

Aquatic Systems and Watersheds¹

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Water is often at the heart of contentious debates over natural resource policy in the Sierra Nevada. Besides the obvious issues of dams, diversions, fish, wetlands, and pollution, connections abound with other resources within the waterways and their watersheds. Whether an argument is over logging, roads, wildfire, endangered species, wilderness, sprawl of foothill communities, ski area expansion, mining, off-highway vehicles, climate change, or overgrazing, potential impacts on water or aquatic habitats quickly enter the discussion. These debates are often dominated by folklore and conjecture because the state-of-knowledge about aquatic systems and their relationship with Sierra Nevada landscapes is remarkably limited. The Sierra Nevada Science Symposium session on aquatic systems and watersheds was a sample of recent research that could contribute to better-informed debates about water-related aspects of natural resource policy in the Sierra Nevada. Six speakers delved into the problems facing specific taxa, the relationships between aquatic organisms and their physical environment, changes in water chemistry and sediment in response to land use, analysis of cumulative impacts at the watershed scale, and policy responses to impacts at the State level.

Much of what is known about water resources, watersheds, and aquatic biology of the Sierra Nevada was synthesized and summarized by the Sierra Nevada Ecosystem Project (SNEP) Report in 1996 (Centers for Water and Wildland Resources 1996). Recognition of inadequacies in scientific knowledge about the Sierra Nevada led to Congressional legislation that spawned the SNEP. A primary goal for this 3-year long project was to compile information to provide a basis for subsequent policy and management decisions. About 30 chapters of the SNEP report dealt with water-related topics. The authors of these various chapters found that development of streams and watersheds over the past 150 years has degraded the quality and availability of water for both ecological and social needs in many locations throughout the Sierra Nevada. Construction of the extensive network of dams and diversions has left few river segments with a natural flow regime. Further degradation of Sierra Nevada rivers has been caused by secondary effects of resource development, road construction, and other alterations from land use in the watersheds (Kattelman 1996). As human-induced impacts have changed the nature of stream characteristics, such as water volume, duration of low flows, peaks of floods, seasonal timing, sediment supply, water temperature, and quantities of organic matter and nutrients, aquatic and riparian ecosystems and their constituent elements have coped in various ways with differing results.

Declines in the health of aquatic ecosystems were particularly apparent from dramatic changes in fish populations: most native fishes have decreased in abundance, although the ranges of several have been artificially expanded, with consequent impacts on native amphibians. Thirty species of non-native fishes have been introduced into streams throughout the Sierra Nevada, and anadromous fishes have been excluded from most of their former habitat by dams (Knapp 1996, Moyle 1996, Moyle and others 1996). These activities

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have resulted in formal listing of 6 of the 40 native fishes of the Sierra Nevada as endangered or threatened; another 12 species are regarded as species of special concern (Moyle and others 1996). Observed declines in aquatic species were found to be strongly associated with degradation of aquatic habitats and the surrounding landscape (Moyle 1996). A SNEP evaluation of the biotic integrity of 100 watersheds found that the aquatic communities of only 7 watersheds were in excellent condition, 34 were in good to very good condition, 48 were rated as fair, and 9 were judged to be poor (Moyle and Randall 1996).

Since the SNEP report was released, the Forest Service's Pacific Southwest Region has embarked on a program to systematically update the forest plans of Sierra Nevada National Forests, using some of the primary conclusions from the SNEP (USDA Forest Service 2000 and 2001). Considerable attention has been directed to watershed, riparian, and aquatic issues in this bioregional-scale planning effort. In parallel, the State has supported watershed analysis and restoration projects on the west side of the range through CALFED and Proposition 204 and 13 funds. In addition, nongovernmental organizations, such as the Sierra Nevada Alliance, the Sierra Business Council, and the Pacific Rivers Council, have assessed watershed condition, advocated for strong monitoring programs, and proposed an ambitious watershed restoration program for the Sierra Nevada (for example, Pacific Rivers Council 2002).

Meanwhile, pressures on Sierra Nevada aquatic systems continue to mount, largely expressed as concerns about water quantity due to the rapid growth of California's population. Drier-than-average conditions for 1999 through 2002 produced widespread concern about future water availability throughout the State. Shortages of electricity in 2001 led to many warnings about hydropower capacity as well as fears of future water shortages. In turn, such concerns led to increasing political support for more storage and diversion projects on Sierra Nevada rivers. At the close of 2002, a complex debate over the future of water deliveries from the Colorado River to southern California included calls for more water from northern California and the Sierra Nevada to the southern part of the state. These examples suggest ever-increasing demands on the streams of the Sierra Nevada.

Relationship to Other Sierra Nevada Science Symposium Sessions

The fundamental availability of precipitation to generate runoff from Sierra Nevada watersheds was addressed in the Sierra Nevada Science Symposium session on climate change. Reconstruction of past climate from various indicators suggests that California's water resources infrastructure was planned and built during a relatively wet and hydrologically stable period. Significant evidence indicates the occurrence of severe and sustained droughts in past centuries as well as floods greatly exceeding those of the historical period. Modeling exercises suggest the future possibility of markedly different snowfall and snowmelt regimes than those in the recent past. Such climatic shifts would alter vegetation and fire patterns, with consequent hydrologic effects: changes in volume and timing of runoff would affect stream channels and aquatic biota. These potential hydrogeomorphological effects have yet to be examined in detail but may have dramatic impacts on existing ecological resources.

The Sierra Nevada Science Symposium session on forest ecosystems discussed variations in vegetation distribution and stand structure. Terrestrial vegetation and hydrologic systems interact principally through the water and nutrient relations of the soil mantle, with secondary impacts on temperature and evaporation from shading and protection from wind. Alternatives for forest management can greatly affect generation of streamflow and its constituents of sediment and nutrients, riparian structure, and availability of woody debris to stream channels. Similarly, the session on wildland fuels and fires addressed many potential interactions with the hydrologic cycle. Although the 2002 fire season generated only one

major fire in the Sierra Nevada, large wildfires in other western states generated Federal policy initiatives that could have dramatic effects on Sierra Nevada streams (Kattelman 1999).

Although most of the papers in the session on biodiversity dealt with terrestrial species, conservation concepts are largely similar for aquatic species. However, strategies for the design of aquatic reserves and feasible approaches to conserving aquatic biodiversity have not received the same attention as terrestrial species or even individual aquatic species. The more than one hundred posters at the Sierra Nevada Science Symposium represent a wealth of new post-SNEP research that has implications for the conservation of Sierra Nevada aquatic systems.

Papers of the Aquatic Session

The five papers of the Sierra Nevada Science Symposium session on aquatic systems highlighted a sample of the critical issues facing waters of the Sierra Nevada. The SNEP report (Centers for Water and Wildland Resources 1996; Volume 1, page 125) recognized the “best indicators of the health of the aquatic system of the Sierra Nevada may be the group of organisms we know the least about— invertebrates.” The chapter devoted to aquatic invertebrates observed that very few inventories exist and the distribution of most species is unknown (Erman 1996). David Herbst (in these proceedings) documents how rapidly the state-of-knowledge has progressed in the past 6 years about these creatures and their use both as indicators of stream condition and a way of classifying streams in the Sierra Nevada. This bioassessment work has the potential to provide critical information about how the aquatic life of Sierra Nevada streams is coping with human impacts. Similarly, Roland Knapp (in these proceedings) reports on the rapid advance in knowledge about Sierra Nevada amphibians since the SNEP Report. His research in the past few years has established the linkages between introduced fish and severe declines in amphibian populations that were only hypothesized in the mid-1990s.

The other papers in the aquatic session dealt with physical processes, namely the interaction between watersheds and waterways through chemical and sediment inputs. Robert Coats (in these proceedings) updates our understanding of nutrient cycling within the Lake Tahoe basin and consequent effects on lake clarity since the SNEP case study about the lake (Elliott-Fisk and others 1996). Lee MacDonald and others (in these proceedings) and Reid (in these proceedings) both address the difficulties of assessing cumulative impacts of multiple activities on watershed processes and outputs. Both papers focus on accelerated erosion and sediment delivery to streams, which have typically been the impacts of greatest concern from logging operations and associated road construction. Lee MacDonald and others describe a field study and modeling approach, whereas Leslie Reid critiques the inadequacies of operational analyses of cumulative impacts associated with land development and resource extraction.

Art Baggett’s policy discussion (unpublished) that concluded the aquatic session covered several issues at the intersection between water and other resource management activities that the State Water Resources Control Board is grappling with, including: (1) citizen monitoring of water quality as a public involvement and education device; (2) the background load of “legacy” pollutants in waters from activities long abandoned; (3) pollution “offsets”—treating manageable sources while accepting some intractable ones; (4) ecosystem and river basin analysis instead of traditional single-species approaches; (5) examination of interrelationships between ecosystems; (6) deposition of air pollutants as a source of water pollution (for example, Lake Tahoe); and (7) examination of total environmental costs associated with activities and mitigation alternatives.

State of Science and Knowledge

A lengthy quotation from the SNEP Report (Centers for Water and Wildland Resources 1996; Volume 1, page 131) still seems to capture what we know about the waters of the Sierra Nevada:

“The knowledge base for improving water allocation and implementing sound watershed management in the Sierra Nevada is notably weak. Economic values of water in different uses are not well established. Information about water demand and historic water rights is not easily accessible. Records of water quality and sediment yield are available at very few sites throughout the mountain range. Rates of natural and accelerated erosion have not been measured at many locations in the Sierra Nevada. The impacts of various water and land management practices are not quantified or even known in some cases. In the few cases where long-term rangewide surveys exist, such as grazing transects on wet meadows on the National Forests, data have not been summarized until now. The effectiveness of best management practices and restoration techniques are largely untested. In general, the basic data for sound decision making about improving water and watershed management are lacking. Specific habitat requirements of most riparian-dependent terrestrial vertebrate species are poorly documented, and general surveys of species distribution for most aquatic invertebrates are missing. Adequate monitoring of natural processes, impacts, mitigation, and restoration could provide a much better basis for water resources planning and administration. Inadequate information is currently a major constraint on improvements in water and land management.”

Papers presented at the Sierra Nevada Science Symposium helped relieve some of the lack of information and knowledge described in the previous paragraph. In particular, a large number of surveys of aquatic-invertebrate distribution have been completed since the SNEP, as described by Herbst (in these proceedings). Advances in other areas are progressing more slowly, and some areas of needed research continue to be ignored. Nevertheless, policy and management decisions will be made, whether or not there is a scientifically sound basis for those decisions. The term “adaptive management” was heard throughout the symposium as a means of decisionmaking in the light of inadequate knowledge and scientific uncertainty. This management approach requires collecting information about affected systems and impacts of actions taken and synthesizing that data into knowledge to inform future decision making. Hopefully, learning will occur through both experience and deliberate scientific studies.

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