determine the amount of solutes (sulfate, inorganic nitrogen, base cations or acidity) that are "loaded" into the sensitive systems of interest. These sensitive ecosystems include low-acid neutralizing capacity (ANC) surface waters, acidic soils, small watersheds, and nitrogen-limited estuaries. The NADP/NTN data summaries include an estimate of the loading of nitrogen and sulfur in wet deposition, based on the amount of rain or snow that fell at that point. For many park ecosystems, such as high elevation watersheds, where snow and cloudwater inputs are an important part of the hydrologic budget, or in aridlands, where dry deposition is most important, these point estimates are inadequate to characterize loading. Other, alternate methods to estimate deposition inputs are needed to calculate total chemical inputs. In the snow zone we have used snowpack sampling at maximum accumulation to estimate winter chemical and hydrological inputs (14).

To obtain complete data sets for these sites, including both concentrations and loading, refer to the NADP/NTN web site at http://nadp.sws.uiuc.edu.

Dryfall

In 1997, the Clean Air Status and Trends Network (CASTNet) monitored atmospheric concentrations of sulfur dioxide, nitric acid, and particulate sulfate and nitrate at six PRIMENet sites; Big

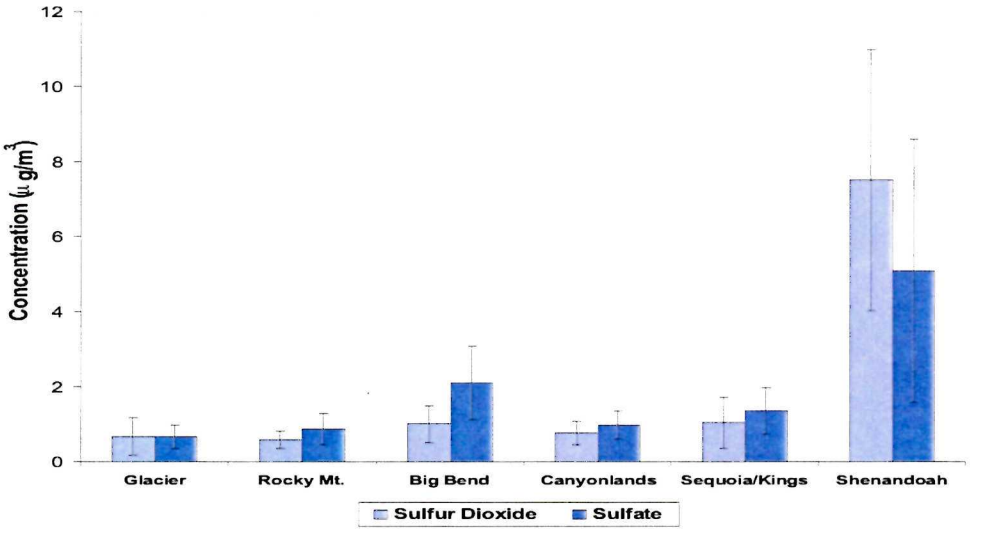

Figure 5. Atmospheric Concentrations of Sulfur Dioxide and Particulate Sulfate in 1997.

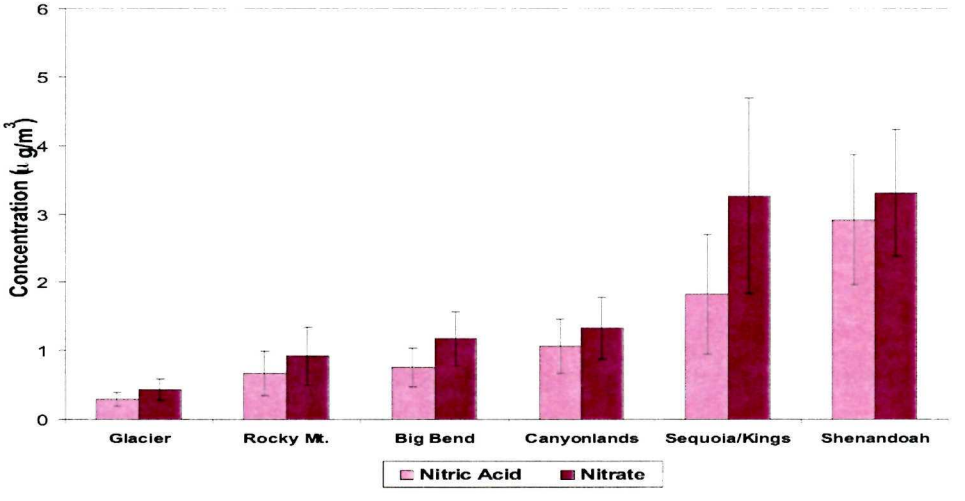

Figure 6. Atmospheric Concentrations of Nitric Acid and Particulate Nitrate in 1997.

Bend, Canyonlands, Glacier, Rocky Mountain, Sequoia/Kings Canyon, and Shenandoah NPs. CASTNet filter pack systems have subsequently been installed in the remaining PRIMENet parks, with the exception of Hawaii Volcanoes, which is scheduled for July 1999. Site information and operation dates are found in Appendix D.

Atmospheric concentration data are collected at each site with open-faced, 3-stage filter packs. The filter pack contains a teflon filter for collection of particulate species, a nylon filter for nitric acid and a base-impregnated cellulose filter for sulfur dioxide. Filter packs are exposed for 1-week intervals at a flow rate of 1.5 liters per minute (3.0 liters per minute for

western sites), and sent to the laboratory for chemical analysis.

Figures 5 and 6, compare atmospheric concentrations of sulfur dioxide and particulate sulfate, and nitric acid and particulate nitrate, respectively. Again only one year of data is presented because operation dates were highly variable. Shenandoah NP had the highest sulfur concentrations, while Shenandoah and Sequoia/Kings Canyon NPs had the highest nitrogen concentrations.

To estimate total deposition to a park site, both wet and dry deposition must be monitored. As part of CASTNet, dry deposition rates will be calculated using a multi-layer version of the NOAA "big leaf" model, with the parameters of atmospheric concentration, meteorological data and information on land use, vegetation, and surface conditions. Dry deposition estimates for each site will be available when runs of the model are complete. Updated information on CASTNet is available at http://www.epa.gov/ardpublc/acidrain/castnet.

Ultraviolet Radiation

During 1997, six Brewer spectrophotometers operated year-round in PRIMENet parks as part of the UV Network. Brewers have been installed in all of the remaining parks, the last of which was Hawaii Volcanoes NP in February 1999. Refer to Appendix B for a list of the site operators and to Appendix D for site information and operation dates.

The Brewer spectrophotometer measures the spectrally resolved irradiance reaching a horizontal surface both directly from the sun and indirectly from the sky. On a typical summer day, there may be 25 separate measurements (or scans) as the sun moves across the sky. The spectrum of wavelengths covered by the Brewer ranges from 286 to 363 nanometers (nm). The highest energy UV and the most damaging to humans is designated UV-B and generally ranges from 280 to 315 nm. The range of 315 to 400 nm is designated UV-A and may be important to plant life.

Each scan of spectral irradiance is integrated over all wavelengths to give a measure of energy flux for the entire spectrum (e.g. energy per square meter per second). This integration can include a weighting function, also called an action spectrum, which weights wavelengths in proportion to their importance for biological effects. The Diffey action spectrum emphasizes the wavelengths responsible for damage to human skin, most of which is in the UV-B range.

The Brewer automatically computes and records measurements of Diffey-weighted UV radiation (DUV) throughout the day. These measurements can be further integrated over the day to yield an energy dosage for the day (energy per square meter) weighted to the critical wavelengths. This total daily dosage, daily DUV, is also recorded by the Brewer as a single number.

Figure 7 shows daily DUV integrals at four sites that had coverage over a significant portion of 1997. Each data point represents a 5-day running maximum of UV. The graphs display seasonal bell-shaped curves, with values highest in the summer and lowest in the

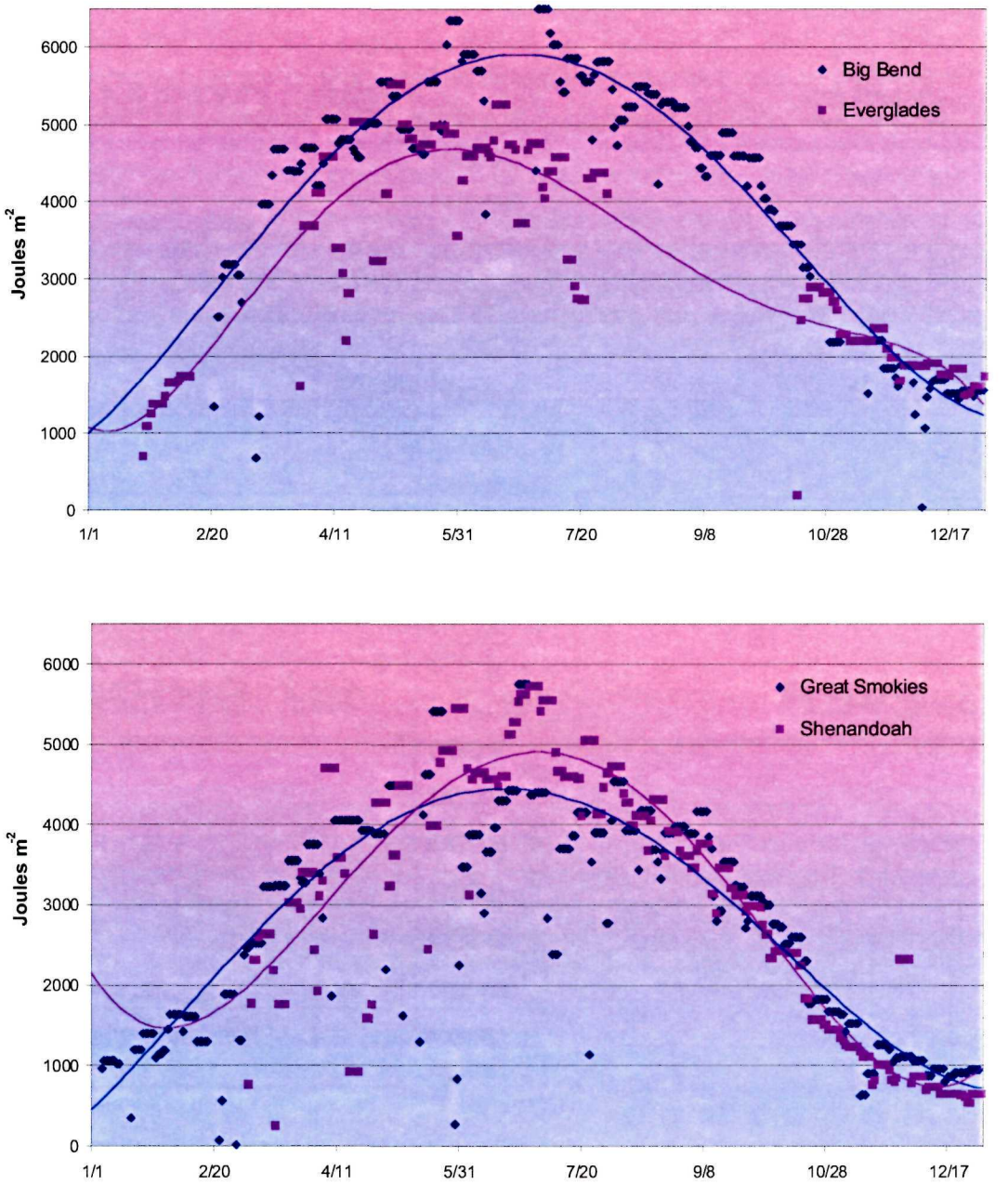

Figure 7. Daily DUV Integrals in 1997.

winter. Big Bend NP had the highest reported DUV, even though Everglades is located farther south and Shenandoah NP had higher DUV than Great Smoky Mountains NP.

The box and whisker plots shown in Figure 8 summarize the spread of the data in months of the year. The box covers the middle 50% of the data (the middle two

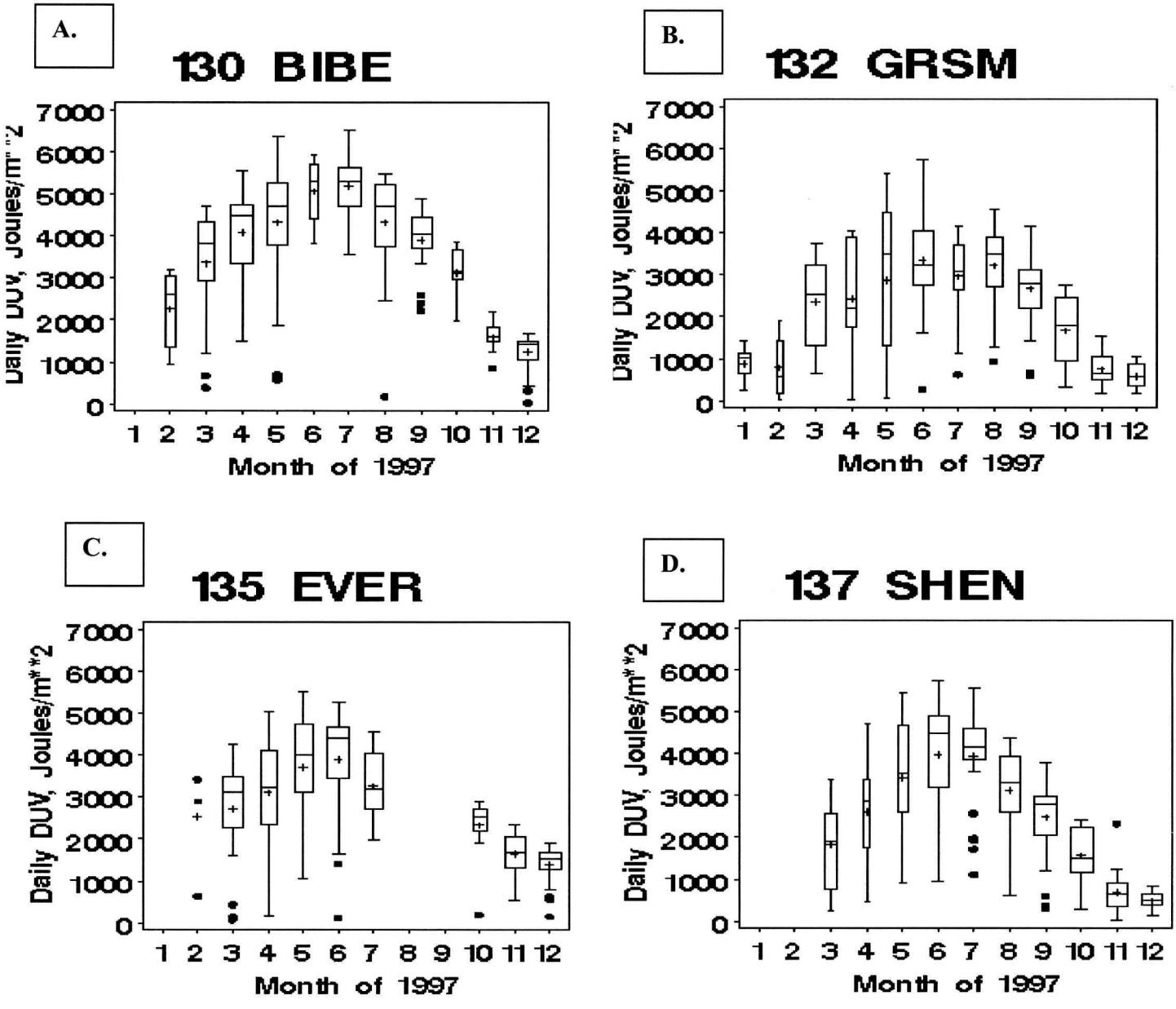

Figure 8. Statistical summary of the UV radiation in 1997; A. Big Bend NP; B. Great Smoky Mountains NP; C. Everglades NP; and D. Shenandoah NP.

quartiles), with the median given by a hash mark and the mean by a "+". The whiskers extend to the most extreme data point or to 1.5 times the length of the box, whichever is less. Data points beyond the whisker are given individual symbols. The width of the box is proportional to the number of good data points. The envelope shape of the seasonal curve, monthly range of values, and peak DUV during the summer all varies for the four sites.

Clouds and haze are major factors in determining the daily DUV and account for most of the variability during the month. Some facets of the climatology of the sites can be inferred from these plots.

Although daily DUV is the total energy input, it is concentrated during mid-day when the sun is at minimum zenith angle, which is determined by the latitude of the site. Daily DUV is also determined by the length of the day. Therefore, a site like Denali NP will have a more pronounced seasonal cycle than a site like Everglades NP, but the summertime maximum values at Denali may be surprising high due to the length of day at that latitude. More information on the UV network is available at http://www.epa.gov/uvnet.

Climate

Each PRIMENet site records basic meteorological data, including wind speed and direction, air and soil temperature, relative humidity, solar radiation, and precipitation amount. These data are used to interpret air quality and UV measurements and also to determine long-term trends in climate. Variations in climate are likely to affect the way that natural ecosystems respond to air-pollution stress. For example, vegetation response to ground-level ozone is determined by the availability of soil moisture.

Table 1 summarizes 1997 meteorological data for twelve of the PRIMENet parks. Meteorological stations were installed at Theodore Roosevelt and Virgin Islands NPs in 1997. The windiest sites are Acadia, Big Bend, Hawaii Volcanoes, and Rocky Mountain NPs. Everglades NP had the highest mean temperature, while Denali NP had the lowest. Hawaii Volcanoes and Everglades NPs received over 2000 mm of annual precipitation. Big Bend NP received less than 300 mm. The maximum solar radiation was also recorded at Big Bend NP, while the lowest values were recorded at Denali NP. In future reports, climate trends will be presented for parks with long-term data sets.

Table 1. Summary of Meteorological Data for 1997.

Park	Scalar Wind Speed m/s mean ± std dev	Ambient Temperature ° C			Relative Humidity % mean ± std dev	Precipitation mm mean ± std dev	Solar Radiation watts/m^{2**} mean ± std dev
		mean ± std dev	Maximum	Minimum			
Acadia	4.2 ± 2.3	6.7 ± 10.0	31.2	-23.3	75 ± 19	1150.8*	N/A
Big Bend	3.5 ± 1.6	18.9 ± 8.8	38.4	-8.0	52 ± 20	235.5 ± 2.3	497 ± 333
Canyonlands	2.7 ± 1.4	11.4 ± 10.4	33.8	-9.7	48 ± 21	240.2 ± 1.4	400 ± 294
Denali	1.4 ± 0.8	-1.3 ± 12.9	26.4	-37.2	70 ± 20	282.4 ± 1.0	210 ± 206
Everglades	2.0 ± 1.2	23.3 ± 5.0	33.4	-2.3	82 ± 15	2056.6 ± 7.4	381 ± 257
Glacier	1.1 ± 0.8	5.1 ± 9.8	34.5	-29.1	78 ± 19	711.2 ± 1.0	278 ± 241
Great Smoky Mtns.	2.4 ± 1.3	12.4 ± 8.6	30.4	-17.9	74 ± 20	1288 ± 2.5	359 ± 280
Hawaii Volcanoes	3.5 ± 1.7	15.7 ± 2.5	24.5	7.6	N/A	2549.9 ± 2.3	401 ± 289
Olympic	1.1 ± 0.5	9.3 ± 5.0	28.0	-6.2	84 ± 11	746.8 ± 1.0	303 ± 245
Rocky Mountain	3.2 ± 1.3	3.4 ± 9.4	24.3	-30.0	59 ± 26	363.5 ± 1.5	367 ± 268
Sequoia/Kings Canyon	1.6 ± 0.7	9.2	29.9	-11.6	59 ± 22	845.3 ± 2.5	350 ± 299
Shenandoah	2.7 ± 1.3	7.7 ± 8.7	27.1	-21.7	72 ± 21	639.6 ± 1.5	351 ± 278

*Precipitation amount recorded by Belfort rain gauge at the NADP/NTN site. All other measurements made by tipping buckets gauges.
**Daytime average flux.

III. PRIMENet Research Projects

As a result of a competitive RFA process, the EPA awarded research projects to six teams of investigators in summer 1998. These projects will be funded for two years and are designed to investigate the effects of anthropogenic stressors on natural ecosystems. Results are expected by early 2001. Other projects that are listed in this inventory include "in-kind" projects by EPA investigators (R. McKane and E. Heithmar), and a series of amphibian projects funded by PRIMENet. Projects that make use of PRIMENet data, but which are not directly funded through the program are listed in Appendix E.

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1. Nitrogen deposition and UV stressor impacts in Canyonlands National Park as affected by climatic pulse events

Principal Investigator:
Jayne Belnap[1], USGS-BRD

Co-Investigators:
Martyn M. Caldwell, Utah State University
James R. Ehleringer, University of Utah
David Evans, University of Arkansas
Robert F. Sanford Jr., University of Denver

Park:
Canyonlands NP

Project Summary:

Historically, arid systems in the western U.S. and arctic are thought to have derived much of their nitrogen (N) from N-fixing components of the biological soil crusts. These crusts, which can represent up to 70% of the living cover (often referred to as cryptobiotic crusts), are consolidated matrices of cyanobacteria, lichens, mosses, algae and fungi that are ubiquitous on undisturbed soil surfaces. Increased N deposition, increased UV-B, and land-use change are likely to cause large changes in the integrity and sustainability of the arid ecosystems through impacts of these stressors on the biological crusts. Altering the function of cryptobiotic crusts will directly affect critical ecosystem processes such as soil carbon (C) and N transformations, and this in turn will have a direct impact on productivity of higher plants. Through a series of field N-deposition and UV-augmentation experiments, we will quantify the direct impacts of these stressors on biological crusts, soil C and N dynamics, and higher plants within Canyonlands NP. We will also identify and quantify the anthropogenic sources of N deposition that are likely to impact ecosystem dynamics.

Canyonlands NP is an ideal site because of several long-term (30 year) research and monitoring efforts directed at understanding the response of arid ecosystems to anthropogenic change. The proposed research will provide the scientific basis for understanding the response of arid ecosystems to the interaction of anthropogenic N deposition,

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increased UV-B radiation, and land-use change. Biological soil crusts are the keystone component of arid ecosystems in the western United States and will provide large-scale information about the "health" of these arid ecosystems. The research results will improve our understanding of anthropogenic stressors by quantifying and further defining the relationships between biological crusts, soil C and N transformations, and higher plant sustainability-performance in arid lands. Results will apply to 65 national park units and 300 million acres of federal land, including four national parks with UV monitors (Canyonlands, Denali, Big Bend, and Grand Canyon NPs). Information on the project can be accessed at http://www.soilcrust.org.

2. Using the inter-relationships of stable isotopes in natural abundance as indicators of environmental stress and ecosystem vitality

Principal Investigator:
Jonathon P. Comstock[1], Boyce Thompson Institute

Co-Investigator:
John A. Laurence, Boyce Thompson Institute

Parks:
Sequoia/Kings Canyon, Big Bend, and Glacier NPs

Project Summary:

We propose to relate the pattern of occurrence of natural abundance stable isotope ratios for five key elements (C, N, O, S, and H) in tree rings, roots, and leaves of plants to the environmental conditions under which the plants grow. These isotopes are naturally occurring, non-radioactive tracers. Plant material will be sampled across gradients of N deposition, ozone exposure, and elevation in three national parks. The technique is based on the fact that natural materials are often made of atoms which have different numbers of neutrons but the same number of protons. This gives them almost identical chemical properties, but slightly different masses. Variation in isotopic composition originates in biogeochemical processes discriminating against the heavy isotopes, and can occur at the ecosystem level resulting in naturally labeled resource pools upon which different species may specialize, or on a small scale within organisms due to individual physiology. Analysis of stable isotope composition of plants can therefore yield information about resource capture, physiological specialization, and altered

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metabolism under stress. Use of stable isotopes of single elements to analyze discrete questions in water relations (D and O), photosynthetic physiology (C) and nutrient capture (N and S) are now becoming commonplace. Sometimes isotopes of two or (rarely) three elements have been analyzed simultaneously to unravel the mechanisms of ecosystem function. However, we believe that in addition to the established patterns of isotope discrimination associated with single environmental resources, isotope "fingerprints" resulting from multivariate analyses of D/H, $^{13}C/^{12}C$, $^{15}N/^{14}N$, $^{34}S/^{32}S$, and $^{18}O/^{16}O$ will be associated with the complex variation of multiple resource gradients and their interactions. Including these interactions in a single multivariate analysis will generate hitherto unrealized resolution of both ecotypes and spatial/temporal distribution of unique stress syndromes. Furthermore, isotope abundance ratios laid down during growth are retained in old biomass fractions, and by looking at materials that may be dated, such as tree rings, historical patterns of resource utilization and physiological behavior can be determined. By examining the isotope ratios in tree rings, we should, for example, be able to detect changes in N deposition over time, and relate those changes not only to the record of altered nutrient relationships, but the indirect effects on water and C metabolism as well.

3. UV dosimetry along an elevation gradient to characterize amphibian habitat exposure in six PRIMENet parks: Acadia, Great Smoky Mountains, Rocky Mountain, Glacier, Olympic, and Sequoia/Kings Canyon National Parks

Principal Investigator:
Steve Diamond[1], EPA-MED

Co-Investigators:
Bruce Connery, Acadia NP
Dana Soehn, Great Smoky Mountains NP
Ken Czarnowski, Rocky Mountain NP
Dan Fagre, USGS-Glacier NP
Harold Werner, Sequoia/Kings Canyon NP
Patte Happe, Olympic NP
Mike Adams, USGS-Olympic NP
Steve Corn, USGS-Glacier NP
Dave Bradford, EPA-Las Vegas
Roland Knapp, UCSB

Parks:
Acadia, Great Smoky Mountains, Rocky Mountain, Glacier, Olympic, and Sequoia/Kings Canyon NPs

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Project Summary:

Experimental treatments have implicated UV-B as a stressor that can affect reproduction and development of some amphibian species. The EPA and NPS are currently monitoring UV radiation at the fourteen PRIMENet parks with Brewer spectrophotometers. We need to be able to extrapolate the Brewer data to locations along the elevation gradient in parks in order to characterize exposure to pond breeding amphibians. We have selected six of the PRIMENet parks to carry out this extrapolation. At three of the parks (Glacier, Olympic, and Sequoia/Kings Canyon) researchers will also collect amphibian data coincident with the UV exposure data. At the other three parks (Acadia, Great Smoky Mountains, and Rocky Mountain) we will take advantage of existing amphibian data to relate to UV exposure statistics.

During the summer months, field teams will collect the following data at sites along an elevation gradient in the six parks: UV extinction using a hand-held radiometer, water samples collected at each sample site to be analyzed for dissolved organic carbon (DOC), and characterization of habitat to allow for calculation of open water extent. These measurements would optimally be performed 2-3 times per season at each site.

4. Does nitrogen deposition mitigate ozone injury to ponderosa pine?

Principal Investigator:
Nancy Grulke[1], USDA-FS

Co-Investigators:
Mike Arbaugh, USDA-Forest Service
Andrzej Bytnerowicz, USDA-Forest Service
Mark Fenn, USDA-Forest Service
Pamela Padgett, USDA-Forest Service
Mark Poth, USDA-Forest Service

Park: Sequoia/Kings Canyon NP

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Project Summary:

The primary objective of this study is to test whether increased nitrogen (N) fertility mitigates ozone injury to ponderosa pine. The response of this common western conifer to oxidant exposure has been well described and plant responses to N fertilization are generally understood, but the combined effects of elevated N deposition and oxidant exposure have not been tested. Nitrogen-induced mitigation of foliar ozone injury will be evaluated by a multivariate assessment of visible foliar injury and associated characteristics. A collection of biochemical attributes which play a role in foliar carbon acquisition (CO_2 fixation) and export (via translocation), and N metabolism and storage will be tested as indicators of changes in forest health.

Ozone concentrations frequently reach or exceed 100 ppb in mid-elevation forests in Sequoia/Kings Canyon NP, California. Nitrogen deposition, however, has been estimated for only a few sites in the Sierra Nevada. Ozone and nitrogenous pollutants are believed to be the major pollutant types in the west-side mid-elevation forests of the Sierra Nevada and are usually co-occurring. Only one study, to date, has addressed the combined effects of these co-occurring pollutants on mature trees in situ. In that study two mid-elevation mixed conifer sites in the San Bernardino Mountains with differing ozone levels have been exposed to background N deposition, or fertilized with 50 or 150 kg ha^{-1} of slow release urea (USDA funding awarded to Mark Fenn, Mark Poth, and Paul Miller; ongoing). The study proposed here will replicate the San Bernardino work using background N deposition levels and the lower fertilization treatment (+50 kg ha^{-1}).

This will provide additional information regarding the responses of a Sierran mixed conifer ecosystem to similar ozone exposures. This work will extend beyond the San Bernardino data set by using a design that includes two levels of soil moisture availability.

Ponderosa pine trees growing in mesic and xeric microsites at similar elevations will be selected for this study. The differences in summer water availability will be used to drive differences in ozone uptake. The mesic sites will extend stomatal opening later on both a diurnal and seasonal basis, thus increasing ozone uptake as compared to the xeric microsites. Within each microsite, five blocks of ten trees will be fertilized at the rate of 50 kg ha^{-1} and five blocks will receive no fertilizer. Background N deposition levels have been estimated to be approximately 9 kg ha^{-1} yr^{-1}. Statistical comparisons of tree response variables will be made within a soil moisture level across fertilizer treatments (background and elevated N), and between soil moisture levels in unamended blocks. The proposed study would make a major contribution in evaluating whether N deposition, at current and potentially higher future levels mitigates a known environmental stressor (oxidant pollution) in the Sierran mixed conifer zone.

An additional supporting objective is to quantify and determine the extent to which ozone exposure and N deposition co-vary at four sites along an elevational gradient in the Sequoia/Kings Canyon NP from 580 m to 2900 m.

The specific objectives of the study are to (1) test whether N deposition mitigates foliar oxidant injury and associated tree response variables in ponderosa pine at two different levels of ozone, (2) describe the effects of soil moisture availability and N amendment on available soil N forms (ammonium and nitrate) and on various foliar N attributes, and (3) quantitatively correlate N deposition with ozone exposure along an elevational transect.

5. Anthropogenic chemical contaminant levels at national park index sites

Principal Investigator:
Edward M. Heithmar[1], EPA-NREL

Parks:
Acadia, Big Bend, Canyonlands, Denali, Glacier, Great Smoky Mountains, Everglades, Olympic, Rocky Mountain, Sequoia/Kings Canyon, Shenandoah, and Theodore Roosevelt NPs

Project Summary:

National park index sites are being used as platforms for studying the occurrence of anthropogenic chemical contamination at continental U.S. sites that are minimally impacted by direct human activity. Two fish species (bottom feeding and higher predator), sediment, water, and plant tissue collected at twelve parks will be analyzed for a suite of contaminants including volatile organic compounds, polynuclear aromatic hydrocarbons, individual congeners of polychlorinated biphenyls, selected pesticides, and mercury. Most of this target list comprises chemicals suspected to be endocrine disrupting compounds (EDCs). Fish from a probability sample of wadeable stream sites from the Mid-Atlantic Integrated Assessment (MAIA) Project will be subjected to the same protocol as the index site fish. The concentrations of contaminants found in the index site fish will be compared to the distributions of concentrations found in the MAIA fish, the latter being assumed to be exposed to a broad range of stressors and to be representative of a large region of the U.S. Results from the media other than fish collected at the index sites cannot be compared to distributions obtained for MAIA sites; available literature data for similar matrices will be used to assess the relative magnitude of these contaminant loads.

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Because the index sites are purportedly less subject than typical continental U.S. ecosystems to chemical contamination, conventional analytical approaches would be expected to produce many results below method detection limits. Maximizing the percentage of useable data by improving detection limits would allow more detailed interpretation of the results. Therefore, new analytical techniques with potentially superior performance to conventional methods will be developed and used. The emergent analytical techniques will be compared with conventional methods to assess the relative figures of merit of the methodologies. New analytical approaches to be tested include accelerated-solvent, solid-phase, and microwave-assisted extraction procedures; vacuum distillation of volatile organic compounds; multidimensional separation methods; state-of-the-science mass spectrometry techniques; direct analysis of solid samples for mercury; rapid screening approaches including direct aqueous injection analysis and capillary electrophoresis/laser induced fluorescence; and elemental speciation. A screening procedure for contaminants not in the target suite will also be developed.

The contaminant levels found in the index site fish will be analyzed, using data on regional chemical contaminant sources, geochemistry, and meteorology, in an attempt to assess the relative importance of local and regional sources, compared to long-range transport. It is also hoped that some Index Sites will become long-term platforms to develop and evaluate new monitoring approaches.

6. Standardized monitoring methods for amphibians in national parks and associations in time and space between amphibian abundance and environmental stressors

Principal Investigator:
Robin E. Jung[1], USGS Patuxent Wildlife Research Center

Co-Investigators:
Sam Droege, USGS Patuxent Wildlife Research Center
John R. Sauer, USGS Patuxent Wildlife Research Center

Parks:
Acadia, Big Bend, and Shenandoah NPs

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Project Summary:

Amphibian declines world-wide have created a need for more extensive and standardized monitoring of amphibian populations and for elucidating underlying causes of amphibian declines. In response to concerns about amphibian populations, a study evaluating and validating amphibian survey techniques was initiated in Acadia, Big Bend, and Shenandoah NPs under the auspices of PRIMENet.

The goals for the project are to document spatial and temporal variation in amphibian populations and associations between amphibian populations and natural and anthropogenic environmental factors in the Parks. We will (1) evaluate bias, precision, and efficiency for several sampling methods for amphibians, (2) conduct validation studies to determine the relationship between capture indices and adjusted population estimates using capture-recapture and other techniques, 3) evaluate temporal and spatial variation in amphibian populations in association with environmental features, and (4) implement park-wide monitoring programs that will provide baseline data on amphibian populations.

In order to design appropriate monitoring programs, it is necessary to first develop sampling frames for the species of interest, then validate and estimate variances associated with site-specific population estimates within the sampling frames. Several different sampling frames and estimation procedures will be needed to ensure that amphibian groups are adequately sampled. In the first year, emphasis will be placed on studies designed to validate population indices and estimate variation in the indices spatially and in relationship to environmental variables. In the second year, the information from the first year will be used to develop extensive surveys based on the tested indices (or visibility-adjusted population estimates) within sampling frames based on information on habitats and on spatial variation in environmental variables. In the third year, which will be continued through a series of university contracts, further development and testing of methodological and spatial components will occur.

Sampling frames must be developed for terrestrial salamanders, stream and streamside salamanders, and frogs and toads. For each group, habitats will be identified and preliminary strata will be developed using GIS information from the parks. Within these preliminary strata, a variety of validation studies will be conducted to assess appropriate sampling methods in the first year of the project. In the second year, the GIS-based sample frames will be used to select random samples within strata and sampling (and additional validation) conducted within the strata. Based on results from the second year, the sampling frames will be reassessed and additional sampling and validation will be conducted in the third year with the intent of better documenting associations between environmental features and amphibian populations.

Central to the development of monitoring methods is validation of population indices. In general, only a portion of animals in a given sampling area are generally encountered, and investigators must either use the count data as an index to abundance or use estimation procedures such as capture-recapture to estimate the

proportion of animals missed. Indices to abundance never provide estimates of absolute abundance unless the proportion of animals sampled (the detection rate) is estimated; differences in indices can not be used to estimate population change unless the detection rates are the same in the indices that are compared. Consequently, before indices are used in a monitoring program or any analysis of population change, it is necessary to estimate detection rates to determine their magnitudes and evaluate whether the rates change over time or space. If the indices are not consistent (i.e., the detection rates differ over time or space), estimation of detection rates must be an implicit component of the monitoring program.

With amphibians, further complications are introduced because a single sampling method cannot be used to monitor all the species. Instead, several methods must be used, each of which samples a group of species with common life history attributes. Each of these methods must be evaluated with regard to variation in detection rates for each group of species.

We will implement a variety of validation studies for preliminary indices to amphibian abundance. Additional studies in progress at the USGS Patuxent Wildlife Research Center and other sites will provide information that will also be used to estimate detection rates for indices used in the PRIMENet monitoring. The validation studies have three primary objectives: (1) estimation of detection rates for selected indices of amphibian abundance, (2) estimation of measurement error associated with indices, and (3) estimation of spatial and temporal variation in indices, and of relevant environmental features likely to be associated with variation in indices. Where possible, these validation studies will be placed in experimental contexts where these estimates of population size and variation can be used to test for relationships with natural and anthropogenic stressors.

In spring/summer 1999, additional tasks of sampling amphibians along contaminant gradients in Acadia NP will be coordinated with the K. Weathers investigation of deposition gradients.

7. Inferring regional patterns and responses in nitrogen and mercury biogeochemistry using two sets of gauged paired-watersheds

Principal Investigator:
Steve Kahl[1], Water Research Institute

Co-Investigators:
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Stephen Norton, University of Maine
Bruce Wiersma, University of Maine
George Jacobson, University of Maine
David Manski, Acadia National Park

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Co-Investigators:
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Lindsey Rustad, USDA-Forest Service
Charles Roman, USGS-BRD
Robert Lent, USGS-WRD

Park:
Acadia NP

Project Summary:

This project is part of long-term ecological research using two gauged-watersheds to be implemented at Acadia NP through collaborative funding by USGS and this proposal to EPA. The focus of this request is atmospheric deposition of nitrogen (N) and mercury (Hg), and their ecological consequences. Both elements are of major concern, both regionally and to the Park Service at Acadia. This location offers the advantages of a) co-funding for cost-effectiveness; b) a natural experimental design for the two watersheds because of a major forest fire in part of the Park in 1947; c) parallel design with the acidic deposition experiment on paired-watersheds at the nearby Bear Brook Watershed, Maine (BBWM); and d) prior research at Acadia and BBWM that supply background data, and provide the basis for ecosystem indicators to be applied at Acadia. Our objectives will address N cycling and saturation, and Hg input and bioavailability, in paired watersheds with different forest types. We will use the natural landscape contrasts provided by fire to compare patterns and processes in N and Hg sequestration and mobility. Nitrogen loading to estuaries will be addressed by periodic sampling of estuary tributaries as "satellite" locations, whose N loading will be extrapolated from occasional sampling by using the more intensively monitored main watersheds as index sites.

Our approach will involve using input/output measurements at the watershed scale to define the unknowns of Hg inputs to landscapes, determine locations and processes of Hg speciation, resolve the status of N retention, and estimate N loading to selected estuaries that have prior background data. We will determine the relative input of Hg and methyl-Hg from wet deposition, throughfall and litterfall. The expected results will provide new information for Acadia and for the New England region on the ecological consequences of high N deposition at Acadia, and the loading of N to estuaries in the region. We lack an explanation of the high accumulation rates of Hg in sediment and peat cores compared to wet-only deposition, and have not explained why Acadia has some of the highest Hg concentrations in biota in the world. The general representativeness of Acadia forests for the New England region, combined with the fire history to be included in our experimental design (fire also being "typical" of the historical New England landscape), offers the opportunity to understand some key issues for Acadia, while providing insight into these issues at the regional scale.

8. Risk assessment of the effects of natural and anthropogenic stressors on ecosystems in the Olympic National Park

Principal Investigator:
Bob McKane[1], NHEERL/WED

Co-Investigators:
David Tingey, NHEERL/WED
W. E. Hogsett, NHEERL/WED
Andrea Woodward, USGS-BRD
Ed Schreiner, USGS-BRD

Park:
Olympic NP

Project Summary:

Models play a prominent role in ecological risk assessments because they are the primary means for relating stressors to probable effects, and for making meaningful extrapolations across scales of time, space, and biological organization. Models are particularly important for risk assessments at the scale of ecosystems because it is exceedingly difficult to experimentally isolate the interactive effects of natural environmental driving forces (temperature, precipitation, cloudiness, etc.) and anthropogenic stressors (e.g., air pollutants, climate change, land use). Process-based models that simulate biogeochemical cycles or forest succession, for example, can help improve such assessments by providing a self-consistent synthesis of the results of many experiments. The synthesis provided by these models includes the interactions among ecosystem processes that give rise to the synergistic responses to multiple factors.

Under PRIMENet, we propose to use the Marine Biological Laboratory's General Ecosystem Model (MBL-GEM) to assess and predict how natural and anthropogenic stressors may affect the health and sustainability of ecosystems in the Olympic NP. The MBL-GEM is a process-based model of ecosystem carbon (C) and nitrogen (N) dynamics that simulates the effects of changes in atmospheric CO_2 concentration, temperature, precipitation, irradiance, and N deposition on plant and soil processes. Processes in the model include photosynthesis, respiration, tissue growth, N retranslocation, litterfall,

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decomposition, soil N dynamics, and soil-plant-atmosphere hydrology. The MBL-GEM is intended to be generally applicable to most terrestrial ecosystems and has been used in the past to analyze the biogeochemical responses of temperate deciduous forests, tropical evergreen forests, and arctic tundra to changes in atmospheric CO_2 concentration, N deposition, temperature, irradiance (cloudiness), and soil moisture. In addition, the EPA has recently parameterized MBL-GEM for forest ecosystems located along an elevational gradient in the South Santiam watershed in the western Cascades of Oregon, a first step toward the development of a regionally robust parameterization for Pacific Northwest forests.

Our primary objective is to develop a parameterization of MBL-GEM that can be used as a risk assessment tool for ecosystems in the Olympic NP and in the Pacific Northwest in general. Specifically, we will use MBL-GEM to:

- Assess and predict future responses of forest ecosystems to natural and anthropogenic stressors, including changes in temperature, precipitation, cloudiness (light), CO_2, ozone, and N deposition
- Link changes in condition to likely stressors
- Identify efficient and sensitive indicators (early warning measures) for loss of ecosystem integrity and sustainability

To accomplish these objectives we propose to carry out two primary activities under PRIMENet:

- Collect biogeochemical and meteorological data at four sites in the Olympic NP selected based on forest species, elevation, climate and fertility to evaluate the regional applicability of MBL-GEM
- Make improvements to MBL-GEM to better address risk assessment issues of interest to the EPA, e.g. tropospheric ozone exposure and N deposition

A major product of PRIMENet will be to produce a well-validated, single parameter set of MBL-GEM that can be applied with confidence to all major forest types, soils and climatic conditions within the Pacific Northwest, enabling credible, spatially explicit predictions of environmental stressor effects.

9. Collaborative research on below-ground ecosystem function: merging climate monitoring with soil, root, and foodweb dynamics to understand mechanisms regulating C and N transformations in Olympic National Park

Principal Investigators:
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Co-Investigators:
Paul Rygiewicz, US EPA, NHEERL/WED

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Co-Investigators:
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Sarah Green, Michigan Technological University
Jiquan Chen, Michigan Technological University
Andrew Burton, Michigan Technological University
Erik Hobbie, US EPA-NRCA

Park:
Olympic NP

Project Summary:

The overall objective of this program of research and intensive monitoring is to provide a mechanistic understanding of soil foodweb dynamics related to changes in below ground indicators of ecosystem integrity, specifically the production of dissolved organic carbon (DOC) and dissolved organic nitrogen (DON). We believe changes in the quantity and quality of root and mycorrhizal C can be used to predict changes in soil biota - the gatekeepers of nitrogen (N) availability. Soil biota, intimately linked to plant roots, regulate C and N transformations and provide a critical linkage at the landscape level to aquatic environments through their role in the production of DOC and DON. We will link variation in below ground processes to spatial and temporal environmental gradients that control the export of DOC and DON from terrestrial environments to streams and lakes.

A nested, hierarchical sampling strategy will be used to assess the effects of climatic variation and N addition on DOC and DON production and transport in Olympic NP. This will consist of 1.) measurements of vegetation, temperature, soil moisture, and soil solution DOC and DON at a network of sites covering dominant vegetation types along elevation and precipitation gradients, and 2.) intensively studied soil processes within major vegetation types on a subset of plots located along the broad moisture and temperature gradients. Plot level studies will be used to quantify how temporal soil climatic variation and N addition alter soil C inputs, food web C transformations, and the production of various DOC and DON precursors and fractions. Existing and newly established weather monitoring stations will be used in conjunction with vegetation, elevation, aspect, and soil temperature and moisture information to predict DOC and DON export at the landscape scale.

This study addresses all three PRIMENet objectives. The research emphasizes spatial and temporal variation in ecological response to stress, especially from atmospheric N deposition and climate change. The research is proposed for a national park with an existing long-term monitoring and research program. This will help place the study in a broader ecosystem context. Soil biota are intimately linked to plant roots and they regulate C and N transformations. Through the production of DOC/DON, soil biota provide a critical connection with aquatic environments at the landscape level.

10. Relating amphibian population survey data to UV gradients in three PRIMENet parks: Glacier, Sequoia/Kings Canyon, and Olympic National Parks

Principal Investigator:
Peter Trenham[1], EPA-MED

Co-Investigators:
Dan Fagre, USGS-Glacier NP
Harold Werner, Sequoia/Kings Canyon NP
Patte Happe, Olympic NP
Mike Adams, USGS-Olympic NP
Steve Corn, USGS-Glacier NP
Dave Bradford, EPA-Las Vegas
Roland Knapp, UCSB

Parks:
Glacier, Olympic, and Sequoia/Kings Canyon NPs

Project Summary:

Amphibian population declines are occurring in some protected areas, such as the parks of the Sierra Nevada, California. Causes of these declines are not known, but one of the hypotheses implicates UV radiation as a stressor. Currently we are monitoring UV radiation at fourteen PRIMENet parks in an effort to detect trends in this stress through time. We want to make use of this baseline data to extrapolate UV exposure in amphibian habitat along an elevation gradient in three western parks. This will be done in concert with amphibian population surveys over a two-year period. The methods developed during this project can then be used in other parks and protected areas in an effort to link dose/response to explain amphibian population declines, especially if the Department of the Interior amphibian initiative is funded in FY 2000.

This is an interagency research project with investigators from the EPA, NPS, USGS-BRD, and universities. This project is designed to perform amphibian metapopulation analysis on selected pond-breeding amphibian species in three parks along an elevational gradient. Selected pond clusters (patches) will be surveyed in summer 1999-2000 for presence/absence of the target species. At these sites UV will be characterized by measuring UV extinction, concentrations of dissolved organic carbon (DOC), and by habitat mapping.

[1] EPA-MED, 6201 Congdon Blvd., Duluth, MN 55804, Phone: (218) 529-5201, e-mail: trenham.peter@epamail.epa.gov

11. Atmospheric deposition in mountainous terrain: scaling up to the landscape

Principal Investigators:
Kathleen C. Weathers[1], Institute of Ecosystem Studies

Co-Investigators:
Gary M. Lovett, Institute of Ecosystem Studies
Steven E. Lindberg, University of Tennessee

Parks:
Acadia and Great Smoky Mountains NPs

Project Summary:

This project will develop a new modeling approach for scaling point measurements of atmospheric deposition to whole landscapes. Such a model is necessary to understand the complex character of nutrient and pollutant inputs, which occur over the scales of interest in the national parks. Our fundamental hypothesis is that deposition of a variety of airborne constituents shows a predictable response to major landscape features, which can be quantified in the field. These response functions can then be used to predict deposition patterns and relative rates of input of the chemicals of interest. We will quantify these response functions across the landscapes of two national parks, chosen for their potential air pollutant impacts and terrain features that severely restrict where routine flux monitoring can be done.

The parks to be addressed are Acadia NP in Maine and Great Smoky Mountains NP in Tennessee and North Carolina. Two primary methods will be employed to characterize the deposition/terrain response fields: sulfate fluxes in throughfall and lead in surface soils. These approaches have been shown to be excellent tracers of the primary deposition processes, and each addresses a time scale critical to the modeling approach (from seasons to decades). Once quantified, the response functions, which indicate the enhancement of deposition in areas of interest relative to routine monitoring locations, will be used with a GIS-based approach to scale up from the monitoring location to the entire landscape based on the spatial distribution of the primary controlling landscape features. The models will be tested against field data and existing databases. The modeling approach will be generic, allowing for application to other parks, and to a variety of airborne materials.

This project represents a crucial step in atmospheric deposition research: the empirical modeling approach proposed

[1] Institute of Ecosystem Studies, P.O. Box AB, Millbrook, NY 12545, Phone: (914) 677-5343, e-mail: weathersk@ecostudies.org

here offers the best means available to scale up atmospheric deposition measurements in complex terrain. In addition, this research is also extremely important for the management of ecosystems exposed to atmospheric deposition. It will allow managers to address the utility of the current atmospheric exposure monitoring for estimating atmospheric deposition to sensitive ecosystems at 'far-flung' corners of the park. Furthermore, in the face of limited budgets, it will allow Park Superintendents to identify which portions of the parks are at greatest risk of air pollution induced damage--which areas are "hotspots" of deposition--and therefore might require the most intense research or remediation effort. Finally, to the extent that this project will quantify deposition loads to park landscapes, it will allow managers to evaluate the potential effect of a proposed upwind pollution source. The GIS-based deposition models developed in this research will be a valuable tool specifically designed to help park scientists address these questions.

IV. Future Plans and Opportunities in PRIMENet

There is a commitment from the NPS and EPA to continue long-term monitoring of atmospheric stressors and UV at the fourteen PRIMENet parks. However, there is no continued funding provided for research on ecosystem response to anthropogenic stress. Opportunities for additional research at these index site parks include:

1) NPS programs: The NPS Inventory and Monitoring Program has requested increased funding in FY 2000. Additional funds will allow for the more timely completion of biotic inventories, soil and water surveys, and vegetation inventories at the PRIMENet parks. Acadia and Olympic NPs will be funded in FY 99 to complete their amphibian surveys as part of this program. Some leveraged funding at PRIMENet sites has been realized through the NPS and USGS Natural Resource Protection Program. PRIMENet parks are encouraged to submit proposals to this funding source to augment research related to anthropogenic stressors.

The NPS is planning a FY 2001 Natural Resource Initiative, which requests a base budget increase of $20 million per year for inventory and monitoring projects in park units. PRIMENet parks are among those that will benefit from this increased funding.

2) USGS programs: PRIMENet parks are already being used by USGS researchers as sites for long-term watershed and global change research (see Appendix E for leveraged projects). USGS has requested an addition of $5.6 million under the FY 2000 DOI amphibian budget initiative. This funding would allow us to extend the current amphibian research program to more of the PRIMENet parks. In FY 99 the USGS-WRD received $2.5 million funding for water-related projects in parks. A number of PRIMENet parks proposed projects that were funded. Additional years of funding under the NPS/USGS water resources partnership program are being considered.

3) EPA programs: The EPA-National Center for Environmental Research and Quality Assurance (NCERQA) administers a grants program to support research on environmental stress/response. The plan is for NCERQA to issue an RFP in FY 2000 to solicit research methods for regional scaling of environmental measurements at index sites. PRIMENet sites should be included in this RFP solicitation. Announcements of NCERQA opportunities can be found at http://www.epa.gov/ncerqa.

The Environmental Monitoring and Assessment Program (EPA-EMAP) convened a symposium in April 1999 to discuss monitoring and research methods, and information gaps relating to ecological systems in the western United States. The EMAP-Western Pilot project will be modeled after the Mid-Atlantic Integrated Assessment and may provide opportunities for research and monitoring in selected PRIMENet parks.

Appendices

Appendix A. PRIMENet Park Representatives

Park Code	Contact	Phone Number	Address
ACAD	David Manski	(207) 288-5463	Acadia National Park PO Box 177 Bar Harbor, ME 04609
BIBE	Vidal Davila	(915) 477-2251 x-143	Big Bend National Park PO Box 129 Big Bend NP, TX 79834
CANY	Charlie Schelz	(435) 259-3911 x-2135	Canyonlands National Park 2282 S. West Resource Blvd. Moab, UT 84532
DENA	Gordon Olson	(907) 683-9531	Denali National Park & Preserve PO Box 9 McKinley Park, AK 99755
EVER	Dewitt Smith	(305) 242-7818	Everglades National Park 40001 State Road 9336 Homestead, FL 33034-6733
GLAC	Bill Michels	(406) 888-7917	Glacier National Park West Glacier, MT 59936
GRSM	Jim Renfro	(423) 436-1708	Great Smoky Mountains NP 1314 Cherokee Orchard Rd. Gatlinburg, TN 37738
HAVO	Tim Tunison	(808) 985-6085	Hawaii Volcanoes National Park PO Box 52 Volcanoes, HI 96718
OLYM	Cat Hoffman	(360) 452-0314	Olympic National Park 600 East Park Ave. Port Angeles, WA 98362
ROMO	Ken Czarnowski	(970) 586-1263	Rocky Mountain National Park Estes Park, CO 80517-8397
SEKI	Harold Werner	(559) 565-3123	Sequoia/Kings Canyon NP Three Rivers, CA 93271-9651
SHEN	Christi Gordon	(540) 999-3499	Shenandoah National Park 3655 U.S. Hwy. 211 East Luray, VA 22835
THRO	Russ Runge	(701) 623-4466 x-3407	Theodore Roosevelt NP PO Box 7 Medora, ND 58645
VIIS	TBD		Virgin Islands National Park 6310 Estate Nazareth St. Thomas, VI 00802

Appendix B. UV Instrument Operators and Agency Contacts

Park Code	Contact	E-mail	Telephone
ACAD	Bill Gawley	Bill_Gawley@nps.gov	207 288 5463
	Bob Breen	Bob_Breen@nps.gov	207 288 5463
BIBE	John Forsythe	John_H_Forsythe@nps.gov	915 477 2251 x149
CANY	Colin Smith	Colin_Smith@nps.gov	801 259 4712 x11
DENA	Pam Sousanes	Pam_Sousanes@nps.gov	907 683 9573
EVER	Erik Knight	Erik_Knight@nps.gov	305 242 7881
GLAC	Lisa McKeon	Lisa_McKeon@usgs.gov	406 888 7987
	Dan Fagre	Dan_Fagre@usgs.gov	406 888 7993
GRSM	Scott Berenyi	Scott_Berenyi@nps.gov	423 436 1708
	Jim Renfro	Jim_Renfro@nps.gov	
OLYM	Roger Hoffman	Roger_Hoffman@nps.gov	360 452 4501 x247
ROMO	Mark Losleben	Markl@culter.colorado.edu	303 492 8842
	Tim Bardsley	Timbard@culter.colorado.edu	
SEKI	Donna Meisky	Donna_meisky@nps.gov	209 565 3127
	Harold Werner	Harold_w_werner@nps.gov	209 565 3123
SHEN	Rick Frederick	Frederrd@jmu.edu	540 298 0181
	Shane Spitzer	Shane_Spitzer@nps.gov	540 999 3434
VIIS	Sandy West		340 770 4968
THRO	Steve Hager	Steve_Hager@nps.gov	701 623 4466 x3433
HAVO	Tamar Elias	Telias@tako.wr.usgs.gov	808 967-8826

NPS	John Ray	JDR@aqd.nps.gov	303 9692820
EPA	Jack Shreffler	Shreffler.jack@epamail.epa.gov	919 541 2194
ARS	John Faust	Jfaust@air-resource.com	800 324 5423
SciTec	Albert Maione	Albert.maione@sci-tec.com	306 934 0101
UGA	John Rives	Jrives@hal.physast.uga.edu	706 542 5755
UGA	Tom Taylor	tetaylor@hal.physast.uga.edu	706 542 5755

Appendix C. PRIMENet Oversight Committee

Affiliation	Member	Phone Number/ E-mail	Address
NPS	Kathy Tonnessen	(303) 969-2738 kathy_tonnessen@nps.gov	NPS Air Resources Division P.O. Box 25287 Denver, CO 80225
NPS	John Karish	(814) 865-7974 john_karish@nps.gov	NPS Alleghany & Chesapeake SO 209-B Ferguson Building Penn State University University Park, PA 16802
NPS	Cat Hoffman	(360) 452-0314 cat_hoffman@nps.gov	Olympic National Park 600 East Park Ave. Port Angeles, WA 98362
NPS	Gary Williams	(970) 225-3539 gary_williams@nps.gov	NPS Natural Resources Information Division 1201 Oakridge Drive, Suite 350 Fort Collins, CO 80525
EPA	Barbara Walton	(919) 541-7776 walton.barbarat@epamail.epa.gov	US-EPA NHEERL MD-87 Research Triangle Park, NC 27711
EPA	Jack Shreffler	(919) 541-2194 shreffler.jack@epamail.epa.gov	US-EPA Research Triangle Park, NC 27711
EPA	Naomi Detenbeck	(218) 529-5204 detenbeck.naomi@epamail.epa.gov	US-EPA Mid-Continent Ecology Division 6201 Congdon Blvd. Duluth, MN 55804
EPA	Ed Heithmar	(702) 798-2626 heithmar.ed@epamail.epa.gov	US-EPA Office of Research and Development National Exposure Research Laboratory 944 E. Harmon Las Vegas, NV 89119
EPA	Bill Hogsett	(541) 754-4632 hogsett.william@epamail.epa.gov	US-EPA NHEERL/WED 200 SW 35th St. Corvallis, OR 97333

Appendix D. Monitoring site information

Table A. IMPROVE Particle Monitor Site Information. Data available at ftp://alta_vista.cira.colostate.edu.

Site	Site ID	Latitude (N)	Longitude (W)	Elevation (m)	Dates of Operation
Acadia	ACAD	44.37	68.26	122	03/88-present
Big Bend	BIBE	29.31	103.18	1067	03/88-present
Canyonlands	CANY	38.45	109.82	1799	03/88-present
Denali	DENA	63.45	149.3	640	03/88-present
Everglades	EVER	25.39	80.68	2	03/88-present
Glacier	GLAC	48.51	113.10	1372	03/88-present
Great Smoky Mtns.	GRSM	35.75	83.5	762	03/88-present
Hawaii Volcanoes	HAVO	19.26	155.16	1250	03/88-04/93
Olympic	OLYM	N/A	N/A	N/A	to be installed 01/00
Rocky Mountain	ROMO	40.28	105.55	2409	03/88-present
Sequoia/Kings Canyon	SEKI	36.52	118.18	549	03/92-present
Shenandoah	SHEN	38.48	78.12	1098	03/88-present
Theodore Roosevelt	THRO	N/A	N/A	N/A	to be installed 01/00
Virgin Islands	VIIS	18.34	64.47	46	10/90-present

*Virgin Islands NP was not included in Figure 2 because it only had Module A until 1997.

Table B. Ozone Monitor, CASTNet Filter Pack, and Meteorological Station Site Information. Data available at http://www2.nature.nps.gov/ard/gas.

Site	Site ID	Latitude (N)	Longitude (W)	Elevation (m)	Ozone	Filter Pack	Met. Station
Acadia	ACAD	44.37	68.26	122	10/82-present	11/98-present	06/91-present
Big Bend	BIBE	29.31	103.18	1052	09/90-present	01/95-present	09/90-present
Canyonlands	CANY	38.45	109.82	1814	07/92-present	01/95-present	07/92-present
Denali	DENA	63.73	148.96	661	07/87-present	07/98-present	07/87-present
Everglades	EVER	25.39	80.68	2	05/86-present	11/98-present	01/89-present
Glacier	GLAC	48.51	113.10	967	01/89-present	01/95-present	01/95-present
Great Smoky Mtns.	GRSM	35.63	83.94	793	07/88-present	10/98-present	07/88-present
Hawaii Volcanoes	HAVO	19.43	155.26	1215	to be installed 07/99	to be installed 07/99	11/86 - present
Olympic	OLYM	48.10	123.43	125	08/85-present	11/98-present	05/91-present
Rocky Mountain	ROMO	40.28	105.55	2743	07/87-present	01/95-present	12/94-present
Sequoia/Kings Canyon	SEKI	36.57	118.78	1902	06/84-present	01/97-present	09/88-present
Shenandoah	SHEN	38.52	78.44	1073	05/83-present	06/88-present	01/88-present
Theodore Roosevelt	THRO	49.60	108.27	700	11/82-present	10/98-present	09/98-present
Virgin Islands	VIIS	18.34	64.80	80	04/98-present	05/98-present	05/98-present

*Virgin Islands NP was not presented in Figure 3 because it was not in operation in 1997.
*Only sites with continuous data for 1997, Big Bend, Canyonlands, Glacier, Rocky Mountain, Sequoia/Kings Canyon, and Shenandoah NPs were included in Figures 5 and 6.
*Theodore Roosevelt and Virgin Islands NPs were not included in Table 1 because they were not in operation in 1997.

Table C. NADP/NTN Site Information. Data available at http://nadp.sws.uiuc.edu.

Site	Site ID	Latitude (N)	Longitude (W)	Elevation (m)	Dates of Operation
Acadia	ME98	44.37	68.26	129	11/81-present
Big Bend	TX04	29.31	103.18	1056	04/90-present
Canyonlands	UT09	38.45	109.82	1813	11/97-present
Denali	AK03	63.73	148.96	649	06/80-present
Everglades	FL11	25.39	80.68	2	06/80-present
Glacier	MT05	48.51	113.10	968	06/80-present
Great Smoky Mtns.	TN11	35.66	83.59	640	08/80-present
Hawaii Volcanoes	HI99	N/A	N/A	N/A	to be installed 07/99
Olympic	WA14	47.86	123.93	176	05/80-present
Rocky Mountain-Beaver Meadows	CO19	40.36	105.58	2490	05/80-present
Rocky Mountain-Loch Vale	CO98	40.29	105.66	3159	08/83-present
Sequoia/Kings Canyon	CA75	36.57	118.78	1902	07/80-present
Shenandoah	VA28	38.52	78.44	1074	05/81-present
Theodore Roosevelt	ND07	47.60	103.26	611	05/81-present
Virgin Islands	VI01	18.34	64.80	75	04/98-present

*Canyonlands and Virgin Islands NPs were not presented in Figure 4 due to insufficient years of data.

Table D. UV Monitor Site Information. Data available at http://www.epa.gov/uvnet.

Site	Brewer ID	Latitude (N)	Longitude (W)	Elevation (m)	Dates of Operation
Acadia	138	44.37	68.26	122	03/98-present
Big Bend	130	29.31	103.18	1052	02/97-present
Canyonlands	133	38.45	109.82	1814	09/97-present
Denali	141	63.73	148.96	640	10/97-present
Everglades	135	25.39	80.68	2	03/97-present
Glacier	134	48.51	113.10	968	09/97-present
Great Smoky Mtns.	132	35.60	83.78	564	01/97-present
Hawaii Volcanoes	140	19.42	155.29	1243	02/99-present
Olympic	147	48.10	123.43	2	12/97-present
Rocky Mountain	146	40.03	105.53	2891	04/98-present
Sequoia/Kings Canyon	139	36.49	118.83	610	08/98-present
Shenandoah	137	38.52	78.44	1073	03/97-present
Theodore Roosevelt	131	46.90	103.38	870	09/98-present
Virgin Islands	144	18.34	64.80	250	05/98-present

*Only Big Bend, Everglades, Great Smoky Mountains, and Shenandoah NPs were presented in Figures 7 and 8 because they were in operation for most of 1997.

Appendix E. Inventory of Research Projects Related to PRIMENet by Park

Table of Contents

Acadia National Park

Title: Water quality, nutrient loading and eutrophication monitoring of the Northeast Creek Estuarine Wetland at Acadia National Park
PI: Charles Roman
Contact Information: USGS-BRD, University of Rhode Island, Narragansett, RI, (401) 874-6886, e-mail: charles_roman@usgs.gov
Funding: USGS-BRD
Duration: 1998-1999

Title: Forested watershed N cycling and estuarine N loading at Acadia National Park
PI: Robert Lent
Contact Information: USGS, Maine District, Augusta, ME, (207) 622-8202, e-mail: rmlent@usgs.gov
Funding: USGS/NPS Partnership
Duration: 1998-1999

Title: Amphibian populations of Acadia National Park: patterns and processes in relation to anthropogenic and natural changes in wetland ecosystems
PI: Malcolm Hunter, et al.
Contact Information: University of Maine, Orono, ME, (207) 581-2865, e-mail: hunter@maine.maine.edu
Funding: USGS-BRD
Duration: 1997-2001

Acadia National Park

Title: Northeast region amphibian and reptile inventory
PI: Robert Cook, et al.
Contact Information: Cape Cod National Seashore, Waltham, MA (508) 487-3262, e-mail: bob_cook@nps.gov
Funding: NPS I&M Program
Duration: 1999-2001

Title: Mercury wet deposition monitoring, Mercury Deposition Network, National Atmospheric Deposition Program
PI: Bob Breen and Bill Gawley
Contact Information: Acadia National Park, Bar Harbor, ME, (207) 288-5463, e-mail: bob_breen@nps.gov
Funding: NPS/ACAD, Maine Department of Environmental Protection
Duration: Ongoing since 1995

Title: Mercury in Tree Swallow and feathers of other species that line Tree Swallow nests at Acadia National Park Wetlands
PI: Jerry Longcore
Contact Information: USGS at University of Maine, Orono, ME, (207) 581-2874, e-mail: jerry_longcore@usgs.gov
Funding: USGS-BRD
Duration: Ongoing since 1998

Title: Mercury deposition in New England.
PI: Lee Alter
Contact Information: NESCAUM, Boston, MA, (617) 367-8540, e-mail: lalter@nescaum.org
Funding: USEPA/NESCAUM
Duration: 1997-1999

Title: Application of the Biomonitoring of Environmental Status and Trends Contaminant Assessment Program to Acadia National Park, Maine
PI: Terry Haines
Contact Information: USGS at University of Maine, Orono, ME, (207) 581-2578, e-mail: haines@maine.edu
Funding: USGS-BRD
Duration: 1998-1999

Title: Photochemical Assessment Monitoring Site (PAMS), Acadia National Park
PI: Paul Nichols
Contact Information: Maine Department of Environmental Protection, Bangor, ME (207) 941-4570, e-mail: Paul.R.Nichols@state.me.us
Funding: Maine DEP/USEPA
Duration: Ongoing since 1996

Acadia National Park

Title: PM 2.5 Monitoring Network, Maine Department of Environmental Protection.
PI: Don Darling
Contact Information: Maine Department of Environmental Protection, Bangor, ME, (207) 941-4570, e-mail: Don.Darling@state.me.us
Funding: Maine DEP/USEPA
Duration: Ongoing since 1999

Title: Re-sampling lichens for elemental analysis at Acadia National Park.
PI: Jim Bennett
Contact Information: USGS-BRD, Madison WI, (608) 270-2442, e-mail: jim_bennett@usgs.gov
Funding: USGS-BRD
Duration: 1998

Title: Acadia National Park Lake Monitoring Program
PI: Bob Breen, and Bill Gawley
Contact Information: Acadia National Park, Bar Harbor, ME, (207) 288-5463, e-mail: bob_breen@nps.gov
Funding: NPS/ACAD
Duration: Ongoing since 1997

Title: Benthic macroinvertebrate monitoring, Acadia National Park
PI: Bob Breen, Bill Gawley
Contact Information: Acadia National Park, Bar Harbor, ME, (207) 288-5463, e-mail: bob_breen@nps.gov
Funding: NPS/ACAD, Maine Department of Environmental Protection
Duration: Ongoing since 1997

Title: Ant and bee abundance and distribution along an atmospheric deposition gradient
PI: Howard Ginsberg
Contact Information: USGS-BRD, University of Rhode Island, Kingston, RI, (401) 874-4537
Funding: USGS-BRD
Duration: 1999-2000

Big Bend National Park

Title: Pine Canyon Watershed Program: Understanding the effects of climate change on the structure and functioning of arid ecosystems at Big Bend National Park
PI: John Zak
Contact Information: Program in Ecology & Conservation Biology, Department of Biological Sciences, Texas Tech University, Lubbock, TX, e-mail: YZJOZ@TTACS.TTU.EDU
Funding: USGS
Duration: Ongoing since 1995

Title: The USDA UV-B Radiation Monitoring Program
Program Director: Dr James H. Gibson, (970) 491-3611
PI: James R. Slusser
Contact Information: Colorado State University, Natural Resources Ecology Laboratory, Fort Collins, CO 80523, (970) 491-3623, web page: http://nadp.nrel.colostate.edu/UVB/home_page.html
Funding: USDA

Title: Endocrine disruption and pesticide exposure in the Rio Grande Leopard Frog
Principal Investigator: Thomas E. Lacher, Jr.
Contact Information: Department of Wildlife Science, 210 Nagle Hall, Texas A&M, University, College Station, TX 77843-2258, (409) 862-7667, e-mail: tlacher@tamu.edu
Funding: USGS-BRD
Duration: January 1999 through December 2000

Denali National Park

Title: Long-term study of boreal watershed/lake ecosystems; Michigan, Colorado, and Alaska
PI: Robert Stottlemyer,
Contact Information: USGS, MESC, Forest and Range Experiment Station, 240 W. Prospect, Fort Collins, CO 80526, (970) 498-1017, e-mail: crhoades@lamar.colostate.edu
Funding: USGS
Duration: Ongoing since early 1980's

Title: Are anthropogenic changes in the atmosphere altering the rate of atmospheric oxidation?
PI: William R. Simpson
Contact Information: Geophysical Institute, University of Alaska Fairbanks, 903 Koyukuk Dr., P.O. Box 757320, Fairbanks, AK 99755-7320, (907) 474-7235
Funding Source: University of Alaska Fairbanks
Duration: 1999

Denali National Park

Title: A watershed ecosystem approach to monitoring environmental change in interior Alaska, Denali National Park and Preserve
PI: Gordon Olson
Contact Information: NPS, Denali National Park and Preserve, Denali Park, AK, e-mail: gordon_olson@nps.gov
Funding: NPS I&M Program, USGS-BRD
Duration: Long-term and ongoing

Everglades National Park

Title: The USDA UV-B Radiation Monitoring Program
Program Director: *Dr James H. Gibson, (970) 491-3611*
PI: James R. Slusser
Contact Information: Colorado State University, Natural Resources Ecology Laboratory, Fort Collins, CO 80523, (970) 491-3623, web page: http://nadp.nrel.colostate.edu/UVB/home_page.html
Funding: USDA
Duration: Ongoing - agreement is for 5 years

Title: National Dioxin Monitoring Network (NDAM)
Contact Information: David Cleverly, USEPA, 808 17th Street, Washington, DC 20074, (202) 564-3238, e-mail: cleverly.david@epa.gov
Funding: EPA
Duration: 5 years for project - uncertain how long at EVER

Glacier National Park

Title: Climate change and thresholds of ecosystem change: invasibility of tundra in the northern Rocky Mountains
PI: Dan Fagre, George Malanson, David Butler, Steve Walsh and others
Contact Information: Dan Fagre, USGS Science Center, Glacier National Park, West Glacier, MT 59936, (406) 888-7993, e-mail: dan_fagre@usgs.gov
Funding: USGS-BRD Global Change Research Program
Duration: 5 years (1999-2004)

Title: Climatic variability, ecosystem dynamics, and disturbance in mountain protected areas: assessing the vulnerability of natural resources
PI: David Peterson and Dan Fagre
Contact Information: (for Glacier) Dan Fagre USGS Science Center, Glacier National Park, West Glacier, MT 59936, (406) 888-7993, e-mail: dan_fagre@usgs.gov
Funding: USGS-BRD Global Change Research Program
Duration: 5 years (1999-2004)

Glacier National Park

Title: Effects of climate change on hydrologic systems and associated aquatic biotas
PI: F. Richard Hauer and Dan Fagre
Contact Information: Dan Fagre, USGS Science Center, Glacier National Park, West Glacier, MT 59936, (406) 888-7993, e-mail: dan_fagre@usgs.gov
Funding: USGS-BRD Global Change Research Program **Duration:** 5 years (1999-2004)

Title: UV effects on amphibians and UV extrapolation at Rocky Mountain and Glacier National Parks
PI: Ed Little
Contact Information: USGS-BRD, Columbia Environmental Research Center, 4200 New Haven Road, Columbia, MO 65201
Funding: USGS-BRD Global Change Research Program
Duration: 5 years (1999-2004)

Title: Synoptic snow survey of the Rocky Mountains
PI: George Ingersoll
Contact Information: USGS-WRD, Box 25046, Federal Center, Lakewood, CO 80225, (303) 236-4882, e-mail: gpingers@usgs.gov
Funding: USGS-WRD, NPS-ARD
Duration: Ongoing

Title: Elevational gradients in snow chemistry: east and west of the Continental Divide in Glacier National Park, Montana
PI: Kristi Heuer
Contact Information: NPS-ARD, P.O. Box 25287, Denver, CO 80225, (303) 987-6941, e-mail: kristi_heuer@nps.gov
Funding: NPS-ARD
Duration: 1999

Great Smoky Mountains National Park

Title: Inventory and monitoring the amphibians of GSMNP
PI: Ken Dodd
Contact Information: USGS-BRD Florida Caribbean Science Center, 7920 NW 71st St, FL 32653, (352) 378-8181, e-mail: ken@dodd@usgs.gov
Duration: 1998-2001

Title: Assessing diversity, abundance and habitat associations of salamanders in GSMNP
PI: Ted Simons & Erin Johnson
Contact Information: North Carolina State University, Box 7617, Raleigh NC 27695, (919) 515-2689, e-mail: tsimons@ncsu.edu, ejohnso2@unity.ncsu.edu
Duration: 1998-2000

Great Smoky Mountains National Park

Title: Evaluation of salamander population monitoring techniques in GSMNP
PI: Ted Simons, Larissa Bailey, & Ken Pollack
Contact Information: North Carolina State University, Box 7617, Raleigh NC 27695, (919) 515-2689, e-mail: tsimons@ncsu.edu, lbailey@unity.ncsu.edu, pollock@stat.ncsu.edu
Duration: 1999-2002

Title: Long-term monitoring of amphibians, GSMNP
PI: James Petranka & Chuck Smith
Contact Information: Petranka; Department of Biology, University of NC-Asheville, Asheville, NC 28804, (828) 232-5153, e-mail: petranka@unca.edu, Chuck Smith; Highpoint University, (910) 841-9256, e-mail: csmith@highpoint.edu
Duration: Ongoing since 1993

Title: Impact of riverine water quality on salamander diversity and abundance along an upland stream site, GSMNP
PI: Erik Lindquist & Paul DeLaLuz
Contact Information: Department of Natural Sciences, 1120 North Ocoee St, Cleveland, TN 37320-3450, (423) 614-8282, e-mail: amphibia@leeuniversity.edu, delaluz@leeuniversity.edu
Duration: 1999

Title: Unique aspects of the life history of the salamander *Gyrinophilus porphyriticus* in GSMNP
PI: Richard Bruce
Contact Information: Biological Station Highlands, Highlands NC 28741, (828) 526-2602, e-mail: bruce@wpoff.wcu.edu
Duration: 1998

Title: The relative abundance and distribution of *Eurycea junaluska* in GSMNP
PI: Bill Gutzke & Liz Raulerson
Contact Information: University of Memphis, Campus Box 526080, Memphis, TN 38152, (901) 678-2596, e-mail: wgutzke@latte.memphis.edu
Duration: 1998-1999

Title: Populations of salamanders within old and second growth mesic cove forests with special regard to coarse woody debris
PI: Jason Lydic & Cynthia E. Rebar
Contact Information: Edinboro University of PN, Erie, PA 16509, e-mail: serena@velocity.net
Duration: 1998 only

Title: Long-term monitoring of a population of *Plethodon jordani* by undergraduate classes
PI: Haven Wiley
Contact Information: Department of Biology, University of NC, Chapel Hill, NC 27599-3280, (919) 962-1340, e-mail: haven_wiley@unc.edu
Duration: Ongoing since 1972

Great Smoky Mountains National Park

Title: Biogeochemical research at the Noland Divide Watershed, Great Smoky Mountains National Park, Tennessee, North Carolina
PI: Helga Van Miegroet
Contact Information: Department of Forest Resources, Utah State University, Logan, UT, e-mail: helgavm@cc.usu.edu
Funding: USGS
Duration: Ongoing since the mid 1980's

Title: Regional Ozone Vegetation Effects (ROVE)
PI: Niki Nicholas et al.
Contact Information: Tennessee Valley Authority, 17 Ridgeway Road, Norris, TN 37828, (423) 632-1676
Funding: Tennessee Valley Authority, EPRI
Duration: 1991-2001

Title: Biogeochemical cycling in Noland Divide Watershed
PI: Niki Nicholas et al.
Contact Information: Tennessee Valley Authority, 17 Ridgeway Road, Norris, TN 37828, (423) 632-1676
Funding: Tennessee Valley Authority, USDA National Research Institute, USGS
Duration: 1996-2003

Title: Development of a regional site for special purpose measurement of fine particulate mass and composition and enhanced gaseous pollutants
PI: Roger Tanner et al.
Contact Information: Tennessee Valley Authority, Atmospheric Sciences & Environmental Assessment Department, Environmental Research & Services, Muscle Shoals, AL 35660, (256) 386-2958
Funding: Tennessee Valley Authority, NPS, Department of Energy, EPRI
Duration: 1998-2001

Title: Long-term watershed monitoring of Noland Divide and other key watersheds in Great Smoky Mountains National Park
PI: Jim Smoot, University of Tennessee
Contact Information: Steve Moore, NPS, 107 Park Headquarters Rd, Gatlinburg, TN 37737, (423) 436-1250, e-mail: steve_moore@nps.gov
Funding: NPS I&M Program
Duration: 1991-Present (Long-term)

Title: Inventory and Monitoring Prototype Park
Principal Investigator: Keith Langdon
Contact Information: Great Smoky Mountains National Park, Gatlinburg, TN, (423) 436-1200, e-mail: keith_langdon@nps.gov
Funding: NPS I&M Program, USGS-BRD
Duration: Long-term and ongoing

Olympic National Park

Title: Ecosystem and watershed studies in an old growth forested watershed, Olympic National Park, Washington
PI: Robert Edmonds
Contact Information: University of Washington, College of Forest Resources, Box 352100, Seattle, WA 98195, (206) 685-0953, e-mail: bobe@u.washington.edu
Funding: USGS-BRD Small Watershed Program
Duration: Long-term and ongoing

Title: Climate and disturbance in mountainous National Parks: Glacier and Olympic
PI: David Peterson
Contact Information: FRESC, University of Washington Field Station, Box 352100, Seattle, WA 98195, (206) 543-1587, e-mail: wild@u.washington.edu
Funding: USGS-BRD Global Change Research Program
Duration: 5 years (1999-2004)

Title: Amphibians in North Cascades and Olympic National Parks
PI: R. Bruce Bury
Contact Information: Forest and Rangeland Ecosystem Science Center, USGS-BRD, 3080 SE Clearwater Drive, Corvallis, OR 97333, (541) 754-4382, e-mail: buryb@epamail.cor.epa.gov
Funding: NPS NRPP, now USGS-BRD
Duration: Ongoing since 1991

Title: National water quality assessment
PI: Robert Black
Contact Information: USGS, 1201 Pacific Avenue, Suite 600, Tacoma, WA 98402-4301, (253) 593-6530, x 239, e-mail: rwblack@usgs.gov
Funding: USGS
Duration: Ongoing since 1995

Title: Biochemical interactions between riparian forest and rivers
PI: Scott Bechtold
Contact Information: College of Forest Resources, University of Washington, Box 352100, Seattle, WA 98195, (206) 543-3507
Funding: Mellon Foundation
Duration: Ongoing since 1998

Title: Monitoring air quality using lichens
PI: Linda Geiser
Contact Information: USDA-FS, Siuslaw National Forest, PO Box 1148, Corvallis, OR 97339, (541) 750-7058, e-mail: geiserll@proaxis.com
Funding: USFS
Duration: 1998

Olympic National Park

Title: Stable isotope systematics of soil water and soil carbon dioxide in the Olympic National Park
PI: Carey Gazis
Contact Information: Geology Department, Central Washington University, Ellensburg, WA 98926
Funding: NSF
Duration: 1998

Title: Concentrations of dioxins in some Washington state soils
PI: Mr. David Rogowski
Contact Information: Toxics Investigation Section, Environmental Investigations and laboratory Services Program, Washington Department of Ecology, PO Box 47600, Olympia, WA 98504-7600
Funding: WDOE
Duration: 1998

Title: Process linking phosphorus and carbon in forest litter in two climatic zones
PI: John McColl
Contact Information: University of California, ESPM Department, Ecosystem Science Division, 151 Hilgard Hall, #3110, Berkeley, CA 94720-3110, 510 642-1028 e-mail: forsoil@nature.berkeley.edu
Funding: Kearny Foundation, California Agricultural Experiment Station, UC, USDA
Duration: Ongoing since 1997

Title: Long Term Ecological Monitoring: various and numerous projects
PI: Andrea Woodward
Contact Information: Western Fisheries Research Center, 6505 NE 65th Street, Seattle, WA 98115, (206) 526-6282 x332, e-mail: andrea_woodward@usgs.gov
Funding: USGS-BRD
Duration: Ongoing since 1998

Rocky Mountain National Park

Title: Long-term ecological research in Loch Vale Watershed, Rocky Mountain National Park
PI: Jill Baron
Contact Information: USGS, MESC, Natural Resource Ecology Laboratory, Colorado State University, Fort Collins, Colorado, e-mail: jill@nrel.colostate.edu
Funding: USGS
Duration: Ongoing since 1981

Rocky Mountain National Park

Title: Water sampling and discharge measurements at the Loch Vale WEBB Site, ROMO
PI: David Clow and Don Campbell
Contact Information: USGS-WRD, Box 25046, Federal Center, Lakewood, CO 80225, (303) 236-4882, e-mail: dwclow@usgs.gov
Funding: USGS-WRD, NPS-ARD
Duration: Long-term and ongoing

Title: Monitoring boreal toad populations in ROMO
PI: Stephen Corn
Contact Information: USGS-BRD, Aldo Leopold Research Institute, P.O. Box 8089, Missoula, MT 59807, (406) 542-4190, e-mail: scorn@forestry.mtu.edu
Funding: USGS-BRD
Duration: Long-term and ongoing

Title: Assessment of hydrologic and geochemical functions of Colorado wetlands
PI: John C. Emerick
Contact Information: Colorado School of Mines, Environmental Science and Engineering Division, Golden, CO 80401, (303) 273-3520, e-mail: jemerick@mines.edu
Duration: Ongoing

Title: NOAA-funded snow distribution study
PI: Glen E. Liston
Contact Information: CSU, Department of Atmospheric Science, Ft. Collins, CO 80523, (970) 491-8449, e-mail: liston@iceberg.atmos.colostate.edu
Funding: NOAA
Duration: 1999

Title: Boreal Toad, *Bufo boreas,* reproduction and aquatic predator communities
PI: Lauren J. Livo
Contact Information: CU, EPO Biology, Campus Box 334, Boulder, CO 80309, (303) 936-0440, e-mail: ljlivo@aol.com
Duration: Ongoing

Title: Global change research program in the Colorado Rockies
PI: Tom Stohlgren
Contact Information: CSU, NREL, Ft. Collins, CO 80523, (970) 491-1980, e-mail: toms@nrel.colostate.edu
Funding: USGS-BRD
Duration: 1992-2003

Rocky Mountain National Park

Title: A plan for long-term ecosystem science and resource management in RMNP
PI: Tom Stohlgren
Contact Information: CSU, NREL, Ft. Collins, CO 80523, (970) 491-1980, e-mail: toms@nrel.colostate.edu
Funding: USGS-BRD
Duration: Ongoing

Title: Paleolimnological investigations in RMNP
PI: Alexander P. Wolfe
Contact Information: CU, INSTAAR, Campus Box 450, Boulder, CO 80309-04, (303) 492-7132, e-mail: wolfea@stripe.colorado.edu
Duration: 1999 with possible new funding

Title: Synoptic snow survey of the Rocky Mountains
PI: George Ingersoll
Contact Information: USGS-WRD, Box 25046, Federal Center, Lakewood, CO 80225, (303) 236-4882, e-mail: gpingers@usgs.gov
Funding: USGS-WRD, NPS-ARD
Duration: Ongoing

Title: Bulk deposition study
PI: George Ingersoll
Contact Information: USGS-WRD, Box 25046, Federal Center, Lakewood, CO 80225, (303) 236-4882, e-mail: gpingers@usgs.gov
Funding: NPS-ARD
Duration: 1999-2000

Title: MAGIC modeling of Loch Vale watershed
PI: Tim Sullivan
Contact Information: E & S Environmental Chemistry, Inc., P.O. Box 609, 2161 NW Fillmore Ave., Corvallis, OR 97339, (541) 758-5777, e-mail: tsullivan@proaxis.com
Funding: NPS-ARD
Duration: 1997-1999

Title: Re-sampling of Western Lake Survey Lakes in ROMO
PI: David Clow
Contact Information: USGS-WRD, Box 25046, Federal Center, Lakewood, CO 80225, (303) 236-4882, e-mail: dwclow@usgs.gov
Funding: USGS-WRD
Duration: 1999-2000

Rocky Mountain National Park

Title: *Modeling of Loch Vale watershed using AHM*
PI: Tom Meixner
Contact Information: University of Arizona, Dept. of Hydrology and Water Resources, Tucson, AZ 85721, (520) 626-4601, e-mail: tom@hwr.arizona.edu
Funding: Canon scholarship
Duration: 1997-1999

Title: UV effects on amphibians and UV extrapolation at Rocky Mountain and Glacier National Parks
PI: Ed Little
Contact Information: USGS-BRD, Columbia Environmental Research Center, 4200 New Haven Road, Columbia, MO 65201
Funding: USGS-BRD Global Change Research Program
Duration: 1999-2004

Sequoia/Kings Canyon National Park

Title: An assessment of declining amphibians at Sequoia and Kings Canyon National Parks
PI: Gary M. Fellers
Contact Information: USGS-BRD, Point Reyes National Seashore, Point Reyes, CA 94956, (415) 663-8522 x236, FAX: 415-663-0469, e-mail: Gary_Fellers@usgs.gov
Funding: USGS-BRD, some USFS and USF&WS
Duration: Ongoing

Title: Dry deposition measurement, CORE/Satellite Station
PI: Bruce B. Hicks
Contact Information: Atmospheric Turbulence and Diffusion Division, NOAA ERL Air Resources Lab, P.O. Box 2456, Oak Ridge, TN 37831, (615) 576-1232
Funding: NOAA
Duration: Ongoing

Title: Modeling ozone flux to forests across an ozone concentration gradient in Sierra Nevada Mountains
PI: Jeanne Penek and Allen H. Goldstein
Contact Information: College of Natural Resources, Department of Environmental Science, Policy, and Management, Division of Ecosystem Sciences, 151 Hilgard Hall, Berkeley, CA 94720
Funding: EPA-NCERQA
Duration: 3 years

Sequoia/Kings Canyon National Park

Title: Historical-scale biochemical markers of oxidant injury and exposure in pines
PI: Richard M. Higashi
Contact Information: Crocker Nuclear Laboratory, 1 Shields Avenue, Davis, CA 95616, (530) 752-1450, e-mail: rmhigashi@ucdavis.edu
Funding: CARB
Duration: 2 years

Title: *Rana muscosa* movement and habitat use study in Dusy Basin, Kings Canyon National Park
PI: Kathleen R. Matthews
Contact Information: USFS, Pacific Southwest Research Station, P.O. Box 245, Berkeley, CA 94701, (510) 559-6454, FAX: 510-559-6440, e-mail: kmatthew@violet.berkeley.edu
Funding: USDA-FS/PSW
Duration: 2 years

Title: Hydrology, hydrochemical modeling, and remote sensing in seasonally snow covered alpine drainage basins; comparative analyses of high elevation lakes and catchments
PI: John M. Melack and James Sickman
Contact Information: Department of Biological Sciences, University of California, Santa Barbara, CA 93106, (805) 893-3879, FAX: 805-893-4724, e-mail: melack@lifesci.ucsb.edu
Funding: NASA, EOS
Duration: Ongoing

Title: High elevation amphibians in Kings Canyon National Parks
PI: Vance T. Vrendenburg
Contact Information: Department of Integrative Biology, Museum of Vertebrate Zoology, 3101 Valley Life Science Bldg, Berkeley, CA 94720, (510) 642-7960, e-mail: vancev@socrates.berkeley.edu
Funding: USGS-BRD, Other
Duration: 3 years

Title: Air pollution as a possible cause of mountain yellow-legged frogs decline
PI: Jeff Angerman and Fumio Matsumura
Contact Information: Department of Environmental Toxicology-ITEH, University of California, Davis, CA 95616, (916) 752-7775, e-mail: jiangermann@ucdavis.edu
Duration: 2 years

Title: A study of the partitioning of organophosphate pesticide vapors into ponderosa pine needles
PI: Linda Aston and James N. Seiber
Contact Information: University of Nevada, University Center for Environmental Science and Engineering, 130 Fleischmann Agr. Bldg, Reno, NV 89557, (702) 784-6460, FAX: 702-784-1142, e-mail: jseiber@med.usr.edu
Duration: 2 years

Sequoia/Kings Canyon National Park

Title: Distribution of non-native fish and native aquatic taxa in Sierra Nevada lakes
PI: Roland A. Knapp and Kathleen Matthews
Contact Information: Sierra Nevada Aquatic Res. Lab, University of California, Star Route 1, Box 198, Mammoth Lakes, CA 93546, (760) 647-0034, FAX: (760) 935-4867, e-mail: knapp@lifesci.lscf.ussb.edu
Funding: USDA-FS, PSW
Duration: 2 years

Title: Atmospheric transport and deposition of pesticides on input to Sierra Nevada surface waters
PI: James Lenoir and James N. Seiber
Contact Information: University of Nevada, University Center for Environmental Science and Engineering, 130 Fleischmann Agr. Bldg, Reno, NV 89557, (702) 784-6460, FAX: (702) 784-1142, e-mail: jseiber@med.usr.edu
Funding: USDA-NRI
Duration: 2 years

Title: Regional analysis of critical loads and threshold values of sulfur and nitrogen deposition
PI: Timothy J. Sullivan
Contact Information: E & S Environmental Chemistry, Inc., P.O. Box 609, 2161 NW Filmore Avenue, Corvallis, OR 97339, (561) 758-5777, FAX: (561) 758-4413, e-mail: tsullivan@proaxis.com
Funding: NPS-ARD
Duration: 1997-1999

Title: Watershed research in Sequoia and Kings Canyon National Parks
PI: Claudette Moore
Contact Information: USGS Sequoia National Park, Three Rivers, CA, e-mail: claudette_moore@usgs.gov
Funding: USGS-BRD
Duration: Ongoing since 1981

Title: Climate dynamics and vegetation response in Sequoia National Park
PI: Keely and Stephenson
Contact Information: California Science Center
Funding: USGS-BRD Global Climate Change Research Program
Duration: 1999-2004

Shenandoah National Park

Title: Isotope monitoring of atmospheric deposition at Big Meadows, SNP, VA
PI: J.K. Bohlke
Contact Information: USGS, 431 National Center, Reston, VA 22902, (703)648-6325, e-mail: jkbohlke@usgs.gov
Funding: USGS
Duration: Ongoing since 1989

Title: Low level SO_2, NO_X, CO at Big Meadows
PI: Bruce Doddridge
Contact Information: University of Maryland, Department of Meteorology, College Park, MD 20742 (Part of Enhanced Ozone Monitoring Network), 301-405-7628, e-mail: bruce@atmos.umd.edu
Funding: NPS, Donor funds
Duration: Ongoing since 1995, FY00 + potential NPS & EPA

Title: Shenandoah Watershed Study (SWAS)
PI: Jim Galloway
Contact Information: University of Virginia, Clark Hall, Charlottesville, VA 22903 (804) 924-0561, e-mail: jng@virginia.edu
Funding: Mostly NPS with EPA funds for episodic acidification studies
Duration: Ongoing and expanding since 1979 via long-term cooperative agreement

Title: Virginia Trout Stream Sensitivity Study (VTSSS)
PI: Jim Galloway
Contact Information: University of Virginia, Clark Hall, Charlottesville, VA 22903 (804) 924-0561, e-mail: jng@virginia.edu
Funding: EPA, Trout Unlimited funds
Duration: Ongoing since 1987

Title: Temporally Integrated Monitoring of Ecosystems (TIME)
PI: Jim Galloway
Contact Information: University of Virginia, Clark Hall, Charlottesville, VA 22903 (804) 924-0561, e-mail: jng@virginia.edu
Funding: EPA
Duration: Ongoing since 1994

Title: Acid rain: current and projected status of coldwater fish communities in the southeastern U.S. in the context of continued acid deposition
PI: Art Bulger
Contact Information: University of Virginia, Clark Hall, Charlottesville, VA 22903 (804) 924-0531, e-mail: abulger@virginia.edu
Funding: Coldwater Conservation Fund, Virginia Department of Game and Inland Fisheries, NPS, USFS, EPA, Trout Unlimited funds
Duration: 1998 report using VTSSS & SWAS data

Shenandoah National Park

Title: Fish In Sensitive Habitats (FISH), Shenandoah National Park, Virginia
PI: Art Bulger
Contact Information: University of Virginia, Clark Hall, Charlottesville, VA 22903, (804) 924-0531, e-mail: abulger@virginia.edu
Funding: NPS
Duration: Final Report Due FY99 (John Karish)

Title: Groundwater quality, age, and residence times at Shenandoah National Park
PI: Niel Plummer
Contact Information: USGS, 423 National Center, Reston, VA 22092, (703) 648-5841, e-mail: nplummer@usgs.gov
Funding: USGS FY96-98, EPA FY99, potential USGS FY00-02
Duration: Ongoing since 1996; will request USGS funding as part of USGS/NPS water quality assessment partnership

Title: Hydrological and geochemical controls on episodic acidification of streams in Shenandoah National Park, Virginia: development and testing of a predictive model
PI: Karen Rice
Contact Information: USGS, Virginia Forestry Building, 900 Natural Resources Drive, Richmond, VA (804) 297-4069, e-mail: kcrice@usgs.gov
Funding: USGS with NPS and EPA funds for SWAS data FY99-01
Duration: FY99-01

Title: Surficial geology mapping at Shenandoah National Park
PI: Ben Morgan
Contact Information: USGS, MS 926A - Morgan, Reston, VA 22092, (703)648-6927, e-mail: bmorgan@usgs.gov
Funding: USGS
Duration: 1995-1999; one USGS Open File Report submitted 1998, publications pending

Title: Episodic acidification of streams in Shenandoah National Park
PI: Keith Eshleman
Contact Information: Appalachian Laboratory, University of Maryland, Center for Environmental Science, 301 Braddock Rd., Frostburg, MD 21532-2307, (301) 689-7170, e-mail: eshleman@ael.umd.edu
Funding: NPS-ARD
Duration: Final Report Due FY99

Title: Integrated analysis of acid deposition at Shenandoah National Park
PI: Jim Galloway
Contact Information: University of Virginia, Clark Hall, Charlottesville, VA 22903 (804) 924-0561, e-mail: jng@virginia.edu
Funding: NPS
Duration: Final Report Due FY99

Shenandoah National Park

Title: Assessment of air quality and air pollution impacts at Shenandoah National Park
PI (acid deposition): 1) Tim Sullivan, E&S Environmental Chemistry, PO Box 609, Corvallis, OR 97339, (541) 758-5777, e-mail: tsullivan@proaxis.com, 2) Jack Cosby, University of Virginia, Clark Hall, Charlottesville, VA 22903, (804) 924-7787, and 3) Art Bulger, University of Virginia, Clark Hall, Charlottesville, VA 22903, (804) 924-0531
PI (ozone): Bruce Nash, NPS Air Resources Division, PO Box 25287, Denver, CO 80225-0287, (303) 987-6697, e-mail: bruce_nash@nps.gov
PI (atmospheric modeling): Robin Dennis, US EPA Mail Drop 80, Research Triangle Park, NC 27711, (919) 541-2870, e-mail: rdennis@hpcc.epa.gov
PI (visibility): Bill Malm, NPS Air Resources Division, Colorado State University, CIRA, Foothill Campus, Fort Collins, CO 80523, (970) 491-8292, e-mail: malm@CIRA.colostate.edu
Funding: NPS with in-kind EPA/NOAA modeling team contributions and use of multi-financed data sets
Duration: FY00-01 with Final Assessment due 12/31/01

Title: Inventory and Monitoring Prototype Park
PI: Tom Blount
Contact Information: Shenandoah National Park, Luray, VA, 22835, (540) 999-3497, e-mail: tom_blount@nps.gov
Funding: NPS I&M Program, USGS-BRD
Duration: Ongoing

Title: Amphibian decline in the Mid-Atlantic Region: monitoring & management of a sensitive resource
PI: Joseph Mitchell
Contact Information: University of Richmond, Dept of Biology, Richmond, VA 23173, (804) 740-7086, e-mail: JMitchell@Richmond.edu
Funding: DOD
Duration: 1996-1998; Final Report submitted 1998

Title: Mid-Atlantic Highlands Assessment (EMAP)
PI: John Stoddard
Contact Information: US-EPA, NHEERL/WED, 200 SW 35th St., Corvallis, OR 97333, (541) 754-4441, e-mail: stoddard.john@epamail.epa.gov
Funding: EPA
Duration: Ongoing since 1996; (Amended) Final Reports pending

Title: Long term aquatic recovery of a 500+ year flood event in Shenandoah National Park
PI: Craig Snyder
Contact Information: USGS, Biological Resources Division, Aquatic Ecology Laboratory, 1700 Leetown Rd, Kearneysville, WV 25430, (304) 724-4468, e-mail: craig_snyder@usgs.gov
Funding: UVA/VPI
Duration: FY98-00

Shenandoah National Park

Title: Forest vegetation, watershed topography, and nitrogen export in Shenandoah National Park
PI: Steve Seagle
Contact Information: UMCES Appalachian Laboratory, Gunter Hall, Frostburg, MD 21532, (301) 689-3115 x 210, e-mail: seagle@al.umces.edu
Funding: EPA
Duration: Ongoing since 1998

Title: Collection of gypsy moth data, re-measurement of forest plots, collection of tree cores
PI: Hank Shugart
Contact Information: University of Virginia, Clark Hall, Charlottesville, VA 22903, (804) 924-7642, e-mail: hhs@virginia.edu
Funding: UVA
Duration: Ongoing since 1993

Title: Stream groundwater interaction in a saprolite aquifer
PI: Jeff Raffensperger
Contact Information: University of Virginia, Clark Hall, Charlottesville, VA 22903, (804) 924-0581, e-mail: jpr2y@virginia.edu
Funding: UVA, VA Water Resources
Duration: Ongoing since 1995

Title: Dendroecological study of a dominant eastern forest tree species [Eastern Hemlock]
PI: Patrick Dougherty
Contact Information: 1128 Hillside Lane, Louisville, CO 80027, (303) 939-6684, e-mail: pdougher@ball.com
Funding: PI
Duration: Ongoing since 1996; Ph.D. and publications pending

Title: Forest inventory & analysis
PI: John Scrivani
Contact Information: Virginia Dept of Forestry, P.O. Box 3758, 900 Natural Resources Drive, Charlottesville, VA 22903, (804) 977-6665, email: jscrivani@mindspring.com
Funding: USFS
Duration: Ongoing since 1997

Title: Re-sampling permanent vegetation plots of the long-term ecological monitoring system of Shenandoah National Park
PI: Philip Coulling
Contact Information: University of North Carolina, Coker Hall, Chapel Hill, NC 27599-3280, e-mail: twist.wilson@mhs.unc.edu
Funding: PI
Duration: Ongoing since 1997; M.S. pending

Shenandoah National Park

Title: Impact of acid rain on geologically sensitive watersheds
PI: Owen Bricker
Contact Information: USGS - MS 432, 12201 Sunrise Valley Drive, Reston, VA 20192
Funding: USGS, EPA
Duration: 1982-1998; further research & monitoring coordinated with University of Virginia (Jeff Raffensberger & George Hornberger); additional M.S. and publications pending

Virgin Islands National Park

Title: Inventory and Monitoring Prototype Park
Principal Investigator: Carolyn Rogers
Contact Information: Virgin Islands NP, St. Thomas, Virgin Islands, (809) 693-8950
Funding: NPS I&M Program, USGS-BRD
Duration: Long-term and ongoing

References

1. S. Paulsen. 1997. A Research Strategy for the Environmental Monitoring and Assessment Program, Phase II. U.S. Environmental Protection Agency, Office of Research and Development, National Health and Environmental Effects Research Laboratory, Research Triangle Park, NC.

2. National Research Council (NRC). 1995. Review of EPA's Environmental Monitoring and Assessment Program. National Research Council, Washington, DC.

3. Committee on Environment and Natural Resources (CENR). 1997. Integration of the Nation's Environmental Monitoring and Research Networks and Programs: A Proposed Framework. National Research and Technology Council, Washington, DC.

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