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ACID DEPOSITION/ INTEGRATED ECOSYSTEM STUDIES, SEQUOIA NATIONAL PARK: OVERVIEW

Sequoia National Park, in the southern Sierra Nevada of California, is the site of a long term research program on the potential impacts of acid deposition and associated air pollutants on Park ecosystems. Begun in 1982, primarily under the auspices of the National Acid Precipitation Assessment Program (NAPAP), the research effort focuses on measuring atmospheric input chemistry and on collection of the types of baseline ecosystem data necessary to detect subtle but potentially profound changes in soils, vegetation, and aquatic environments. The program is a cooperative effort of federal, state, university and private investigators.

Sequoia National Park has a particular role in understanding potential threats from air pollution: the detection, through long-term monitoring of unaltered wildlands, of changes in ecosystems; identification of the factors causing such changes; and provision of information necessary for averting profound but often insidious adverse effects. An added benefit is the fact that the information collected as part of the acid deposition/ ecosystem research program will provide data of value in detecting impacts from visitor use and management activities on sensitive park ecosystems. It will provide a basis for the type of long term ecosystem monitoring so often lacking in national parks.

Given the modest NAPAP and National Park Service (NPS) monies available for acid deposition, oxidant air pollutant and baseline resource studies, we decided at an early stage that cooperative funding would be required to carry out the type of integrated ecosystem study that was needed. During the early years of the program, the interest of other federal and state agencies as well as private and university scientists in acid deposition related baseline ecosystem studies in Sequoia has been substantial. At this time, outside funding is supporting much of the research necessary to carry out major aspects of an integrated watershed-based ecosystem study. The California Air Resources Board (CARB) is providing the largest source of funds.

Scope of the Program

The Sequoia National Park acid deposition/ecosystem research program has been designed as a long term, cooperative, integrated study of ecosystems thought to be sensitive to anthropogenic pollutants. Cooperative funding from a variety of federal, state and private sources provides support for scientists working at three primary study sites (watersheds) spanning an elevation gradient from 2460 feet (750 m) to 11,150 feet (3400 m). Studies focus on baseline measurements of precipitation chemistry and atmospheric pollutant concentrations, as well as soil description and chemistry; geology and mineralogy; vegetation composition, biomass, productivity, phenology and water stress; tree ring chronology; stream hydrology; lake and stream chemistry and biology;

fisheries; lake sediment buffering; paleolimnology; plant litter production and decomposition; ozone effects on vegetation; nutrient cycling; and snow and watershed hydrology. The work is focused at a low elevation (2460 ft; 750 m) chaparral intermittent stream site (Elk Creek), a middle elevation (6890 ft; 2,100 m) mixed conifer forest perennial stream site (Log Meadow), and a high elevation (9840 ft; 3,000 m) subalpine lake and stream site (Emerald Lake). Each study site is a headwater drainage basin. Work at each site is designed to quantify sensitive ecosystem parameters, including fluxes of H2O and important ions. Additional adjacent watersheds are being studied in the Elk Creek and Log Meadow areas. These will be burned to evaluate the effects of fire on soil and water chemistry and selected vegetation parameters. Project coordination and integration is the joint responsibility of the scientific staff of Sequoia National Park and the California Air Resources Board. Annual meetings are held to review research progress and program direction.

Cooperators

Cooperative efforts supporting aspects of Sequoia National Park's acid deposition/ecosystem study include the following:

1. National Park Service Interagency Acid Precipitation Funds (NAPAP)

   National Park Service NAPAP funding is projected through 1991. To date these funds have been used primarily to establish and describe the three primary study sites, to monitor precipitation and stream chemistry, gauge stream flow at the Log Meadow and Elk Creek sites, establish and maintain meteorological stations at each site, establish a long term vegetation research program, study litter accumulation rates, establish and maintain a water chemistry laboratory, and provide logistical assistance to contract and cooperative studies. Experimental burns at Elk Creek and Log Meadow will be supported by these funds. The following cooperative studies have also been supported with NPS-NAPAP funds:

   a) Soil survey and mapping of the three study sites - Gordon Huntington and Mark Akeson, UC Davis (1982-85).

   b) Soil chemistry and mineralogy of major soil types at all sites - Richard Burau and Lynn Whittig, UC Davis (1983-86).

   c) Basic plant ecological research (phenology, water relations, biomass and productivity) at all sites - Philip Rundel, UCLA (1982-85).

   d) Baseline studies of aquatic chemistry and biology and integration of water chemistry data at all sites - John Melack and Scott Cooper, UC Santa Barbara (1982-88).

   e) Regulation of element fluxes in Sierran conifer forests - Peter Vitousek, Stanford University (1986-89)

2. Other National Park Service (NPS) Programs

The NPS Denver air quality office has funded several projects related to air quality effects:

a) Ozone effects on selected tree species (includes field observations, fumigation, tree ring and needle phenology studies) - Paul Miller, US Forest Service, Riverside (1982-86+).

b) Inventory of lichens susceptible to air pollution damage - Clifford Wetmore, University of Minnesota (1984-1985).

c) Air quality monitoring (ozone and visibility) and establishment of permanent ozone damage plots in pine and oak vegetation types - NPS staff and Dan Duriscoe, Eridanus Associates (1982-86+).

d) Regional air quality model - Joint contract with EPA to Systems Applications, Inc., San Rafael (1985-86).

Additional studies providing information complementary to the program have been funded by the NPS Denver Service Center and the Washington Office as follows:

a) Stream-forest ecosystem interactions in the mixed conifer forest zone - Jointly funded with US Forest Service to Jerry Franklin and Kenneth Cummins, USDA Forest Service, Corvallis, and Oregon State University (1982-85).

b) Geologic survey of Giant Forest/Lodgepole area - Thomas Sisson and James Moore, USDI, Geological Survey, Menlo Park (1983-84).

c) Geomorphology and glacial geology of the Crescent Meadow area - Clyde Wahrhaftig, USDI Geological Survey, Menlo Park (1983-84).

d) Overview of geology of Emerald Lake basin in relation to acid precipitation: preliminary study - James Moore and Clyde Wahrhaftig, USDI Geological Survey, Menlo Park (1983-84).

3. State of California, Air Resources Board (CARB)

The California Air Resources Board has selected Emerald Lake as the site for a 5 year integrated watershed study on the effects of acid deposition on the Sierra Nevada. They have also funded some mixed conifer forest work. CARB has funded the following studies to date:

a) Aquatic ecosystems (stream and lake chemistry, plankton, diatoms and invertebrates) at Emerald Lake - John Melack, Scott Cooper and Robert Holmes, UC Santa Barbara (1984-86).

b) Snow deposition, melt, runoff, and chemistry at Emerald Lake - Jeffrey Dozier, Danny Marks and John Melack, UC Santa Barbara (1984-87).

c) Vegetation studies (biomass, productivity, root growth etc.) at Emerald Lake and Log Meadow - Philip Rundel and Ted St. John, UCLA (1984-86).

d) Tree ring chronology and trace element analysis at Emerald Lake - Thomas Nash and Brad Kincaid - Arizona State University (1984-85).

e) Soil processes at Emerald Lake - Lanny Lund, Aaron Brown and Mary Leuking UC Riverside (1984-85).

f) Lake sediment buffering - John Harte and Ronald Amundson, UC Berkeley (1984-86).

g) Maintenance and analysis of Aerochem-metrics event precipitation samplers at Ash Mountain, Giant Forest and Emerald Lake (summer only) - CARB staff (1984-indefinite).

h) Fish and amphibian studies at Emerald Lake - Scott Cooper and Tom Jenkins, UC Santa Barbara (1985-87).

i) Biota of the Emerald Lake system, including stream channel experiments - Scott Cooper, Robert Holmes and John Melack, UC Santa Barbara (1986-87).

j) Hydrologic mass balance for the Emerald Lake watershed - John Dracup, UCLA, Danny Marks and John Melack, UC Santa Barbara (1985-87).

k) Calibration of diatom-pH-alkalinity method for interpretation of sedimentary record - Robert Holmes, UC Santa Barbara (1985-86).

l) Particulate monitoring - Thomas Cahill, UC Davis (1985-86).

m) Atmospheric circulation using tracers - Fred Shair, Cal. Tech. (1985).

n) Nitric acid and ammonia concentrations in the atmosphere - Robert Braman, U. South Florida (1985).

o) Transport of atmospheric aerosols - Leonard Myrup and Robert Flocchini, UC Davis (1985).

p) Fog and cloudwater chemistry - Michael Hoffman and Bruce Daube - Cal. Tech. (1985-86).

q) Statewide survey of lake and stream chemistry - Kim McCleneghen, California Dept. Fish and Game and John Melack, UC Santa Barbara (1985-86).

r) Mapping and development of digital terrain model for Emerald Lake basin - Danny Marks, UC Santa Barbara (1985-86).

s) Trace metals in Emerald Lake watershed - Howard Taylor (1986).

4. USDI Geological Survey (USGS)

The Geological Survey has made a long term commitment to monitor stream hydrology and water chemistry (including aluminum and other metals) at Emerald Lake. This is part of its national watershed monitoring program under the direction of Owen Bricker. The USGS is supporting the following investigations:

a) Stream hydrology (including installation, calibration and maintenance of monitoring equipment) - Ken Lee and Tom Hunter, USGS, Merced (1983-indefinite).

b) Stream chemistry - Roy Schroeder and Vance Kennedy, USGS, Laguna Nigel and Menlo Park (1983-indefinite).

c) Geology of the Triple Divide Peak quadrangle - Jim Moore, USGS Menlo Park (1984-86)

5. Man and the Biosphere Program/USDA Forest Service

This is a jointly funded project to study dry deposition (including throughfall chemistry) of N and S compounds at the low elevation site Paul Miller, USFS, and Lanny Lund, UC Riverside (1982-86).

6. Electric Power Research Institute (EPRI)

EPRI has funded a study of surficial geology and mineralogy of the Emerald Lake basin. Contract to Robert Newton, Smith College and Richard April, Colgate University (1984-85).

EPRI is planning to support a major ozone fumigation study in the southern Sierra Nevada.

7. University of California

Special UC research funds for acid precipitation related topics have been acquired to supplement the soil mapping and chemistry projects of Gordon Huntington, Richard Burau and Lynn Whittig as well as to support the following:

a) Effects of aluminum on mycorrhizae - Mark Akeson and Don Munns, UC Davis and Mary Firestone, UC Berkeley (1984-86).

b) Survey of moss species in the three primary study sites - A. J. Steen, UCLA (1985-86).

8. National Aeronautics and Space Administration (NASA)

As part of its Global Biology Program, NASA-Ames (Moffett Field, California) has supported three studies related to the integrated

ecosystem project. These are designed to help predict basic ecosystem parameters from remote sensing data:

a) Forest biomass and productivity in the mixed conifer zone - Philip Rundel and Walt Westman, UCLA, Steve Running, University of Montana (1984-85).

b) Nitrogen mineralization, canopy nutrients and litter processes at Log Meadow and Elk Creek - Pamela Matson, NASA-Ames (1984-86+).

c) Topographic drainage model of Emerald Lake basin - Larry Band, Hunter College, NY (1984).

d) Remote sensing of air pollution effects on forest vegation - Dave Peterson and Walt Westman, NASA-Ames (1986).

9. Southern California Edison Co. (SCE)

SCE is funding the following:

a) Event precipitation chemistry at Ash Mountain - Bob Brewer, Global Geochemistry (1983-indefinite).

b) Survey of water chemistry of high Sierra lakes - Gordon Bradford, Alvin Page and others, UC Riverside (1980-85).

c) Paleolimnology - Don Whitehead, Don Charles and Mark Whiting University of Indiana (1985-87).

d) Lake chemistry of selected lakes - Gordon Bradford and Al Page, UC Riverside (1986 +).

10. USDA Forest Service (USFS)

In addition to the cooperative efforts on the ozone and dry deposition studies the Forest Service is funding the following:

a) Ozone effects on leaf microorganisms - Paul Dunn and Dan Durall, USFS, Riverside (1985-86).

11. Environmental Protection Agency (EPA)

The EPA has funded an extensive survey of water chemistry of western lakes (1985).

12. National Atmospheric Deposition Program (NADP/NTN)

NADP/NTN has an acid precipitation monitoring station (wet deposition) that is part of the federal monitoring network located at Giant Forest near Log Meadow. (1980-indefinite).

13. National Oceanographic and Atmospheric Administration (NOAA)

    NOAA is funding the establishment and associated analysis of a dry deposition monitoring station near the middle elevation site - Bruce Hicks, NOAA.

14. EG & G National Lab, ID.

    EG & G funded preliminary measurements of trace elements both in the atmosphere and in plant, water, soil and litter at Log Meadow - Bruce Wiersma, EG & G (1983).

15. California State University, Fresno

    CSUF has funded a study of rock weathering and neutralization of acidic deposition in Emerald Basin - David Clow and Art Barabas, CSU Fresno (1985-86).

16. NSF Long Term Ecological Research Program (LTER)

    The LTER program has funded a survey study of soil sulfur transformations at the three study sites - John Fitzgerald, University of Georgia (1986).

The combined interest of federal, state and private groups in participating in an integrated, interdisciplinary ecosystem study is unprecedented in the western United States. Although the southern Sierra Nevada is one of the most sensitive areas in the country to potentially damaging effects of acid precipitation, it is also apparent that the information needed to document such threats will be of direct and indirect value to basic science, as well as park management. The National Park Service will receive direct benefits in terms of an increased understanding of park ecosystems, an understanding of threats posed by acidic deposition and air pollution, baseline data important both for management decisions and as a basis for long term monitoring, and recognition as a supporter of high quality research. While these benefits are hard to measure at this time, the interest of other groups in the program is evidence that the value will far exceed the monetary commitment of NPS funds.

TABLE 1. PROJECTS AND PARTICIPANTS IN AIR POLLUTION RELATED RESEARCH IN SEQUOIA NATIONAL PARK

	Sponsor	Principal Investigator	Study/Site*
PROJECT COORDINATION			
1	NPS	D. Parsons, D. Graber, T. Stohlgren, T. Nichols, A. Esperanza NPS	Site administration and coordination
2	CARB	K. Tonnessen, L. Ashbaugh, E. Fujita CARB	Project coordination
METEOROLOGY/DEPOSITION			
1	NPS	T. Stohlgren, A. Esperanza NPS	Meteorology 1,2,3
2	NPS/NADP	D. Parsons, T. Stohlgren, A. Esperanza NPS	Precipitation chemistry 1,2,3
3	CARB	E. Fujita, A. Westerinen CARB	Event precipitation chemistry 1,2,3
4	SCE	B. Brewer Global Geochemistry	Event precipitation chemistry 3
5	CARB	J. Dozier, D. Marks, J. Melack UCSB	Meteorology and snow deposition 1
6	CARB	M. Hoffmann, B. Daube CAL TECH	Fog and cloudwater chemistry 2
7	MAB/USFS	L. Lund, P. Miller UCR	Dry deposition, throughfall chemistry 3
8	NOAA/ CARB/NPS	B. Hicks NOAA	Dry deposition 2

*1 - Subalpine zone; 2 - Mixed conifer forest zone; 3 - Foothill zone
** Project completed

	Sponsor	Principal Investigator	Study/Site*
AIR QUALITY/OZONE			
1	NPS	T. Nichols NPS	Ozone and visibility monitoring 2,3
2	NPS	D. Duriscoe, ERIDANUS T. Nichols NPS	Ozone effects plots 2
3	NPS	P. Miller USFS	Ozone fumigation and effects plots 2
4	NPS	J. Bennett, K. Stolte NPS D. Duriscoe ERIDANUS	Ozone effects on needle retention 2
5	NPS/EPA	Systems Applications Inc.	Regional air quality model
6	CARB	T. Cahill UCD	Particulate monitoring 1,2,3
7	CARB	L. Myrup, R. Flocchini UCD	Aerosol transport 1,2,3
8	CARB	R. Braman U. SOUTHERN FLORIDA	Atmospheric nitric acid and ammonia 1,2,3
9	CARB	F. Shair CAL TECH	Atmospheric tracer experiments 1,2,3
10	USFS	P. Dunn USFS	Ozone effects on leaf micro-organisms 2
11	NPS	D. Karnofsky MICH TECH	Effects of ozone on aspen 2
VEGETATION			
1	NPS	D. Parsons, T. Stohlgren, A. Workinger NPS	Long-term vegetation plots 1,2,3
2	NPS	T. Stohlgren NPS	Litter accumulation and decomposition 1,2,3
3	CARB/NPS	P. Rundel UCLA	Vegetation description and process studies 1,2
4	CARB	T. St. John UCLA	Root productivity 1,2
5	CARB/NASA	W. Westman, P. Rundel UCLA	Conifer biomass** 2
6	CARB	T. Nash, B. Kincade ARIZONA STATE UNIV	Tree ring chronology 1 and trace elements
7	NPS	C. Wetmore U. MINN	Lichen survey** 2,3
8	NPS/USFS	J. Franklin USFS K. Cummins ORE ST UNIV	Forest-stream dynamics 2
9	NASA	D. Peterson, W. Westman NASA-AMES	Remote sensing of air pollution effects 2
10	UC	A. J. Steen UCLA	Moss inventory 1,2,3

*1 - Subalpine zone 2 - Mixed conifer forest zone 3- Foothill zone
** Project completed

	Sponsor	Principal Investigator	Study/Site*
SOILS/GEOLOGY/TERRAIN			
1	NPS/UC	G. Huntington, M. Akeson UCD	Soils mapping and description 1,2,3
2	NPS/UC	L. Whittig UCD	Soil minerology 1,2,3
3	NPS	R. Burau UCD	Soil chemistry 1,2,3
4	NPS	P. Vitousek STANFORD	Element fluxes 2
5	CARB	M. Leuking, A. Brown L. Lund UCR	Soil biological processes (respiration, mineralization, litter, nitrification) 1
6	CARB	A. Brown, M. Leuking, L. Lund UCR	Soil inorganic processes (weathering, soil and solution chemistry, solute transport) 1
7	CARB	D. Marks UCSB	Digital terrain model 1
8	NASA	P. Matson NASA-AMES	Nitrogen cycling 2,3
9	EPRI	R. Newton SMITH COLLEGE	Surficial geology and minerology 1
10	UC	M. Akeson, D. Munns UCD	Alumminum effects on mycorrhizae 1,2
11	CSUF	D. Clow, A. Barabas CSUF	Rock weathering 1
12	LTER	J. Fitzgerald U. GEORGIA	Sulfur transformations 1,2,3
13	NPS	J. Moore, T. Sisson, C. Wahrhaftig USGS	Geologic survey and geomorphology** 1,2
14	USGS	J. Moore USGS	Geologic mapping 1,2
15	EG&G	G.B. Wiersma EG&G	Trace elements 2
16	NASA	L. Band HUNTER COLLEGE	Topographic drainage model 1

* 1 - Subalpine zone 2 - Mixed conifer forest zone 3 - Foothill zone
** Project completed

	Sponsor	Principal Investigator	Study/Site*
AQUATICS			
1	NPS	T. Stohlgren, A. Esperanza NPS	Stream chemistry and hydrology 1,2,3
2	USGS	R. Schroeder, T. Hunter USGS	Stream chemistry and hydrology 1
3	CARB/NPS	J. Melack, J. Sickman UCSB	Lake/stream chemistry, productivity 1,2
4	CARB	S. Cooper UCSB	Lake/stream biology 1
5	CARB	S. Cooper, J. Melack UCSB	Experimental stream acidification 1
6	CARB	S. Cooper, T. Jenkins UCSB D. Graber NPS	Fish and amphibians 1
7	CARB	R. Holmes UCSB	Diatom pH calibration, sediment history 1
8	CARB	R. Amundson, H. Michaels UCB	Lake sediment buffering 1
9	CARB	J. Harte UCB	Sediment microcosm studies 1
10	CARB	H. Taylor USGS	Trace metals 1
11	CARB	J. Dracup UCLA J. Melack, D. Marks UCSB	Hydrologic mass balance 1
12	CARB	K. McClenegham CF&G J. Melack UCSB	Lake and stream chemistry monitoring 1
13	EPA	K. Greenberg EPA	Lake chemistry survey 1
14	USGS	L. Laird USGS	Snow chemistry survey** 1
15	SCE	G. Bradford, A. Page UCR	Chemical survey high elevation lakes 1
16	SCE	D. Whitehead, D. Charles, M. Whiting INDIANA UNIV	Paleolimnology 1

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