Chapter 16: Ecoregion 11.1.1 California Coastal Sage, Chaparral, and Oak Woodlands: San Dimas Experimental Forest, California

Peter M. Wohlgemuth, Philip J. Riggan, and Shirley A. Birosik[1]

Introduction

This chapter is a review and synthesis of research conducted in and adjacent to the San Dimas Experimental Forest (SDEF) on stream nutrients and biological responses to stream nutrients. It is intended to inform national and regional water quality regulatory agencies, such as the U.S. Environmental Protection Agency, the California Regional Water Quality Control Boards, and the California Department of Forestry and Fire Protection, about existing results of relevant scientific studies that are available at SDEF, and to identify future field and synthetic research of potential use to regulatory agencies that might be conducted at SDEF.

Site Description

SDEF is located in a front range of the San Gabriel Mountains, 45 km northeast of Los Angeles in southern California (fig. 16.1). SDEF (lat. 34.182° N, long. 117.764° W) is 7000 ha in area, ranges in elevation from 450 to 1675 m, and has very steep hillslopes averaging 65 to 70 percent and stream channel gradients averaging 10 to 15 percent (Dunn et al. 1988). Vegetation on SDEF is predominantly mixed chaparral with chamise (*Adenostoma fasciculatum* Hook. & Arn.), scrub oak (*Quercus berberidifolia* Liebm.), and various ceanothus species (*Ceanothus* spp). Scattered trees grow in the upper riparian zones, including California live oak (*Q. agrifolia* Née) and California laurel (*Umbellularia californica* (Hook. & Arn.) Nutt.), while the lower reaches support fairly dense riparian woodlands of sycamore (*Platanus occidentalis* L.), willow (*Baccharis salicifolia* (Ruiz & Pav.) Pers. Liebm.), various oaks, and white alder (*Alnus rhombifolia* Nutt.). Some pine-oak forest occurs at higher elevations, especially on north-facing aspects, including canyon live oak (*Q. chrysolepis* Liebm.), big-cone Douglas-fir (*Pseudotsuga macrocarpa* (Vasey) Mayr), sugar pine (*Pinus lambertiana* Douglas), and remnant ponderosa pine (*P. ponderosa* Lawson & C. Lawson). Major disturbance events have included stand-replacing wildfires that burned large areas within SDEF in 1919, 1960, and 2002.

[1] **Peter M. Wohlgemuth** is a physical scientist and **Philip J. Riggan** is a research ecologist, U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, 4955 Canyon Crest Drive, Riverside, CA 92507; **Shirley A. Birosik** is a senior environmental scientist, California Regional Water Quality Control Board, Region 4, 320 W 4th Street, Suite 200, Los Angeles, CA 90013.

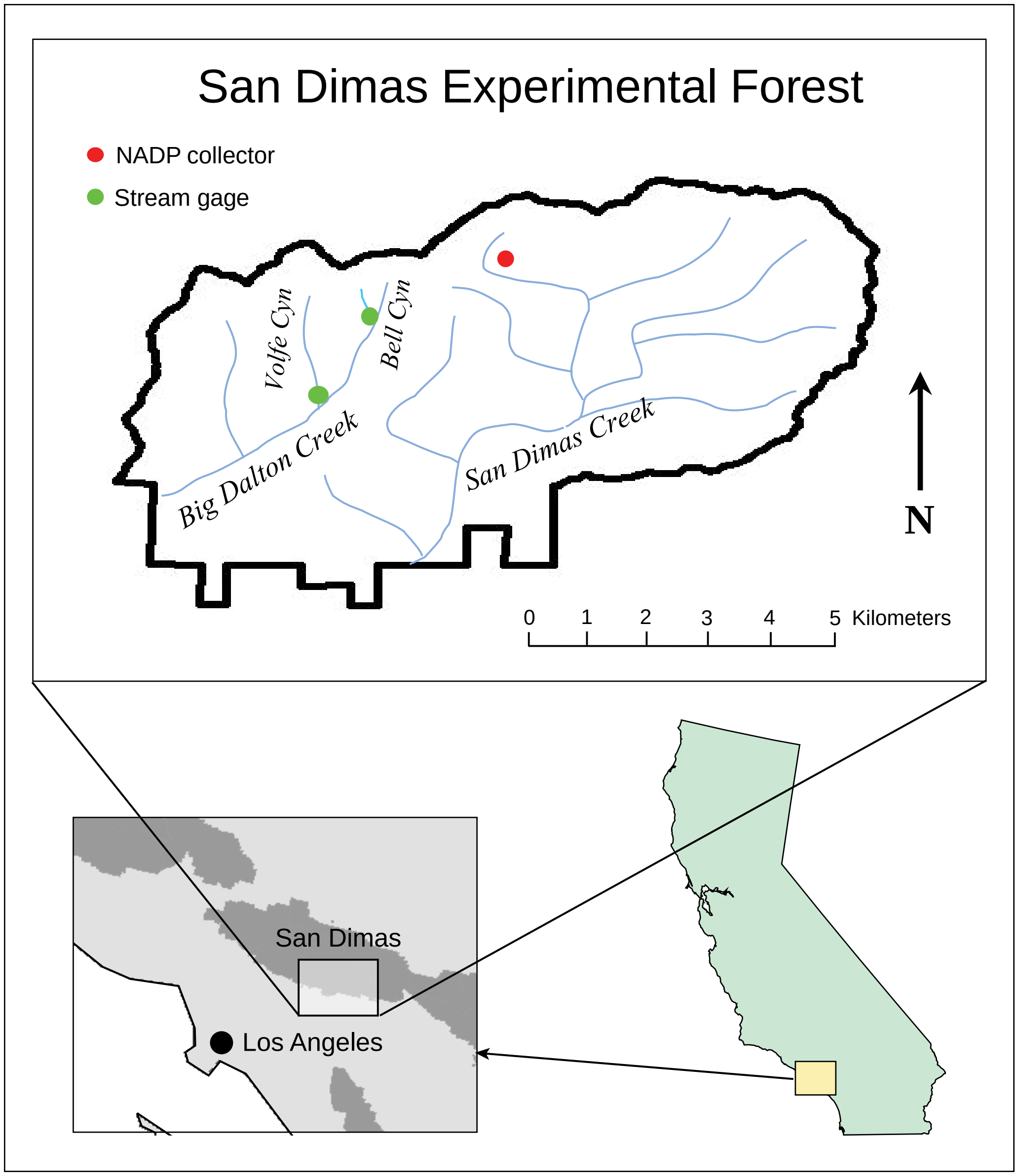

Figure 16.1—The San Dimas Experimental Forest showing major streams, sites of stream gages, and the National Atmospheric Deposition Program (NADP) monitoring station.

SDEF headwater catchments contain ephemeral first- and second-order streams with little riparian zone development. Lower elevation fourth- and fifth-order streams are intermittent, with year-round surface flow in wet years, but periods of no flow in dry years. The structure of streams in SDEF consists primarily of steep, bedrock channels with a shallow alluvial lag. Well-defined pools and riffles are not usually apparent in SDEF streams.

The streams in SDEF are part of the San Gabriel River contributing area and are useful for regional comparisons because they have had relatively few anthro-pogenic impacts. For example, SDEF streams have received minimal recreational visitation and thus reflect an absence of associated streamside roads or extensive trail systems that can affect natural stream structure and water quality. In addition, SDEF channels have not been hydromodified, a common practice in this region, to stabilize channels and control flow characteristics by lining streambeds with concrete and armoring streambanks. Because of their relatively natural condition, SDEF streams can provide a baseline for assessing human impacts to streams elsewhere in the region.

The SDEF has a Mediterranean-type climate with cool, wet winters and hot, dry summers. The mean annual temperature is 14 ^{o}C, with summer maxima frequently exceeding 38 ^{o}C but winter minima seldom below -4 ^{o}C. Average annual precipitation is 715 mm but has varied greatly with extremes ranging from 250 to 1800 mm/yr over an 80-year record. Precipitation is dominated by rain that falls primarily between December and March (Dunn et al. 1988).

SDEF has shallow, azonal, coarse-textured upland soils of low fertility. These soils are classified as loamy, mixed, thermic, shallow, Typic Xerorthents that developed from tectonically fractured igneous and metamorphic bedrock (Riggan et al. 1985).

Research History

The SDEF was established in 1934 on federal lands of the Angeles National Forest (ANF), and all land use has been thoroughly documented since that time. Since 2014, the SDEF has been part of the San Gabriel Mountains National Monument. The original mission of SDEF was to study the water cycle in semiarid upland terrain and determine if any extra water could be harvested to support agriculture and domestic water supply in the valleys below (Robinson 1980). Research has followed a number of themes at SDEF. Hydrology studies have included developing stream instrumentation (Wilm et al. 1938), paired watershed comparisons (Crouse 1961), and lysimeter studies (Patric 1961). Soils and slope stability research have investigated surface sediment transport (Wohlgemuth 2015), shallow soil slips (Rice et al. 1969), and large mass movements (Morton and Streitz 1969).

Since the 1950s, research at SDEF has investigated the effects of wildland fire and management practices on water quantity. Studies of the effects of fire have included soil water repellency (DeBano 1981), streamflow (Krammes and Rice 1963), sediment yield (Wohlgemuth 2015), and erosion control (Rice et al. 1965). Chaparral ecology and physiology have documented postfire vegetation development (Horton and Kraebel 1955), species composition shifts (Hanes 1971), rooting depths (Hellmers et al. 1955), biomass accumulation (Riggan et al. 1988), plant water relations (Patric 1974), and litter decomposition (Kittredge 1955). Wildlife studies have investigated insects (Ikeda 1985), small mammals (Larson 1985), and Neotropical birds (Rechel et al. 2000). Vegetation management and experimental manipulations have included type conversion of chaparral to grass and prescribed burning.

Long-term, continuous monitoring at SDEF includes measurements of air temperature, windspeed and direction, relative humidity, solar radiation, precipitation, and stream discharge. Stream water quality monitoring began in the early 1980s but was suspended in 2002 when siltation from a wildfire precluded stream discharge measurements. Both stream runoff and water quality monitoring were scheduled to resume in 2012, but prolonged and unprecedented regional drought resulted in no measurable flow. Discharge and water quality measurements finally resumed in 2017, with the return of normal storm patterns. Short-term studies have documented rainfall interception, infiltration, evapotranspiration, and hillslope overland flow.

Availability of publications and data—
Data are available in archives housed at SDEF, some of which have been summarized in published papers (see references in Dunn et al. 1988). Chemical loading by wet atmospheric deposition has been monitored since 1986 as part of the National Atmospheric Deposition Program (NADP), and these data are available online (NADP 2019a). Streamflow data, most of which have been converted to digital records, and water quality monitoring records are housed at the U.S. Forest Service (USFS), Pacific Southwest Research Station in Riverside, California. For more details about the history and scientific studies on SDEF, see Robinson (1980), Dunn et al. (1988), or USDA FS (2017).

Biological Responses to Stream Nutrients N and P

Issues of Concern

A major concern for regulators and water suppliers is that the high levels of nitrate (NO_3^-) in southern California surface waters may pollute the groundwater sources that help supply Los Angeles and surrounding cities. In upland forests such as SDEF, the main source of nitrates is from high rates of atmospheric deposition of nitrogen (N), primarily generated by air pollution from automobile emissions. These air pollutants are trapped in an inversion layer that is pushed against the inland mountains by onshore airflows from the Pacific Ocean. Surface water NO_3^- levels in southern California reflect a gradient of air pollution loading that was measured across the region (Fenn and Poth 1999, Fenn et al. 2008, Riggan et al. 1985). Atmospheric deposition of N compounds in headwater mountains, including SDEF, is thought to be the driver of surface water levels of NO_3^- that approach the federal drinking water standard of 10.0 mg NO_3^--N/L that was set to protect human health. Following wildland fire, stream water NO_3^- levels in this region sometimes exceed this standard (Riggan et al. 1994). However, it is difficult to assess the downstream impact of this headwater NO_3^- source on regional aquifers because valley lands also have legacy sources of NO_3^- from past intensive agriculture and N fertilizer application (Main San Gabriel Basin Watermaster 2013). A related concern is impacts on benthic invertebrates and fish from overfertilization and eutrophication of surface streams and acidification of upland ecosystems. Phosphorous (P) is of lesser regional concern, although it is suspected of contributing to the eutrophication of stream water after wildland fires.

Hydromodification is another regional concern. Naturally flowing streams and their associated riparian habitats and floodplains mitigate effects of nutrient loading by a variety of biological, chemical, and physical processes that reduce amounts of nutrients, sediments, and organic material delivered to downstream waters (US EPA 2015). These ameliorating effects are impaired in hydromodified streams, allowing more nutrients to remain in the water column, increasing downstream eutrophication and altering benthic invertebrate communities.

Findings From Studies

Overall nutrient conditions—

Annual yields as high as 10.0 kg NO_3^--N/ha/yr and short-term stream water NO_3^- concentrations as high as 7.0 mg NO_3^--N/L have been measured at SDEF watersheds with undisturbed native vegetation (Riggan et al. 1985). These NO_3^- values are some of the highest for undisturbed lands in the United States and up to 1,000 times greater than have been measured in streams in southern California with lower atmospheric deposition loads (Riggan et al. 1985). Dry deposition is a greater contributor of N than wet deposition in the Mediterranean climate of SDEF (Fenn et al. 2012, Padgett et al. 2014). Substantial amounts of NO_3^- and other N compounds are dry deposited onto shrub leaf surfaces and washed off by subsequent rainfall. Wash-off of N in throughfall, which is precipitation collected beneath the vegetation canopy, is greatest during late-summer and early-autumn events, when small storms are interspersed with periods of elevated air pollution (Riggan et al. 1985).

Measurements in the early 1980s indicate that the average combined transfer of inorganic N, including oxides of nitrogen and ammonium, from the air to the soil was 23.3 kg N/ha/yr, of which 8.2 kg N/ha/yr was from wet deposition (Riggan et al. 1985). More recent analyses of long-term monitoring data indicated that wet deposition of N has declined slightly at SDEF since 1986 (NADP 2019a), possibly reflecting more stringent regulation of automobile emissions adopted in California. However, NADP protocols used at SDEF do not effectively capture dry deposition of N compounds. Recent throughfall measurements at SDEF were used to estimate average deposition rates of 23 kg N/ha/yr (Fenn, n.d.), indicating that total N deposition has not declined, despite reduced emissions, and suggesting that the SDEF is a N-saturated system.

Measured levels of NO_3^- in SDEF stream water did not decline from the late 1980s through 2001 (Meixner et al. 2006). The suspension of water quality monitoring at SDEF since 2002, extended by the recent drought, prevented more current collection of stream water NO_3^- until 2017, and these recent results have yet to be analyzed. As a result, it is not possible to tell whether SDEF stream NO_3^- levels have mirrored trends in total atmospheric deposition of N over the past decade. At some other experimental forests and ranges (EFRs), stream water NO_3^- has followed trends in atmospheric deposition of N (see chapter 3, Hubbard Brook Experimental Forest, and chapter 14, Coweeta Hydrologic Laboratory), but not all EFRs have reflected this pattern (see chapter 2, Marcell Experimental Forest, and chapter 13, Fernow Experimental Forest).

Stream water P has not been monitored regularly at SDEF, but levels in downstream rivers are fairly low (~0.5 mg phosphate [PO_4^{3-}]-P/L) (Council for Watershed Health 2012). A comparable nearby site, with relatively undisturbed chaparral vegetation, had stream water total P ranging from 0.02 to 0.07 mg/L (Stein and Yoon 2007), suggesting that total P at SDEF is probably also low.

Biological responses of aquatic species or groups to N and P—
No work has been done at SDEF on the biological responses of aquatic species or functional groups to stream water nutrients. However, stream nutrient observations at SDEF provide indications of whole stream biological activity. Dissolved N concentrations and fluxes are the net result of biologically mediated processes throughout the watershed that sequester, mobilize, or transform the various forms of N. For example, Riggan et al. (1985) reported that experimental NO_3^- additions to stream water at SDEF were greatly attenuated, presumably by biological uptake, when sampled 150 and 300 m downstream. Furthermore, the measured low concentrations in summer base flow indicated high levels of biological uptake of NO_3^- in summer, while larger fluxes of NO_3^- during major winter storms implied reduced biological uptake in winter (Riggan et al. 1985).

A study of several major streams in neighboring Los Angeles and Ventura Counties found that in shaded reaches, diatom cover was positively associated with total P and negatively associated with total N, while in unshaded reaches, algal cover was positively associated with total N and negatively associated with total P. Also, while the cover of algae was generally not detrimental to benthic macroinvertebrates, the cover of diatoms was negatively associated with specific indicators of a healthy invertebrate community (Ambrose et al. 2003). Data from 104 southern California streams, spanning broad nutrient gradients, revealed that the relative abundance of N_2-fixing heterocystous cyanobacteria decreased with increasing ambient inorganic N concentrations within the low end of the N gradient (Stancheva et al. 2013). Similar patterns may prevail at SDEF, but no studies have been performed to test this assumption.

Effects of streamflow on nutrients—
Flux of NO_3^- in stream water is positively correlated with stream discharge, and annual NO_3^- yield is greater in wet years than dry years. Concentrations of NO_3^- are greatest during late summer and early autumn, presumably because storms wash accumulated N deposition off vegetation. However, NO_3^- flux is substantial only during major winter storms that saturate the soil mantle, producing overland flow and throughflow that directly enter streams (Riggan et al. 1985).

Other Factors Relevant to Biological Responses to Stream Nutrients N and P

Other factors studied at SDEF that can influence the biological responses in streams include streamflow, water temperature, and suspended sediment. Streamflow monitoring on SDEF started at 14 watersheds in 1938. With infrastructure deterioration and funding limitations, only five gaging stations remain in operation. Records are discontinuous, with monitoring interrupted following the wildfires of 1960 and 2002. Flow usually commences in the late fall after several large storm events totaling ~150 mm or more and often continues until late spring. During dry years, including the drought of 2012–2016, no flow was recorded. In wet years, streams flowed the entire year. Digital thermometers were added to stream gaging stations in 1999. Suspended sediment was measured for 5 years following the wildfire in 1960 in conjunction with small watershed sediment yield studies.

Reference Watersheds

Two reference watersheds have been continuously managed for minimal human disturbance under native chaparral vegetation and have been monitored for water quality: Volfe Canyon, a drainage of 300 ha, and Bell 3, a drainage of 25 ha. Streamflow has been measured at the outlet of both catchments since the late 1930s, and stream water NO_3^- was monitored from the mid-1980s to 2002. Both watersheds were burned by wildland fires in 1960 and again in 2002. General vegetation surveys of this area were made in the 1930s, and a soil survey was conducted in the early 1960s. Surveys of aquatic organisms have not been performed. Although the large influx of atmospheric deposition and air pollution from the Los Angeles Basin and recurring wildland fires may preclude describing them as strictly pristine, these reference watersheds still likely represent minimally managed headwater basins in the region because air pollution and wildland fire are widespread in southern California.

Cross-Site and Regional Studies

Unlike most other regions where headwater streams are usually less polluted than downstream waters, the levels of NO_3^- in stream water in SDEF headwaters are much higher than concentrations downstream in the San Gabriel River measured by regional watershed-wide monitoring (Council for Watershed Health 2012). This suggests that as N is transported in these streams, it is being altered by some combination of biological uptake leading to sequestration, dilution by lesser impaired waters, and denitrification. Denitrification may be favored in hotspots with anaerobic conditions and an available carbon source such as sediment deposits or vegetated riparian edges.

Atmospheric deposition data collected at SDEF have been used in the development of regional and national assessments and maps of wet deposition rates of N pollutants done periodically by NADP (NADP 2019b). Moreover, patterns of atmospheric deposition have been well documented in southern California along gradients from areas of high- to relatively low-pollution, largely driven by proximity to urban centers and topography (Fenn and Kiefer 1999, Fenn et al. 2010, Padgett et al. 2014). Source water NO_3^- levels generally increased along these gradients of pollution loading across southern California (Riggan et al. 1985).

Monitored streams within the San Gabriel River drainage basin, at elevations both higher and lower than SDEF, exhibited lower NO_3^- levels than SDEF (California Water Resources Control Board 2017). This suggests that perhaps SDEF may lie within an elevation band that receives enhanced N deposition, coinciding with the top of the regional inversion layer at ~1000 m altitude.

Data from SDEF has also been used in a national comparison of stream water NO_3^- measured at sites across the EFR network. The stream water NO_3^- concentrations from the reference watersheds at SDEF are one to two orders of magnitude greater than forested reference watersheds in other regions of the country, all of which also have lower levels of N deposition than SDEF (Argerich et al. 2013). Research results from several EFR sites, with which SDEF was compared, are presented in other chapters in this volume.

Responses to Management and Natural Disturbances

Some of the watersheds in SDEF were deliberately type converted from native chaparral to nonnative grass vegetation following a wildland fire in 1960. The purpose of this paired watershed experiment was to determine if replacing the deep-rooted chaparral shrubs with shallow-rooted grasses would increase water yield for downstream human use. Water yields were, and continue to be, significantly higher in the treated watersheds compared to the untreated reference basins. Twenty years posttreatment, greater concentrations and yields of NO_3^- were measured in watersheds that had been type converted to grasslands (Meixner and Wohlgemuth 2003). Presumably, the greater NO_3^- levels reflected greater subsurface soil exposure caused by landslides in these altered landscapes (Rice et al. 1969), coupled with the more rapid water flux through the shallow-rooted grasses. Maximum measured yield was 19.4 kg N/ha/yr in grass vegetation compared to 10.0 kg N/ha/yr in chaparral (Riggan et al. 1985). Elevated NO_3^- levels along with quicker hydrologic response continue to characterize the type-converted watersheds to the present (USDA FS, n.d.).

Wildland fire is the main driver of natural disturbance in the mountains of southern California. Wildland fires can greatly accelerate NO_3^- loading by mineralizing the N accumulated in the vegetation and leaf litter and producing ash that surface runoff transports to streams. Coupled with increased stream discharge associated with burned watersheds (Hamilton et al. 1954, Krammes and Rice 1963), this NO_3^- flush to aquatic systems may affect downstream waters and aquifers. Following a prescribed fire, initial flows produced stream water NO_3^--N concentrations as high as 15.7 mg/L or 1.5 times the federal drinking water standard (Riggan et al. 1985). Export of NO_3^- increased with fire severity, and levels remained elevated for as long as 5 to 10 years postfire compared to nearby unburned watersheds (Meixner et al. 2003, 2006; Riggan et al. 1994). Export of P also increased after wildfires from P adsorbed on ash and sediment that were transported by streams in initial postfire runoff (Meixner and Wohlgemuth 2004).

Postfire flooding, accelerated erosion, debris flows, and downstream sedimentation have all been documented on SDEF (Dunn et al. 1988, Wohlgemuth 2008, Wohlgemuth and Hubbert 2008). The massive flux of both water and sediment from burned hillsides can create major changes in fluvial geomorphology and aquatic habitats. Although stream biological communities and processes are probably altered in postfire environments by increased nutrient fluxes and drastic physical disturbances (Minshall 2003), biological responses after fires have not been studied at SDEF.

Reliability and Limitations of Findings

The results of the monitoring and research on SDEF should be applicable to the chaparral lands of southern California that are similarly affected by high levels of N deposition. Outside this zone of high pollution and away from urban centers, SDEF data should be applied with caution. In cases of uncertainty, where air pollution or other site characteristics deviate from SDEF, validation monitoring or studies might be beneficial to test how well SDEF findings represent the local conditions.

Research Needs

From the perspective of the water quality regulatory community, the highest priority science question that could be answered at SDEF is, Has total N deposition at SDEF declined or remained stable since the early 1980s, considering the declining trend of wet deposition of N; and, concurrently, has SDEF stream water NO_3^- followed the declining trend in wet N atmospheric deposition since 2002? Answering this question would be important to regulators because it might provide a scientific basis for anticipating how NO_3^- levels in headwater streams, a source of NO_3^- pollution in southern California, might respond to future changes in air pollution levels and associated atmospheric deposition of N. To address this question, future research at SDEF would need to include (1) systematically measuring current total atmospheric deposition of N to the vegetation canopy at SDEF using methods that could be validly compared with the previous measurements, (2) performing a thorough analysis of existing SDEF stream water monitoring NO_3^- data to investigate whether changes in stream water nitrate levels have reflected trends in deposition of N since the mid-1980s, and (3) resuming monitoring of SDEF stream water NO_3^-.

Potential Utility to Water Quality Regulatory Agencies

Water quality regulatory agencies might use SDEF for a number of practical purposes. For example, they might use existing SDEF research findings and datasets for developing total maximum daily loads or to model effects of wildland fire or effects of air pollution and N deposition on NO_3^- levels in headwater streams during other planning efforts. Regulators might also use SDEF reference watersheds to provide a baseline of nutrient conditions that are typical of otherwise undisturbed mountain headwater basins in southern California that receive high air pollution loads. In this region, even undisturbed headwaters areas have received high levels of atmospheric deposition of N and have burned regularly in wildland fires. Unlike SDEF, background conditions in many urbanized Los Angeles Basin stream systems have been confounded by the anthropogenic effects of fertilizer runoff or hydromodification that have strongly influenced nutrients and biological conditions.

Key points:

- Measured NO_3^- concentrations and yields in SDEF reference streams are one to two orders of magnitude greater than low N deposition sites in southern California.
- Source of the NO_3^- at SDEF is primarily air pollution from the Los Angeles Basin that is deposited to the chaparral canopy and subsequently washed off by rain.

- Nitrate flux in stream water was positively correlated with stream discharge, and annual watershed NO_3^- yields were greater in higher rainfall years.
- Wildfires greatly accelerated the NO_3^- loading to streams, and elevated levels of NO_3^- persisted for years after a burn.
- Catchments that were type converted from native chaparral to grasslands had greater NO_3^- concentrations and yields in stream water.
- SDEF stream water nutrient data provide estimates of general biological uptake by stream ecosystems, but no work has been done at SDEF on biological responses to nutrients of aquatic species or functional groups.
- The science gap at SDEF of highest priority for the regulatory community is to understand whether atmospheric deposition of total N has changed since the early 1980s and whether NO_3^- in SDEF stream water have mirrored any change in total deposition of N over that period.
- Regulatory agencies might use existing SDEF data and research findings to model effects of N deposition or wildland fire on headwater stream NO_3^- in southern California.

Biological Responses to Stream Nutrients Other Than N and P

Issues of Concern

Currently, there are no pressing regional issues of concern related to nutrients other than N and P.

Findings From Studies

Weekly measurements of the amounts of calcium, magnesium, potassium, sodium, hydrogen ion, chloride, and sulfate are routinely performed in wet deposition samples at SDEF following established protocols of the NADP network. However, none of these nutrients have been monitored in SDEF stream water, and no work has been done on biological responses to them in streams at SDEF.

Studies of Other Factors

As noted in the section on stream N and P, other factors that can influence biological responses in streams have been monitored at SDEF including streamflow, water temperature, and suspended sediment. These factors would probably also affect biological responses to nutrients other than N and P.

Cross-Site and Regional Studies

Although SDEF has not participated in the regional water quality monitoring in the San Gabriel River drainage, this network has measured dissolved organic and inorganic carbon as well as silica in numerous streams in the area around SDEF (Council for Watershed Health 2012). Atmospheric deposition of nutrients other than N, collected at SDEF have been used in the development of periodic regional and national assessments and maps of deposition by NADP (NADP 2019b).

Reference Watersheds

Streams on reference watersheds at SDEF have not been monitored for nutrients other than N.

Response to Management and Natural Disturbances

It is not known whether there were any effects from nutrients other than N in SDEF streams from management activities such as type conversion, prescribed burning, or wildfire because these nutrients have not been studied.

Research Needs

Research and monitoring of nutrients other than N or P are not a high priority for regulatory agencies in this region, so no priority science gaps on this topic were identified.

Potential Utility to Water Quality Regulatory Agencies

Presently, water quality regulatory agencies have little need for research and monitoring results on nutrients other than N or P. However, if any new concerns were to arise about impacts of these other nutrients on the beneficial uses of water, long-term atmospheric deposition data of these nutrients, collected at the NADP site in SDEF, would be available for use by regulators in the region. However, only wet deposition data are measured by NADP monitoring, which is less than half of total atmospheric deposition in this dry-deposition-dominated ecosystem (Fenn et al. 2012).

Key points:

- There are no pressing regional concerns about nutrients other than N and P, and, except for long-term wet deposition monitoring, little work has been done at SDEF on these nutrients.
- Monitoring of some nutrients other than N or P has been conducted by regional agencies in the downstream San Gabriel River basin, but SDEF has not participated in this network.

Overview and Synthesis

Streams at SDEF have been the site of long-term monitoring of streamflow, stream NO_3^-, and, intermittently, suspended sediment and water temperature. Stream water from SDEF has had very high levels of NO_3^- owing to air pollution-derived atmospheric deposition of N. Reference watersheds at SDEF may be useful to the regulatory community as examples of streams with minimal human disturbance, but subject to combined effects from high levels of air pollution and periodic wildland fires. Unlike many streams in the region, SDEF streams have not been affected by urban runoff or hydromodification. Levels of NO_3^- in headwater stream water at SDEF are much higher than at downstream waters, representing a gradient that is not usual outside of this region.

Wildfires at SDEF have increased stream NO_3^- loading, sedimentation, and turbidity for years after a burn. Watershed vegetation type conversion from chaparral to grass can further increase stream nitrate concentrations and yields. However, apart from whole stream uptake of NO_3^-, no work at SDEF has directly examined biological responses to nutrients.

The highest priority science question for the regulatory community at SDEF is, Has total atmospheric deposition of N at SDEF changed since the 1980s, and has nitrate in SDEF stream water tracked changes in total N deposition? Answering this question might be important for regulatory agencies because it might provide them with a scientific basis for anticipating how NO_3^- levels in headwater streams in this region might respond to future changes in air pollution and N deposition. These streams are sources of NO_3^- to aquifers that are used for drinking water supplies, so better understanding of what controls their water quality might be useful in developing regulations that protect human health. Filling this knowledge gap at SDEF would require remeasuring total atmospheric deposition of N, using methods comparable to the previous measurement in the 1980s, analyzing trends in SDEF stream water NO_3^- data since the early 1980s, and reestablishing the monitoring of NO_3^- in SDEF streams.

If the regulatory community wanted to use SDEF to investigate biological responses to nutrients or other environmental factors, they might consider establishing aquatic bioassessment sites on the SDEF streams. Routine monitoring at SDEF might provide environmental context for interpreting bioassessment results, and further insights might be gained, for example, if monitoring of chlorophyll *a* were added at SDEF. In addition, regulatory agencies might benefit if data from SDEF were incorporated into local and statewide databases such as the California Environmental Data Exchange Network (California Water Resources Control Board 2017). Any future research or monitoring undertaken at SDEF to address the needs of the regulatory community would benefit from collaboration among water quality regulatory agencies, the USFS, and university investigators and coordination with ongoing state and regional water quality monitoring programs.

Key points:

- SDEF is the site of detailed and long-term monitoring and studies of stream physical factors and stream water NO_3^-, but almost no studies of stream biology.
- Reference watersheds at SDEF represent baseline conditions in headwaters in the region with minimal onsite human disturbance but high atmospheric deposition of N and periodic wildland fires.
- Effects of N deposition on headwater stream NO_3^-, a critical information need of regional regulatory agencies, might be addressed by future work at SDEF.
- Regulatory agencies could establish bioassessment sites on SDEF streams to take advantage of routine monitoring and research already done on those streams.
- Research or monitoring at SDEF, to meet the needs of regulators, would best be undertaken through collaboration between state, federal, and other interested investigators.

References

Ambrose, R.F.; Lee, S.F.; Bergquist, S.P. 2003. Environmental monitoring and bioassessment of coastal watersheds in Ventura and Los Angeles Counties. Unpublished report to the State of California, Regional Water Quality Control Board, Los Angeles Region. On file with: California Regional Water Quality Control Board, Region 4, 320 W 4th Street, Suite 200, Los Angeles, CA 90013.

Argerich, A.; Johnson, S.L.; Sebestyen, S.D.; Rhoades, C.C.; Greathouse, E.A.; Knoepp, J.; Adams, M.B.; Likens, G.E.; Campbell, J.L.; McDowell, W.H.; Scatena, F.N.; Ice, G. G. 2013. Trends in stream nitrogen concentrations for forested reference catchments across the USA. Environmental Research Letters. 8(1): 8. 014039. doi:10.1088/1748-9326/8/1/014039.

California Water Resources Control Board. 2017. California Environmental Data Exchange Network. http://www.ceden.org. (1 March 2021).

Council for Watershed Health. 2012. San Gabriel River Regional Monitoring Program, 2012 annual report. http://sgrrmp.org/. (1 March 2021).

Crouse, R.P. 1961. First-year effects of land treatment on dry-season streamflow after a fire in southern California. Res. Note PSW-191. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station. 5 p.

DeBano, L.F. 1981. Water repellent soils: a state-of-the-art. Gen. Tech. Rep. PSW-41. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station. 21 p.

Dunn, P.H.; Barro, S.C.; Wells, W.G., II; Poth, M.A.; Wohlgemuth, P.M.; Colver, C.G. 1988. The San Dimas Experimental Forest: 50 years of research. Gen. Tech. Rep. PSW-105. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station. 49 p.

Fenn, M.E. [N.d.] Unpublished throughfall deposition data. On file with: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, 4955 Canyon Crest Drive, Riverside, CA 92507.

Fenn, M.E.; Allen, E.B.; Weiss, S.B.; Jovan, S.; Geiser, L.; Tonnesen, G.S.; Johnson, R.F.; Rao, L.E.; Gimeno, B.S.; Yuan, F.; Meixner, T.; Bytnerowicz, A. 2010. Nitrogen critical loads and management alternatives for N-impacted ecosystems in California. Journal of Environmental Management. 91(12): 2404–2423.

Fenn, M.E.; Bytnerowicz, A.; Liptzin, D. 2012. Nationwide maps of atmospheric deposition are highly skewed when based solely on wet deposition. BioScience. 62(7): 621.

Fenn, M.E.; Jovan, S.; Yuan, F.; Geiser, L.; Meixner, T.; Gimeno, B.S. 2008. Empirical and simulated critical loads for nitrogen deposition in California mixed conifer forests. Environmental Pollution. 155(3): 492–511.

Fenn, M.E.; Kiefer, J.W. 1999. Throughfall deposition of nitrogen and sulfur in a Jeffrey pine forest in the San Gabriel Mountains, southern California. Environmental Pollution. 104(2): 179–187.

Fenn, M.E.; Poth, M.A. 1999. Temporal and spatial trends in streamwater nitrate concentrations in the San Bernardino Mountains, southern California. Journal of Environmental Quality. 28(3): 822–836.

Hamilton, E.L.; Horton, J.S.; Rowe, P.B.; Reimann, L.F. 1954. Fire-flood sequences on the San Dimas Experimental Forest. Tech. Rep. 6. Berkeley, CA: U.S. Department of Agriculture, Forest Service, California Forest and Range Experiment Station. 29 p.

Hanes, T.L. 1971. Succession after fires in the chaparral of southern California. Ecological Monographs. 41(1): 27–52.

Hellmers, H.; Horton, J.S.; Juhren, G.; O'Keefe, J. 1955. Root systems of some chaparral plants in southern California. Ecology. 36(4): 667–678.

Horton, J.S.; Kraebel, C.J. 1955. Development of vegetation after fire in the chamise chaparral of southern California. Ecology. 36(2): 244–262.

Ikeda, M.K. 1985. The role of thermal factors in determining nest entrance placement in *Pogonomyrmex subnititus.* Pomona, CA: California State Polytechnic University. 33 p. M.S. thesis.

Kittredge, J. 1955. Litter and forest floor of the chaparral in parts of the San Dimas Experimental Forest, California. Hilgardia. 23(13): 563–596.

Krammes, J.S.; Rice, R.M. 1963. Effect of fire on the San Dimas Experimental Forest. In: Proceedings of Arizona's 7th annual watershed symposium. [Place of publication unknown]: [Publisher unknown]: 31–34.

Larson, D.A. 1985. Habitat utilization, diet, and herbivory effects of rabbits in southern California chaparral. Pomona, CA: California State Polytechnic University. 87 p. M.S. thesis.

Main San Gabriel Basin Watermaster. 2013. Five-year water quality and supply plan. Unpublished report. On file with: Main San Gabriel Basin Watermaster, 725 N Azusa Avenue, Azusa, CA 91702. 128 p.

Meixner, T.; Fenn, M.E.; Wohlgemuth, P.M. 2003. Fire disturbance and nitrogen deposition impacts at the watershed scale in southern California. In: Renard, K.G.; McElroy, S.A.; Gburek, W.J.; Canfield, H.E.; Scott, R.L., eds. The first interagency conference on research in the watersheds. [Place of publication unknown]: U.S. Department of Agriculture, Agricultural Research Service: 637–643.

Meixner, T.; Fenn, M.E.; Wohlgemuth, P.M.; Oxford, M.; Riggan, P. 2006. N saturation symptoms in chaparral are not reversed by prescribed fire. Environmental Science and Technology. 40(9): 2887–2894.

Meixner, T.; Wohlgemuth, P.M. 2003. Climate variability, fire, vegetation recovery, and watershed hydrology. In: Renard, K.G.; McElroy, S.A.; Gburek, W.J.; Canfield, H.E.; Scott, R.L., eds. The First interagency conference on research in the watersheds. [Place of publication unknown]: U.S. Department of Agriculture, Agricultural Research Service: 651–656.

Meixner, T.; Wohlgemuth, P.M. 2004. Wildfire impacts on water quality. Southwest Hydrology. 3(5): 24–25.

Minshall, G.W. 2003. Response of stream benthic macroinvertebrates to fire. Forest Ecology and Management. 178(1-2): 155–161.

Morton, D.M.; Streitz, R. 1969. Reconnaissance map of major landslides, San Gabriel Mountains, California. San Gabriel Mountains Mapsheet 15. Sacramento, CA: State of California, Department of Conservation, Division of Mines and Geology.

National Atmospheric Deposition Program [NADP]. 2019a. NTN [National Trends Network] Site CA42. Tanbark Flat. http://nadp.slh.wisc.edu/data/sites/siteDetails.aspx?net=NTN&id=CA42. (2 July 2019).

National Atmospheric Deposition Program [NADP]. 2019b. NTN [National Trends Network] Maps. http://nadp.slh.wisc.edu/NTN/maps.aspx. (2 July 2019).

Padgett, P.; McLaughlin, K.; Sutula, M. 2014. Estimating wet and dry deposition of nitrogen to southern California streams. [Place of publication unknown]. [Publisher unknown]; final report; IA DW-12-92326401-0. Southern California Coastal Water Research Project 0837. 42 p. http://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/837_EPA_ORD_Final_Report_V4.pdf. (8 March 2019).

Patric, J.H. 1961. The San Dimas large lysimeters. Journal of Soil and Water Conservation. 16(1): 13–17.

Patric, J.H. 1974. Water relations of some lysimeter-grown wildland plants in southern California. Upper Darby, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 117 p.

Rechel, J.L.; Freeman, D.M.; Larson, D.A. 2000. Effects of landscape structure on avian community composition and probability of occurrence in fire-dominated Mediterranean ecosystems [Abstract]. In: Ecological Society of America: 85th annual meeting: 183.

Rice, R.M.; Crouse, R.P.; Corbett, E.S. 1965. Emergency measures to control erosion after a fire on the San Dimas Experimental Forest. Misc. Publ. 970. Washington, DC: U.S. Department of Agriculture: 123–130.

Rice, R.M.; Corbett, E.S.; Bailey, R.G. 1969. Soil slips related to vegetation, topography, and soil in southern California. Water Resources Research. 5(3): 647–659.

Riggan P.J.; Goode, S.; Jacks, P.M.; Lockwood, R.N. 1988. Interaction of fire and community development in chaparral of southern California. Ecological Monographs. 58(3): 155–176.

Riggan, P.J.; Lockwood, R.N.; Jacks, P.M.; Colver, C.G.; Weirich, F.; DeBano, L.F.; Brass, J.A. 1994. Effects of fire severity on nitrate mobilization in watersheds subject to chronic atmospheric deposition. Environmental Science and Technology. 28(3): 369–375.

Riggan, P.J.; Lockwood, R.N.; Lopez, E.N. 1985. Deposition and processing of airborne nitrogen pollutants in Mediterranean-type ecosystems in southern California. Environmental Science and Technology. 19(9): 781–789.

Robinson, J.W. 1980. A history of the Dalton and the San Dimas watersheds and the San Dimas Experimental Forest, Part I and II. Mt. San Antonio Historian. 14(2): 47–77 and 14(3): 106–137.

Stancheva, R.; Sheath, R.G.; Read, B.A.; McArthur, K.D.; Schroepfer, C.; Kociolek, J.P.; Fetscher, A.E. 2013. Nitrogen-fixing cyanobacteria (free living and diatom endosymbionts): their use in southern California stream bioassesment. Hydrobiologia. 720(1): 111–127.

Stein, E.D.; Yoon, V.K. 2007. Assessment of water quality concentrations and loads from natural landscapes. Tech. Rep. 500. Costa Mesa, CA: Southern California Coastal Water Research Project. 98 p.

U.S. Department of Agriculture, Forest Service [USDA FS]. [N.d.]. Unpublished stream flow and nitrate data. On file with: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, 4955 Canyon Crest Drive, Riverside, CA 92507.

U.S. Department of Agriculture, Forest Service [USDA FS]. 2017. San Dimas Experimental Forest. http://www.fs.fed.us/psw/ef/san_dimas. (1 March 2021).

U.S. Environmental Protection Agency [USEPA]. 2015. Connectivity of streams and wetlands to downstream waters: a review and synthesis of the scientific evidence. Washington, DC: Final report EPA/600/R-14/475F. 331 p.

Wilm, H.G.; Cotton, J.S.; Storey, H.C. 1938. Measurement of debris-laden streamflow with critical depth flumes. Transactions of the American Society of Civil Engineers. 103: 1237–1278.

Wohlgemuth, P.M. 2008. Post-fire watershed response at the wildland/urban interface, southern California. In: Webb, R.M.T.; Semmens, D.J., eds. Proceedings of the third interagency conference on research in the watersheds. Reston, VA: U.S. Geological Survey, Scientific Investigations Report 2009-5049: 137–142.

Wohlgemuth, P.M. 2015. Hillslope erosion and small watershed sediment yield before and after fire in southern California. In: Proceedings of the 3rd joint federal interagency conference on hydrology and sedimentation. [Place of publication unknown]: Water Information Coordination Program, Advisory Committee on Water Information, Subcommittee on Sedimentation: 977–86.

Wohlgemuth, P.M.; Hubbert, K.R. 2008. The effects of fire on soil hydrologic properties and sediment fluxes in chaparral steeplands, southern California. In: Narog, M.G., tech. coord. Proceedings of the 2002 fire conference. Gen. Tech. Rep. PSW-GTR-189. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station: 115–121.