Air Quality and Air Quality Effects in National Parks: AQRV and AQ Research Findings			
Park	**Title**	**Project Summary/Findings**	**Citation**
N and S Deposition and Effects			
Sequoia/ Kings Canyon National Park (SEKI)	ATMOSPHERIC DEPOSITION AND SOLUTE EXPORT IN GIANT SEQUOIA MIXED CONIFER WATERSHEDS IN THE SIERRA-NEVADA, CALIFORNIA	Atmospheric depostion and stream discharge and solutes were measured for three years 1984 - 1987) in two mixed conifer watersheds in Sequoia National Park. The Log Creek watershed is drained by a perennial stream, while Tharp's Creek watershed contains an intermittent stream. Over the three year period, sulfate (SO4(2-), nitrate (NO3-), and chloride (Cl-) were the major anions in bulk precipitation with volume-weighted average concentrations of 12.6, 12.3 and 10.0-mu-eq/l, respectively. Annual inputs of NO3-N, NH4-N and SO4-S from wet deposition were about 60 to 75% of those reported from bulk deposition collectors. Discharge from the two watersheds occurs primarily during spring snowmelt. Solute exports from Log and Tharp's Creeks were dominated by HCO3-, Ca2+ and Na+. Mean annual atmospheric contributions of NO3-N (1.6 kg ha-1), NH4-N (1.7 kg ha-1), and SO4-S (1.8 kg ha-1), which are associated with acidic deposition, greatly exceed hydrologic losses. Annual watershed yields of HCO3- exceeded by factors of 2.5 to 37 the annual atmospheric deposition of H+.	Stohlgren, T. J., Melack, J. M., Esperanza, A. M. & Parsons, D. J. (1991) ATMOSPHERIC DEPOSITION AND SOLUTE EXPORT IN GIANT SEQUOIA MIXED CONIFER WATERSHEDS IN THE SIERRA-NEVADA, CALIFORNIA. Biogeochemistry, 12, 207-230.
Sequoia/ Kings Canyon National Park (SEKI)	Atmospheric deposition of current-use and historic-use pesticides in snow at national parks in the Western United States	There is growing evidence that pesticides and other semi-volatile organic compounds (SOCs) are accumulating in remote high-elevation and high-latitude ecosystems, according to literature. The objectives of the study were to quantify and document the distribution of pesticides in seasonal snowpack samples from seven national parks in the Western U.S., to investigate potential factors that may influence the distribution of pesticides in these parks, and to estimate the percentage of total concentration due to regional sources versus long-range sources for each of the most frequently detected current and historic use pesticides detected at each park. The current-use pesticides detected in seasonal snowpack samples at national parks in this study were dacthal (DCPA), chlorpyrifos, endosulfans (I and II), ç-hexachlorocyclohexane (lindane), trifluralin, and triallate. The presence of these in remote ecosystems implies that they are persistent enough to undergo transport to remote ecosystems in national parks, according to the researchers.	Hageman, K. J., Simonich, S. L., Campbell, D. H., Wilson, G. R. & Landers, D. H. (2006) Atmospheric deposition of current-use and historic-use pesticides in snow at national parks in the Western United States. Environmental Science & Technology, **40**, 3174-3180.
Sequoia/ Kings Canyon National Park (SEKI)	ATMOSPHERIC DRY DEPOSITION ON PINES IN THE EASTERN BROOK LAKE WATERSHED, SIERRA-NEVADA, CALIFORNIA	Researchers studied atmospheric dry deposition to branches of Pinus contorta and P. albicaulis during the summer of 1987 in a sub-alpine zone at Eastern Brook Lake Watershed (EBLW), eastern Sierra Nevada, California. Deposition fluxes of anions and cations to the pine branches were low, several times lower than the values determined near the Emerald Lake Watershed (ELW), another sub-alpine location in the western Sierra Nevada. A strong positive correlation between depositions of NO3- and NH4+, as well as SO42- and Ca2+, researchers suggested that large portions of these ions might have originated from particulate NH4NO3 and CaSO4 deposited on pine surfaces. An estimated total N dry deposition (surface deposition of NO3- and NH4+ and internal uptake of NO2 and HNO3) to the forested area of the EBLW was 29.54 eq ha-1 yr-1 (about 414 g N ha-1 yr-1).	Bytnerowicz, A., Dawson, P. J., Morrison, C. L. & Poe, M. P. (1992) ATMOSPHERIC DRY DEPOSITION ON PINES IN THE EASTERN BROOK LAKE WATERSHED, SIERRA-NEVADA, CALIFORNIA. Atmospheric Environment Part a-General Topics, 26, 3195-3201.
Sequoia/ Kings Canyon National Park (SEKI)	Changes in the chemistry of lakes and precipitation in high-elevation national parks in the western United States, 1985-1999	Sixty-nine lakes in seven national parks sampled in the U. S. Environmental Protection Agency's Western Lake Survey were resampled during fall 1999 to investigate possible decadal-scale changes in lake chemistry. In most lakes, SO4 concentrations were slightly lower in 1999 than in 1985, consistent with a regional decrease in precipitation SO4 concentrations and in SO2 emissions in the western United States. Nitrate concentrations also tended to be slightly lower in 1999 than in 1985, in contrast with generally stable or increasing inorganic N deposition in the west. Results suggest that rain prior to sampling in 1985 may have caused elevated NO3 in some lakes due to direct runoff of precipitation and flushing of NO3 from alpine soils, which also may explain some of the decrease in NO3 concentrations observed in survey lakes.	Clow, D. W., Sickman, J. O., Striegl, R. G., Krabbenhoft, D. P., Elliott, J. G., Dornblaser, M., Roth, D. A. & Campbell, D. H. (2003) Changes in the chemistry of lakes and precipitation in high-elevation national parks in the western United States, 1985-1
Sequoia and Kings Canyon (SEKI)	Current and future effects of ozone and atmospheric nitrogen deposition on California's mixed conifer forests	The negative impact of atmospheric N deposition occurs at the ecosystem-level as an alteration of biogeochemical nutrient cycling. For trees growing on N-deficient soils, increased supplies of N could moderate harmful O-3 effects on growth for several decades. Over time, levels of soil N rise due to sustained inputs from the atmosphere, and the accelerated production and senescence of N-rich foliage by O-3. At this stage, N-limitation of forest productivity would be partially alleviated, and N emissions from soil and NO3- leaching losses elevated as a result of high soil N availability. In the western San Bernardino Mountains and in low-elevation chaparral watersheds in the San Gabriel Mountains, NO3- revels in streams are as high or higher than in any other undisturbed montane watersheds in North America, and NO3- contamination of domestic water supplies is of near-term concern. The effects of chronic O-3 exposure and N deposition are expected to become more prevalent in the southern Sierra Nevada.	Takemoto, B. K., Bytnerowicz, A. & Fenn, M. E. (2001) Current and future effects of ozone and atmospheric nitrogen deposition on California's mixed conifer forests. Forest Ecology and Management, 144, 159-173.
Sequoia and Kings Canyon (SEKI)	EFFECTS OF LOW PH AND ALUMINUM ON 2 DECLINING SPECIES OF AMPHIBIANS IN THE SIERRA-NEVADA, CALIFORNIA	The present study assesses the sensitivity of embryos and hatchling tadpoles of these species to low pH and an elevated level of dissolved aluminum. LC50 pH values for post-treatment survival of embryos and tadpoles of *R. muscosa* averaged 4.4 and <4.0, respectively, and 4.7 and 4.3, respectively, for *B. canorus* . However, sublethal effects at pH greater-than-or-equal-to 5.0 were evident as reduced body size in *R. muscosa* embryos at pH 5.0 and 5.25, and earlier hatching of B. canorus embryos at pH 5.0. Experimental exposure to aluminum did not affect survival of embryos or tadpoles of either species. However, sublethal effects were evident as reduced body size of B. canorus tadpoles and earlier hatching in B. canorus embryos.	Bradford, D. F., Swanson, C. & Gordon, M. S. (1992) EFFECTS OF LOW PH AND ALUMINUM ON 2 DECLINING SPECIES OF AMPHIBIANS IN THE SIERRA-NEVADA, CALIFORNIA. Journal of Herpetology, 26, 369-377.

Sequoia and Kings Canyon (SEKI)	Episodic Acidification During Snowmelt of High Elevation Lakes in the Sierra Nevada Mountains of California	Atmospheric loads to dilute lakes in the Sierra Nevada mountains of California are very low, and fall almost entirely as snow. When acidic anions preferentially elute from melting snow, these low loads may nontheless be enough to acidify low ANC lakes. All lakes exhibited increases in NO3- concentrations during early snowmelt these were accompanied by increases in base cations, primarily Ca2+. In the first few days of snowmelt, NO3- concentrations at High Lake increased more rapidly than concentrations of base cations, resulting in ANC values below zero. Export of both NO3- and SO42- from the watersheds exceeded the inputs from the snowpack, suggesting that other sources (e.g., watershed minerals, stored inputs from the previous summer, transformations of other inputs) of these anions are important.	Stoddard, J. L. 1995. Episodic Acidification During Snowmelt of High Elevation Lakes in the Sierra Nevada Mountains of California. Water, Air and Soil Pollution. 85:353-358.
Sequoia/ Kings Canyon National Park (SEKI)	DEPOSITION OF ATMOSPHERIC IONS TO PINE BRANCHES AND SURROGATE SURFACES IN THE VICINITY OF EMERALD LAKE WATERSHED, SEQUOIA-NATIONAL-PARK	Researchers measured atmospheric dry deposition of ions to branches of native Pinus contorta and Pinus monticola (natural surfaces), and nylon filters and Whatman paper filters (surrogate surfaces) in the summer of 1987 near Emerald Lake Watershed (ELW) of the Sequoia National Park located on the western slope of the Sierra Nevada in California. Deposition fluxes of airborne NO3-, NH4+ and SO4(2-) to naive pines at the ELW were much higher than in the eastern Sierra Nevada, but several times lower than deposition fluxes to natural and surrogate surfaces at the highly polluted site in the San Gabriel Mountains of southern California. Deposition fluxes of NO3- and NH4+ to the natural and surrogate surfaces at the ELW were much higher than deposition of SO4(2-).	Bytnerowicz, A., Dawson, P. J., Morrison, C. L. & Poe, M. P. (1991) DEPOSITION OF ATMOSPHERIC IONS TO PINE BRANCHES AND SURROGATE SURFACES IN THE VICINITY OF EMERALD LAKE WATERSHED, SEQUOIA-NATIONAL-PARK. Atmospheric Environment Part a-General Topics, 25, 2203-2210.
Sequoia and Kings Canyon (SEKI)	Episodic lake acidification in the Sierra Nevada, California	Seven high-altitude headwater catchments were studied from 1990 to 1994 to evaluate susceptibility to episodic acid neutralizing capacity (ANC) depression. Dilution (decreasing base cation concentrations) was the primary factor in ANC depression during snowmelt, accounting for 75 to 97% of the ANC reduction. In lakes where acidification (increasing anion concentrations) was noted, nitrate and sulfate were equally important during the first half of snowmelt, while sulfate dominated the latter half. Modifications of the model were used to predict that approximately 6 and 10% of Sierran lakes will become episodically acidified with increases in nitrate and sulfate deposition of 50 and 150%, respectively. No lakes will be chronically acidified with these depositional increases.	Leydecker , A., J. O. Sickman and J. M. Melack . 1999. Episodic lake acidification in the Sierra Nevada, California. Water Resources Research. 35:2793-2804.
Sequoia and Kings Canyon (SEKI)	Foliar injury responses of ponderosa pine seedlings to ozone, wet and dry acidic deposition, and drought	A 3 year study evaluated the response of ponderosa pine to multiple interacting stresses in the central Sierra Nevada. Four factors combine to produce a pattern of foliar injury responses observed on the trees. Chlorotic mottle and foliar necrosis increased with increased ozone concentrations, but rarely exceeded 30% as needles with >30% abscised prematurely. Plant genotype strong influenced ozone responses. Susceptible seedlings showed severe ozone injury even at ambient concentrations. Drought stress in trees resulted in decreased ozone damage due to decreased stomatal conductance and ozone flux.	Temple, P. J., G. H. Riechers, and P. R. Miller. 1992. FOLIAR INJURY RESPONSES OF PONDEROSA PINE-SEEDLINGS TO OZONE, WET AND DRY ACIDIC DEPOSITION, AND DROUGHT. Environmental and Experimental Botany 32:101-113.
Sequoia and Kings Canyon (SEKI)	Influences of natural acidity and introduced fish on faunal assemblages in California alpine lakes	In an alpine area of the Sierra Nevada of California, naturally acidic waters and introduced fishes both strongly affect the distributions of native amphibians, zooplankton, and macroinvertebrates. The study area in Kings Canyon National Park contains 104 lakes with pH values between 5.0 and 9.3. The researchers surveyed 33 of these lakes for water chemistry and faunal assemblages. Yellow-legged frog tadpoles (*Rana muscosa*), common microcrustaceans (*Daphnia, Hesperodiaptomus, Diaptomus*), and larvae of a caddisfly (*Hesperophylax*) were rare or absent in acidic lakes but common in non-acidic lakes, and microcrustacean and macroinvertebrate species richness decreased with decreasing pH.	Bradford, D. F., Cooper, S. D., Jenkins, T. M., Kratz, K., Sarnelle, O. & Brown, A. D. (1998) Influences of natural acidity and introduced fish on faunal assemblages in California alpine lakes. Canadian Journal of Fisheries and Aquatic Sciences, 55, 2478-2491.
Sequoia/ Kings Canyon National Park (SEKI)	INTENSIVE STUDIES OF SIERRA-NEVADA CLOUDWATER CHEMISTRY AND ITS RELATIONSHIP TO PRECURSOR AEROSOL AND GAS CONCENTRATIONS	Measurements of inorganic aerosol and gas phase species are presented for three sites in central California during a 4 day period in April 1988. Large concentrations of NH3 at Visalia contributed significant excess alkalinity to the air mass sampled there. Concentrations of all major species were observed to decrease with elevation during most of the sampling periods. Concentrations at the upper two sites exhibited diurnal fluctuations, consistent with the transport of pollutants from San Joaquin Valley sources by daytime upslope winds. Concentrations of most of these species reached a maximum at the elevated sites on 28 April, as a weak cold front approached, reducing the atmospheric stability over the valley floor. In-cloud measurements made near the cloud base indicated a considerable S(IV) oxidation potential in the form of H2O2, but only low S(IV) concentrations. Cloudwater concentrations of formic acid were approximately three times acetic acid concentrations. Carbonyl concentrations were dominated by formaldehyde and glyoxal.	Collett, J. L. Jr., B. C. Daube Jr., D. Gunz and M. R. Hoffmann. 1990. Intensive studies of Sierra Nevada cloudwater Chemistry and its relationship to precursor aerosol and gas concentrations. Atmospheric Environment. 24A:1741-1757. Bibkey 599149
Sequoia and Kings Canyon (SEKI)	NITROGEN ALLOCATION IN PONDEROSA PINE-SEEDLINGS EXPOSED TO INTERACTING OZONE AND DROUGHT STRESSES	Nitrogen (N) resorbed from foliage before leaf abscission is a significant source of N for new leaves. The widely distributed photochemical air pollutant ozone (O-3) accelerates foliar senescence and leaf abscission and therefore could interfere with the process of N resorption. The objective of this study was to determine the effects of O-3 and drought stress on the N economy of ponderosa pine (Pinus ponderosa Laws.), a species highly susceptible to O-3. O-3-injured ponderosa pine seedlings increased resorption of N from older needles and increased partitioning of N to current-year foliage. The increased N in current-year needles facilitated increased rates of photosynthesis in these needles, thus partly compensating for the O-3-induced loss of older leaves.	Temple, P. J. & Riechers, G. H. (1995) NITROGEN ALLOCATION IN PONDEROSA PINE-SEEDLINGS EXPOSED TO INTERACTING OZONE AND DROUGHT STRESSES. New Phytologist, 130, 97-104.

Sequoia and Kings Canyon (SEKI)	Evidence for nutrient enrichment of high-elevation lakes in the Sierra Nevada, California	Based on studies of high-elevation, Sierra Nevada catchments during the period from 1983 through 1996, the researchers describe temporal variations in the concentrations of NO3- and SO42- in surface waters. During snowmelt, some catchments had a pattern of NO3- increase to a plateau between the start of snowmelt and some weeks before runoff peaked, and a decline as runoff increased to its maximum. In other catchments, NO3- concentrations peaked during the autumn and winter. Long-term trends in surface water chemistry were evident in only two catchments: an increase in SO42- concentrations in surface waters of the Ruby Lake basin, and a lowering of annual maxima and minima of NO3- concentrations at Emerald Lake. From October 1987 through April 1994, SO42- concentrations increased from about 6 mu eq L-1 to about 12 mu eq L-1 in Ruby Lake, and in Emerald Lake, NO3- maxima declined by 25-50 %.	Sickman, J. O., Melack, J. M. & Clow, D. W. (2003) Evidence for nutrient enrichment of high-elevation lakes in the Sierra Nevada, California. Limnology and Oceanography, 48, 1885-1892.
Sequoia and Kings Canyon (SEKI)	Nitrogen deposition in California forests: A review	Atmospheric concentrations and deposition of the major nitrogenous (N) compounds and their biological effects in California forests are reviewed. Climatic characteristics of California are summarized in light of their effects on pollutant accumulation and transport. Over large areas of the state dry deposition is of greater magnitude than wet deposition due to the arid climate. Most of the deposition in such areas occurs in summer as a result of surface deposition of nitric acid vapor (HNO3) as well as particulate nitrate (NO3-) and ammonium (NH4+). Internal uptake of gaseous N pollutants such as nitrogen dioxide (NO2), nitric oxide (NO), HNO3, peroxyacetyl nitrate (PAN), ammonia (NH3), and others provides additional N to forests. In locations close to photochemical smog source areas, concentrations of oxidized forms of N (NO2, HNO3, PAN) dominate, while in areas near agricultural activities the importance of reduced N forms (NH3, NH4+) significantly increases. In N saturated forests high concentrations of NO3- are found in streamwater, soil solution, and in foliage.	Bytnerowicz, A. & Fenn, M. E. (1996) Nitrogen deposition in California forests: A review. Environmental Pollution, 92, 127-146.
Sequoia and Kings Canyon (SEKI)	Nitrogen emissions, deposition, and monitoring in the western United States	Nitrogen (N) deposition in the western United States ranges from I to 4 kilograms (kg) per hectare (ha) per year overmuch of the region to as high as 30 to 90 kg per ha per year downwind of major urban and agricultural areas. Primary N emissions sources are transportation, agriculture, and industry. Emissions of N as ammonia are about 50% as great as emissions of N as nitrogen oxides. An unknown amount of N deposition to the West Coast originates from Asia. Nitrogen deposition has increased in the West because of rapid increases in urbanization, population, distance driven, and large concentrated animal feeding operations. Studies of ecological effects suggest that emissions reductions are needed to protect sensitive ecosystem components. National monitoring networks provide long-term wet deposition data and estimated dry deposition data at remote sites.	Fenn, M. E., Haeuber, R., Tonnesen, G. S., Baron, J. S., Grossman-Clarke, S., Hope, D., Jaffe, D. A., Copeland, S., Geiser, L., Rueth, H. M. & Sickman, J. O. (2003) Nitrogen emissions, deposition, and monitoring in the western United States. Bioscience, 5
Sequoia and Kings Canyon (SEKI)	Size and composition distribution of airborne particulate matter in northern California: I-particulate mass, carbon, and water-soluble ions	The San Joaquin Valley (SJV), in California has one of the most severe particulate air quality problems in the United States during the winter season. In the current study, measurements of particulate matter (PM) smaller than 10 mum in aerodynamic diameter (PM10), fine particles (PM1.8), and ultrafine particles (PM0.1) were made from December 2000-February2001 at Sequoia National Park. The majority of the fine particle mass was ammonium nitrate driven by an excess of gas-phase ammonia.Ultrafine particle concentrations were distinctly diurnal, with daytime concentrations similar to 50% lower than nighttime concentrations. The majority of the ultrafine particle mass was associated with carbonaceous material. The high concentrations of ultrafine particles in the SJV pose a potential serious public health threat that should be addressed.	Herner, J. D., J. Aw, O. Gao, D. P. Chang, and M. J. Kleeman. 2005. Size and composition distribution of airborne particulate matter in northern California: I-particulate mass, carbon, and water-soluble ions. Journal of the Air & Waste Management Association 55:30-51.
Sequoia and Kings Canyon (SEKI)	Summer-time distribution of air pollutants in Sequoia National Park, california	Concentrations of air pollutants were monitored during the May-November 1999 period on a network of forested sites in Sequoia National Park, California. Elevated concentrations of O-3 (seasonal means 41-71 ppb), HNO3 (seasonal means 0.4-2.9 mug/ml), NH3 (seasonal means 1.6-4.5 mug/m(3)), NO3- (1.1-2.0 mug/m(3)) and NH4+ (1.0-1.9 mug/m(3)) were determined. Concentrations of other pollutants were low. With increasing elevation and distance from the pollution source area of O-3, NH3 and HNO3 concentrations decreased. Ammonia and NH4+ were dominant N pollutants indicating strong influence of agricultural emissions on forests and other ecosystems of the Sequoia National Park.	Bytnerowicz, A., Tausz, M., Alonso, R., Jones, D., Johnson, R. & Grulke, N. (2002) Summer-time distribution of air pollutants in Sequoia National Park, california. Environmental Pollution, 118, 187-203.
Sequoia/ Kings Canyon National Park (SEKI)	THE CHEMICAL-COMPOSITION OF INTERCEPTED CLOUDWATER IN THE SIERRA-NEVADA	Cloudwater was sampled in Sequoia and Yosemite National Parks between September 1987 and August 1988. Peak interception periods occurred in November and April. pH values ranged from 3.9 to 6.5 in Sequoia NP, and 3.8 to 5.2 in Yosemite NP. Chemical composition is dominated by NO3, SO4, and NH4. The presence of NH4 plays a key role in the neutralization of cloudwater. In the absence of NH4, cloudwater pH values in the Sierra may fall below 3. Cloud interception may be the dominant deposition mechanism for isolated conifers and ridgetop canopies.	Collett, J. L., Daube, B. C. & Hoffmann, M. R. (1990) THE CHEMICAL-COMPOSITION OF INTERCEPTED CLOUDWATER IN THE SIERRA-NEVADA. Atmospheric Environment Part a-General Topics, 24, 959-972.
Ozone Pollution and Effects			
Sequoia and Kings Canyon (SEKI)	Canopy transpiration of Jeffrey pine in mesic and xeric microsites: O-3 uptake and injury response	Canopy transpiration of mature Jeffrey pine was compared in "mesic" and "xeric" microsites differing in topographical position, bole growth, and the level of drought stress experienced. Diurnal and seasonal course of canopy transpiration was monitored with thermal dissipation probes in 1999 and 2000. Based on leaf-level gas exchange measurements, trees in mesic sites had an estimated 46% decrease in O3 uptake from June to August. Xeric trees had an estimated 72% decrease over the same time period. A multivariate analysis of morphological and tissue chemistry attributes in mid-canopy elucidated differences in mesic and xeric tree response. Mesic trees exhibited more O3 injury than xeric trees based on reduced foliar nitrogen content and needle retention in mid-canopy.	Grulke, N. E., Johnson, R., Esperanza, A., Jones, D., Nguyen, T., Posch, S. & Tausz, M. (2003) Canopy transpiration of Jeffrey pine in mesic and xeric microsites: O-3 uptake and injury response. Trees-Structure and Function, 17, 292-298.

Sequoia and Kings Canyon (SEKI)	Changes in gas exchange characteristics during the life span of giant sequoia: implications for the response to current and future concentrations of atmospheric ozone	This study determined the physiological effects of ozone on three age classes of giant sequoia (current year, 12 and 125 years), and assessed the age-related differences in sensitivity to pollutants by examining physiological changes (gas exchange and water use efficiency). The study sites were located in Giant Forest in Sequoia National Park, CA. Carbon dioxide (CO_2) exchange, dark respiration and stomatal conductance were all higher in current age trees. Giant sequoia seedling are sensitive to ozone exposure until they reach 5 years. Low conductance, high water use efficiency and compact mesophyll all contribute to a natural ozone tolerance, or defense, or both in foliage of older trees.	Grulke, N. E. & Miller, P. R. (1994) CHANGES IN GAS-EXCHANGE CHARACTERISTICS DURING THE LIFE-SPAN OF GIANT SEQUOIA - IMPLICATIONS FOR RESPONSE TO CURRENT AND FUTURE CONCENTRATIONS OF ATMOSPHERIC OZONE. Tree Physiology, 14, 659-668.
Sequoia and Kings Canyon (SEKI)	Effects of long-term ozone exposure and drought on the photosynthetic capacity of ponderosa pine	Seedlings of ponderosa pine (*Pinus ponderosa*) were grown for three years under three atmospheric ozone concentrations - clean air (CF), ambient ozone (NF), and 1.5 times ambient ozone (NF1 50) - at a moderately-polluted site in the Sierra Nevada. Current-year needles of NF150 trees had higher photosynthetic capacity than NF and CF trees during late summer. This photosynthetic compensation in well-watered NF150 seedlings was related to higher tissue nitrogen concentration in the current-year foliage and possibly to increased inorganic phosphate cycling, both responses to the loss of older needles. Drought-stressed NF150 seedlings were partially protected from ozone damage by decreased stomatal conductance and did not exhibit the same degree of photosynthetic compensation. No differences in photosynthetic rate were found between CF and NF seedlings or between well-watered and drought-stressed seedlings (across ozone treatments) in any needle age class.	Beyers, J. L., Riechers, G. H. & Temple, P. J. (1992) EFFECTS OF LONG-TERM OZONE EXPOSURE AND DROUGHT ON THE PHOTOSYNTHETIC CAPACITY OF PONDEROSA PINE (PINUS-PONDEROSA LAWS). New Phytologist, 122, 81-90.
Sequoia and Kings Canyon (SEKI)	HISTOLOGICAL DETERMINATION OF OZONE INJURY SYMPTOMS OF PRIMARY NEEDLES OF GIANT SEQUOIA (SEQUOIADENDRON-GIGANTEUM BUCCH)	Giant sequoia (Sequoiadendron giganteum Bucch.) is a unique resource that exists only in groves on the western slopes of the Sierra Nevada in California. Since Sequoia and King's Canyon (SEKI) National Parks are experiencing ozone concentrations phytotoxic to some species of Pinus, we performed several experiments on S. giganteum seedlings to determine the ozone sensitivity of their primary needles and their suitability as sensitive bioindicators during the seedlings stage of growth. The overall anatomy of primary needles from SEKI was similar to that of those sampled from the fumigation experiment; SEKI samples exhibited a high degree of amorphous cell staining (between 67 and 81%). Cell death averaged 5.1% from all the park samples, a percentage within to the range of cell death (0.9-6.2%) in the ambient air chambers.	Evans, L. S. & Leonard, M. R. (1991) HISTOLOGICAL DETERMINATION OF OZONE INJURY SYMPTOMS OF PRIMARY NEEDLES OF GIANT SEQUOIA (SEQUOIADENDRON-GIGANTEUM BUCCH). New Phytologist, 117, 557-564.
Sequoia and Kings Canyon (SEKI)	Regional growth trends in ozone-stressed ponderosa pine (Pinus ponderosa) in the Sierra Nevada, California, USA	This study describes dendroecological techniques to quantify growth trends of ponderosa pine in the mixed conifer forest of the Sierra Nevada. Study sites include Yosemite National Park and Sequoia & Kings Canyon National Park	Arbaugh, M. J., L. J. Robinson and D. L. Peterson. 1991. Regional growth trends in ozone-stressed ponderosa pine (Pinus ponderosa) in the Sierra Nevada, California, USA. The Holocene. 1:50-61.
Sequoia and Kings Canyon (SEKI)	Stricter ozone ambient air quality standard has beneficial effect on ponderosa pine in California	Researchers used a process-based tree-growth model (TREGRO) to show that over the past 37 years, changes in O-3 exposure, with accompanying variation in climate, are reflected in changes in the growth of *Pinus ponderosa Dougl.* Despite variation in temperature and precipitation over the study period (1963-1999), O-3 exposure consistently reduced simulated tree growth. Simulated growth reductions increased concurrent with increasing O-3 exposure. As O-3 exposures decreased during the 1980s and 1990s, effects on growth also decreased. This implies that emission control strategies taken to reduce exposures to attain O-3 standards benefited *P. ponderosa* growth in the San Bernardino Mountains. This modeling approach provides a powerful tool for solving the difficult problem of evaluating regulatory effectiveness by simulating plant response using long-term climate and air pollution exposure records for a given region.	Tingey, D. T., W. E. Hogsett, E. H. Lee and J. A. Laurence. 2004. Stricter Ozone Ambient Air Quality Standard Has Beneficial Effect on Ponderosa Pine in California. Environmental Management. 34:397-407.
Sequoia and Kings Canyon (SEKI)	THE SPATIAL VARIATION OF OZONE CLIMATOLOGY ON THE WESTERN SLOPE OF THE SIERRA-NEVADA	The spatial variability of ozone climatology is described for six remote sites on the western slope of the Sierra Nevada. A statistical analysis was applied to determine relationships between ozone concentrations and atmospheric variables, as well as relationships among sites. The sites, whose locations vary in latitude, elevation, and topography, show considerable variability in climatological patterns and statistics. However, the stations fall into two general groups: those with a distinct diurnal ozone pattern and those with a flat diurnal ozone pattern. Diurnal variations among sites appear to depend primarily on topographic setting rather than on remoteness from urban sources.	Van Ooy, D. J. and J. J. Carroll. 1995. The spatial variation of ozone climatology on the western slope of the Sierra Nevada. Atmospheric Environment. 29:1319-1330
Sequoia and Kings Canyon (SEKI)	Variation in morphological and biochemical O-3 injury attributes of mature Jeffrey pine within canopies and between microsites	Crown morphology and leaf tissue chemical and biochemical attributes associated with ozone (O-3) injury were assessed in the lower, mid- and upper canopy of Jeffrey pine (*Pinus jeffreyi Grev. & Balf.*) growing in mesic and xeric microsites in Sequoia National Park, California. In mesic microsites, canopy response to O-3 was characterized by thinner branches, earlier needle fall, less chlorotic leaf mottling, and lower foliar antioxidant capacity, especially of the aqueous fraction. In xeric microsites, canopy response to 03 was characterized by higher chlorotic leaf mottling, shorter needles, lower needle chlorophyll concentration, and greater foliar antioxidant capacity. Increased leaf chlorotic mottle in xeric microsites was related to drought stress and increased concurrent internal production of highly reactive oxygen species, and not necessarily to stomatal O-3 uptake. Within-canopy position also influenced the expression Of O-3 injury in Jeffrey pine.	Grulke, N. E., Johnson, R., Monschein, S., Nikolova, P. & Tausz, M. (2003) Variation in morphological and biochemical O-3 injury attributes of mature Jeffrey pine within canopies and between microsites. Tree Physiology, 23, 923-929.
Biogeochemistry of Pollutants in Ecosystems			
Sequoia and Kings Canyon (SEKI)	Nutrient export from watersheds on Mt. Desert Island, Maine, as a function of land use and fire history	A study of 13 small watersheds on Mt. Desert Island, Maine, was conducted from January 1999 to September 2000 to determine nutrient export delivery to coastal waters around the island, and to determine whether a series of wildfires in 1947 have affected nutrient export in burned watersheds. Nutrient export (nitrate-nitrogen, total nitrogen, total phosphorus) was determined for each watershed during the study period, and was normalized by watershed area. The yield of nitrate-nitrogen (N) ranged from 10 to 140 kg/km(2)/year. Total N yield ranged from 42 to 250 kg/km(2)/year. Total phosphorus (P) yield ranged from 1.4 to 7.9 kg/km(2)/year. Watersheds entirely within Acadia National Park exported significantly less total N and total P than watersheds that were partly or entirely outside the park boundary. Nitrate-N export was not significantly different in these two groups of watersheds, perhaps because atmospheric deposition is a dominant source of nitrate in the study area.	Nielsen, M. G. & Kahl, J. S. (2007) Nutrient export from watersheds on Mt. Desert Island, Maine, as a function of land use and fire history. Environmental Monitoring and Assessment, 126, 81-96.
Sequoia and Kings Canyon (SEKI)	Processes regulating the solute concentrations of snowmelt runoff in two subalpine catchments of the Sierra Nevada, California.	This study examines the processes of dilution, degradation, and sorption to plant foliage of organophosphate (OF) pesticides during the summertime in an air corridor originating in the southern Central Valley of California and moving into the nearby Sierra Nevada mountains, Residues of chlorpyrifos, methidathion, and their oxons were examined in air and pine needles at three sites in the southern Sierra. At higher elevations needles contained lesser amounts of OP residues and at lower frequency, while air primarily contained the oxon form. With increasing elevation the ratio of thion to oxon form of chlorpyrifos in air decreased from 1.85 to 0.46 indicating that atmospheric oxidation was occuring. Based on the amounts of foliar deposition found, we estimate that during summer months nearly 16 kg of chlorpyrifos and its oxon may enter Sequoia National Park plant foliage; and deduce that for airborne OP insecticides, foliar deposition is a significant summertime fate process, along with atmospheric degradation and dilution.	Williams, M. R., Leydecker, A., Brown, A. D. & Melack, J. M. (2001) Processes regulating the solute concentrations of snowmelt runoff in two subalpine catchments of the Sierra Nevada, California. Water Resources Research, 37, 1993-2008.

Sequoia and Kings Canyon (SEKI)	Spatial and temporal variability in the amount and source of dissolved organic carbon: Implications for ultraviolet exposure in amphibian habitats	The amount, chemical composition, and source of dissolved organic carbon (DOC), together with in situ ultraviolet (UV-B) attenuation, were measured during summers of 1999, 2000, and 2001 at Rocky Mountain National Park (Colorado); Sequoia and Kings Canyon National Park/John Muir Wilderness (California), and Glacier National Park (Montana). Attenuation of UV-B was significantly related to DOC concentrations over the three years in Rocky Mountainand across all parks in 2000. The relatively low R-2 values, however, reflect significant temporal and spatial variability in the specific attenuation per unit DOC. Sites in Sequoia-Kings Canyon were characterized by DOC derived primarily from algal sources and showed much deeper UV-B penetration, whereas sites in Glacier and Rocky Mountain contained a mix of algal and terrestrial DOC-dominated sites. Catchment vegetation and soil characteristics, precipitation, and local hydrology interacted to make it difficult to predict potential exposure from DOC concentrations.	Brooks, P. D., O'Reilly, C. M., Diamond, S. A., Campbell, D. H., Knapp, R., Bradford, D., Corn, P. S., Hossack, B. & Tonnessen, K. (2005) Spatial and temporal variability in the amount and source of dissolved organic carbon: Implications for ultraviolet exposure in amphibian habitats. Ecosystems, 8, 478-487.
Climate Change Effects			
Sequoia and Kings Canyon (SEKI)	LARGE-SCALE ATMOSPHERIC FORCING OF RECENT TRENDS TOWARD EARLY SNOWMELT RUNOFF IN CALIFORNIA	Weather stations in central California, including the central Sierra Nevada, have shown trends toward warmer winters since the 1940s. A series of regression analyses indicate that runoff timing responds equally to the observed decadal-scale trends in winter temperature and interannual temperature variations of the same magnitude, suggesting that the temperature trend is sufficient to explain the runoff-timing trends. The immediate cause of the trend toward warmer winters in California is a concurrent, long-term fluctuation in winter atmospheric circulations over the North Pacific Ocean and North America that is not immediately distinguishable from natural atmospheric variability. Since the late 1940s, winter wind fields have been displaced progressively southward over the central North Pacific and northward over the west coast of North America. These shifts in atmospheric circulations are associated with concurrent shifts in both West Coast air temperatures and North Pacific sea surface temperatures.	Dettinger, M. D. & Cayan, D. R. (1995) LARGE-SCALE ATMOSPHERIC FORCING OF RECENT TRENDS TOWARD EARLY SNOWMELT RUNOFF IN CALIFORNIA. Journal of Climate, 8, 606-623.
Sequoia and Kings Canyon (SEKI)	Evidence that local land use practices influence regional climate, vegetation, and stream flow patterns in adjacent natural areas	64% of the variance in understory species distributions at landscape scales were described generally by gradients of elevation and under-canopy solar radiation. Superimposed on broad-scale climatic gradients are small-scale gradients characterized by patches of light, pockets of fertile soil, and zones of high soil moisture. Plant species showed weak affinities to overstory vegetation types, with 43% of the plant species found in three or more vegetation types. Replicate transects along several environmental gradients may provide the means to monitor plant diversity and species migrations at landscape scales because: (1) ecotones may play crucial roles in expanding the geophysiological ranges of many plant species; (2) low affinities of understory species to overstory forest types may predispose vegetation types to be resilient to rapid environmental change; and (3) ecotones may help buffer plant species from extirpation and extinction.	Stohlgren, T. J., Chase, T. N., Pielke, R. A., Kittel, T. G. F. & Baron, J. S. (1998) Evidence that local land use practices influence regional climate, vegetation, and stream flow patterns in adjacent natural areas. Global Change Biology, 4, 495-504.
Sequoia and Kings Canyon (SEKI)	Response of tree-line populations of foxtail pine (Pinus balfouriana) to climate variation over the last 1000 years	Stand density, recruitment rate, and mortality rate in tree-line forests of foxtail pine (*Pinus balfouriana*) were reconstructed for the last 1000 years. Recruitment and stand density were significantly and inversely correlated with summer temperature during the last 1000 years. Mortality rates were uncorrelated with climate. The inverse correlation between recruitment and climate suggests that water balance may mediate the effects of temperature on tree line forests, a hypothesis that is supported by a significant positive correlation between seedling establishment and winter snowpack during the last 50 years. Despite large changes in the elevation of tree line at these sites during the time period of the reconstruction, populations near tree line were largely unaffected by climate variation, suggesting that steep gradients in vulnerability to climate change may exist at tree line in the Sierra Nevada.	Lloyd, A. H. (1997) Response of tree-line populations of foxtail pine (Pinus balfouriana) to climate variation over the last 1000 years. Canadian Journal of Forest Research-Revue Canadienne De Recherche Forestiere, 27, 936-942.
Sequoia and Kings Canyon (SEKI)	SUB-ALPINE TREE GROWTH, CLIMATE, AND INCREASING CO2 - AN ASSESSMENT OF RECENT GROWTH TRENDS	Five tree-ring series from foxtail pine (Pinus balfouriana), lodgepole pine (P. murrayana), and western juniper (Juniperus occidentalis) collected in the Sierra Nevada, California, were analyzed to determine if the temporal and spatial patterns of recent growth were consistent with the hypothesized CO2-induced growth enhancement. For three of the five sites, 20th-century growth variation can be adequately modeled as a function of climatic variation. Taken together, these results do not indicate that CO2-induced growth enhancement is occurring among subalpine conifers in the Sierra Nevada. Response surfaces demonstrate that precipitation during previous winter and temperature during the current summer interact in controlling growth and that the response can be nonlinear. Although maximum growth rates occur under conditions of high winter precipitation and warm summers for all three species, substantial species-to-species variation occurs in the response to these two variables.	Graumlich, L. J. (1991) SUB-ALPINE TREE GROWTH, CLIMATE, AND INCREASING CO2 - AN ASSESSMENT OF RECENT GROWTH TRENDS. Ecology, 72, 1-11.
Other Atmospheric Deposition Effects			
Sequoia and Kings Canyon (SEKI)	Pesticides and PCB contaminants in fish and tadpoles from the Kaweah River basin, California	There is accumulating evidence of transport and deposition of airborne pollutants including ozone, particulate matter, nitrogen oxides, nitrogen and phosphorus, and pesticides to the Sierra Nevadas. Knowing the types and concentrations of contaminants in various Sierra Nevada ecosystem compartments is important to understanding the impact these pollutants might have on the Sierran plants and wildlife. The researchers found that polychlorinated biphenyls (PCBs) are present in air, surface water, snow and fish (lake trout: *Salvelinus namaycush*) and rainbow trout (*Oncorhynchus mykiss* ssp.) in the Lake Tahoe basin in the central Sierras. The objective of this study was to determine concentrations of PCBs and selected pesticides in brook trout (*Salvelinus fontinalis*) and tree frogs (*Hyla regilla*) in the Kaweah River basin, and to compare the concentrations of these pollutants with those from other locations in California.	Datta, S., Hansen, L., McConnell, L., Baker, J., LeNoir, J. & Seiber, J. N. (1998) Pesticides and PCB contaminants in fish and tadpoles from the Kaweah River basin, California. Bulletin of Environmental Contamination and Toxicology, 60, 829-836.
Sequoia and Kings Canyon (SEKI)	Pesticides in mountain yellow-legged frogs (Rana muscosa) from the Sierra Nevada Mountains of California, USA	In 1997, pesticide concentrations were measured in mountain yellow-legged frogs (*Rana muscosa*) from two areas in the Sierra Nevada Mountains of California, USA. One area (Sixty Lakes Basin, Kings Canyon National Park) had large, apparently healthy populations of frogs. A second area (Tablelands, Sequoia National Park) once had large populations, but the species had been extirpated from this area by the early 1980s. In frog tissues, dichlorodiphenyldichloroethylene (DDE) concentration was one to two orders of magnitude higher than the other organochlorines (46 +/- 20 ng/g wet wt at Tablelands and 17 +/- 8 Sixty Lakes). Both gamma-chlordane and traps-nonachlor were found in significantly greater concentrations in Tablelands frog tissues compared with Sixty Lakes. Organophosphate insecticides, chlorpyrifos, and diazinon were observed primarily in surface water with higher concentrations at the Tablelands sites. No contaminants were significantly higher in our Sixty Lakes samples.	Fellers, G. M., McConnell, L. L., Pratt, D. & Datta, S. (2004) Pesticides in mountain yellow-legged frogs (Rana muscosa) from the Sierra Nevada Mountains of California, USA. Environmental Toxicology and Chemistry, 23, 2170-2177.

Sequoia and Kings Canyon (SEKI)	Processes regulating the solute concentrations of snowmelt runoff in two subalpine catchments of the Sierra Nevada, California	Geochemical processes regulating solute concentrations in snowmelt runoff were investigated for the snowmelt periods of 1992 and 1993 in two subalpine catchments in Sequoia National Park, California. Mineral weathering was the major source of solutes in runoff. Calcium export was attributed to dry deposition and the weathering of mafic minerals and disseminated calcite. Cation exchange was important in the regulation of K and increased base cation export in response to rain-on-snow events and LiBr tracer. Sulfate fluxes were attributed to snowpack elution and SO4 desorption after the beginning of melt. The selective retention of Li during tracer experiments suggests that acid-neutralizing capacity is linked to soil stocks along convoluted flow paths and is not necessarily compromised in areas of sparse soil cover.	Williams, M. R., Leydecker, A., Brown, A. D. & Melack, J. M. (2001) Processes regulating the solute concentrations of snowmelt runoff in two subalpine catchments of the Sierra Nevada, California. Water Resources Research, 37, 1993-2008.
Sequoia and Kings Canyon (SEKI)	RESPONSES OF ZOOPLANKTON AND ZOOBENTHOS TO EXPERIMENTAL ACIDIFICATION IN A HIGH-ELEVATION LAKE (SIERRA-NEVADA, CALIFORNIA, USA)	Researchers conducted an acidification experiment using large enclosure at Emerald Lake in the Sierra Nevada, California, U.S.A in the summer of 1987. The experiment was designed to examine the effects of acidification on the zooplankton and zoobenthos assemblages of Sierran lakes.The zooplankton assemblage was sensitive to acidification. *Daphnia rosea* and *Diaptomns signicauda* decreased in abundance below pH 5.5–5.8, and virtually disappeared below pH 5.0. *Bosmina longirostris* and *Keratella taurocephala* became more abundant with decreasing pH. although *B. longirostris* was rare in the pH 4.7 treatment. These species might serve as reliable indicators of early acidification in lakes such as Emerald Lake. The elimination of *D. rosea* in acidified treatments probably allowed the more acid-tolerant taxa to increase in abundance because interspecific competition was reduced. Even slight acidification can therefore alter the structure of the zooplankton assemblage. There was no evidence that the zoobenthos in the enclosures was affected by acidification.	Barmuta, L. A., Cooper, S. D., Hamilton, S. K., Kratz, K. W. & Melack, J. M. (1990) RESPONSES OF ZOOPLANKTON AND ZOOBENTHOS TO EXPERIMENTAL ACIDIFICATION IN A HIGH-ELEVATION LAKE (SIERRA-NEVADA, CALIFORNIA, USA). Freshwater Biology, 23, 571-586.
Sequoia and Kings Canyon (SEKI)	Summertime transport of current-use pesticides from California's Central Valley to the Sierra Nevada Mountain Range, USA	Agricultural activity in California's Central Valley may be an important source of pesticides that are transported in the air to the: Sierra Nevada Mountain Range, USA. Pesticides may volatilize under warm temperatures typical of the valley and be transported through the atmosphere to be deposited in the cooler, higher elevation regions of the Sierra Nevada Mountains. To determine the extent of summertime atmospheric transport of pesticides to this region, high-volume air, dry deposition, and surface water samples were collected. Results revealed that the highest residue concentrations were those of compounds with heavy summertime agricultural use. A significant drop in pesticide concentrations in both air and water samples was observed within a few 100-m elevation from the valley; however, levels remained relatively constant between similar to 500 and 2,000 m. Aggregate exposure calculations showed concentrations were well below 96-h LC50 values for rainbow trout and stonefly but concentrations may be harmful to amphipods.	LeNoir, J. S., McConnell, L. L., Fellers, G. M., Cahill, T. M. & Seiber, J. N. (1999) Summertime transport of current-use pesticides from California's Central Valley to the Sierra Nevada Mountain Range, USA. Environmental Toxicology and Chemistry, 18, 2715-2722.
Sequoia and Kings Canyon (SEKI)	Wet deposition of current-use pesticides in the Sierra Nevada mountain range, California, USA	Atmospheric inputs of pesticides transported from California's Central Valley to the Sierra Nevada mountains were investigated by collecting winter-spring precipitation (rain and snow) from Sequoia National Park. Pesticides currently used in California's Central Valley were detected in snow and rain samples from two elevations in Sequoia National Park (SNP) in the southern Sierras. At the lower elevation site (533 m), chlorothalonil was present at the highest levels (<0.4-85 ng/L), followed by malathion (<0.046-24 ng/L), diazinon (<0.21-19 ng/L), and chlorpyrifos (1.3-4.4 ng/L). At 1,920 m elevation, chlorothalonil was also present at the highest levels (<0.57-13 ng/L) followed by diazinon (<0.057-14 ng/L), chlorpyrifos (1.1-13 ng/L), and malathion (<0.045-6 ng/L). Trifluralin, alpha- and gamma-hexachlorocyclohexane (HCH), and alpha- and beta-endosulfan were also detected at both locations and at lower concentrations, generally ranging from 0.5 to 2 ng/L. An estimated annual loading of one chemical, chlorpyrifos, of 24 to 31 kg/year was made for the SNP land area.	McConnell, L. L., LeNoir, J. S., Datta, S. & Seiber, J. N. (1998) Wet deposition of current-use pesticides in the Sierra Nevada mountain range, California, USA. Environmental Toxicology and Chemistry, 17, 1908-1916.