Sierra Nevada Network Lake Monitoring Design

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Introduction

Sierra Nevada Network parks (Devils Postpile National Monument, and Sequoia, Kings Canyon, and Yosemite National Parks) protect over 4,500 lakes and ponds and thousands of kilometers of rivers and streams that have some of the highest water quality in the Sierra Nevada. High-elevation lakes are critical components of the parks' ecosystems, popular visitor destinations, and habitat for aquatic and terrestrial organisms including declining amphibian species.

As part of the Vital Signs Monitoring Program, the Sierra Nevada Network (SIEN) identified lake ecosystems and in particular water chemistry, surface water dynamics, and amphibians as high priority vital signs for long-term monitoring. Lake ecosystems were selected for monitoring because they are 1) valued for their ecological importance, contribution to Wilderness character, recreational opportunities, and importance to regional water supplies, 2) threatened by multiple stressors, and 3) sensitive to environmental change.

SIEN recently completed its lake monitoring protocol. The protocol was implemented in summer 2008. This poster highlights the monitoring design.

Monitoring Sites

The monitoring design consists of two types of sites: 1) *index sites*, which are judgmentally selected and sampled multiple times each year and, 2) *extensive sites*, which are probabilistically selected and sampled once every 1-3 years. The two site types address slightly different monitoring objectives.

Index Sites

The goals of the Sierra Nevada Network index sites are to answer objectives at a "finer" temporal scale (i.e. monthly) and allow for a more holistic monitoring approach where we can collocate water chemistry monitoring with hydrologic and amphibian vital signs. Index sites were judgmentally selected using criteria such as accessibility, chemical and physical lake characteristics, amphibian presence, and fish presence/absence.

Emerald Basin: Index site in Sequoia

Monitoring Objectives

- Detect intra- and inter-annual trends in lake water chemistry and trophic conditions for Sierra Nevada Network index lakes by measuring a suite of selected parameters*.
- Detect intra- and inter-annual trends in lake level and outflow for Sierra Nevada Network index sites.
- Detect inter-annual trends in abundance of high-elevation anurans, particularly yellow-legged frog, Yosemite toad, and Pacific treefrog for Sierra Nevada Network index sites.

Extensive Sites

Extensive sites comprise a target population of over 1000 lakes distributed across the network (76 which will be sampled). Information from these sites will be used to make network- and park-level inferences about the status and trends of SIEN lake water chemistry. Extensive sampling sites are probabilistically selected and sampled less frequently than index sites--once every one or three years.

Monitoring Objectives

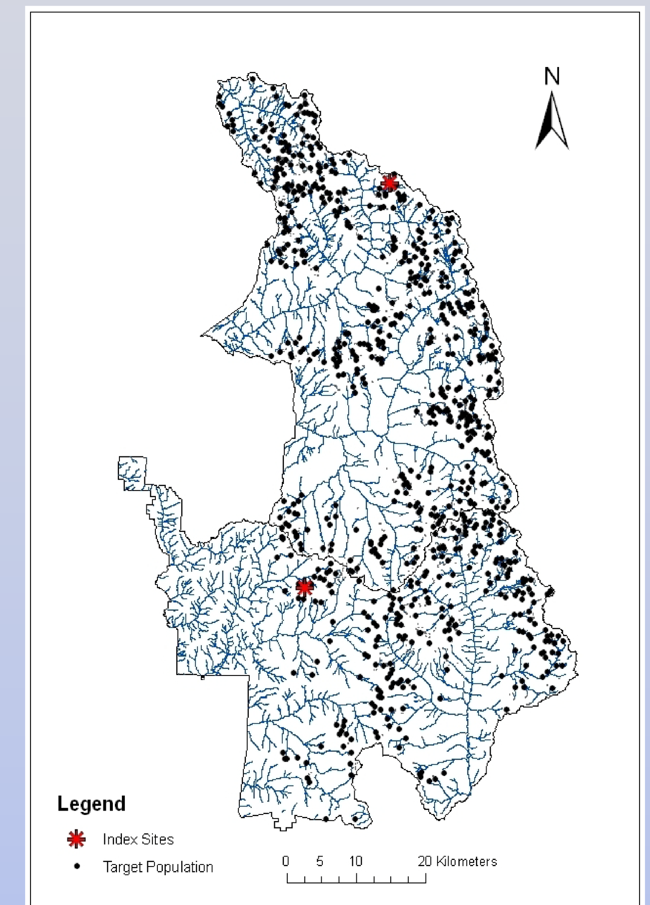
- Detect long-term trends in lake water chemistry and trophic conditions for Sierra Nevada Network lakes by measuring a suite of selected parameters*.
- Characterize Sierra Nevada Network lakes.
- Determine the proportion of Sierra Nevada Network lakes with chemical characteristics above/below threshold values for selected constituents.
- Detect long-term trends in abundance of high-elevation anurans, particularly yellow-legged frog, Yosemite toad, and Pacific treefrog for Sierra Nevada Network lakes.

***Water chemistry measures:**

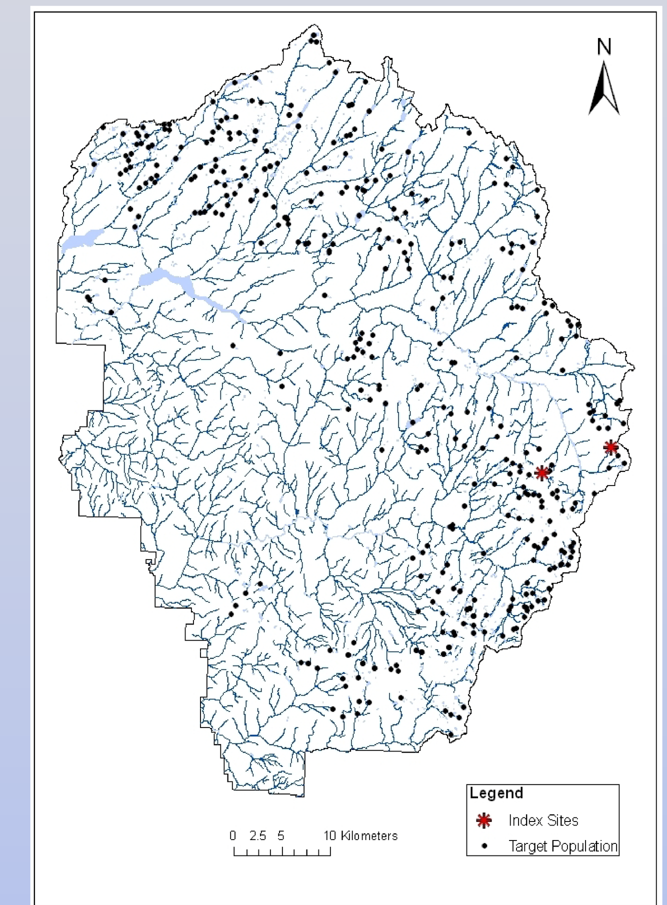
– Temperature, pH, specific conductance, acid neutralizing capacity (ANC)
– Major ions: calcium, magnesium, sodium, potassium, chloride, sulfate
– Dissolved inorganic nitrogen, dissolved organic nitrogen, total dissolved nitrogen, total nitrogen
– Total dissolved phosphorus, particulate phosphorus, total phosphorus, particulate carbon

Target Population

The target population includes all Sierra Nevada Network lakes, sampled at the outlet and mid-lake, during August and September. SIEN defined a lake as greater than/equal to 1.0 ha in surface area *and* greater than/equal to 2.0 m maximum depth.



Sequoia and Kings Canyon



Yosemite

Lakes in Kings Canyon National Park (Photo: B. Meadows)

References

Frakes, B., C. Hurst, D. Pillmore, B. Schweiger, and C. Talbert. 2007. Travel time cost surface model. Rocky Mountain Network, National Park Service, Fort Collins, CO.

Heard, A.M., L.A.H. Starcevich, J.O. Sickman, D.W. Schweizer, M.G. Rose. Sierra Nevada Network Lake Monitoring Protocol. National Park Service-Sierra Nevada Network.

McDonald, T. L. 2003. Review of Environmental Monitoring Methods: Survey Designs. Environmental Monitoring and Assessment 85:277-292.

Stevens Jr., D. L., and A. R. Olsen. 2004. Spatially Balanced Sampling of Natural Resources. Journal of American Statistical Association 99:262-278.

Sample Design

We elected to use a spatially-balanced probabilistic design, specifically the generalized random tessellation stratified (GRTS) design. (For information on GRTS please refer to Stevens Jr. and Olsen 2004).

We incorporated unequal inclusion probabilities into the design to minimize costs and simplify logistics. Inclusion probabilities are based on a cost-surface model that computes relative travel times to all lakes in the parks (Frakes et al. 2007). Lakes that have shorter travel times had a higher probability of being selected, while lakes that are further away and more difficult to access had a lower probability of selection.

The temporal sampling structure is a serial augmented panel design: [(1-0), (1-3)] (Figure 1). We are sampling a total of 25 lakes per year. Thirty-two percent of the annual resources are allocated to the annual panel (1-0) and the remaining to the (1-3) panels. This translates to 8 lakes per year in panel (1-0) and 17 lakes per year for the (1-3) panels. A total of 76 different lakes are sampled after one complete rotation of the panel design.

	Year									
Panel	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	X	X	X	X	X	X	X	X	X	X
2	X				X				X	
3		X				X				X
4			X				X			
5				X				X		

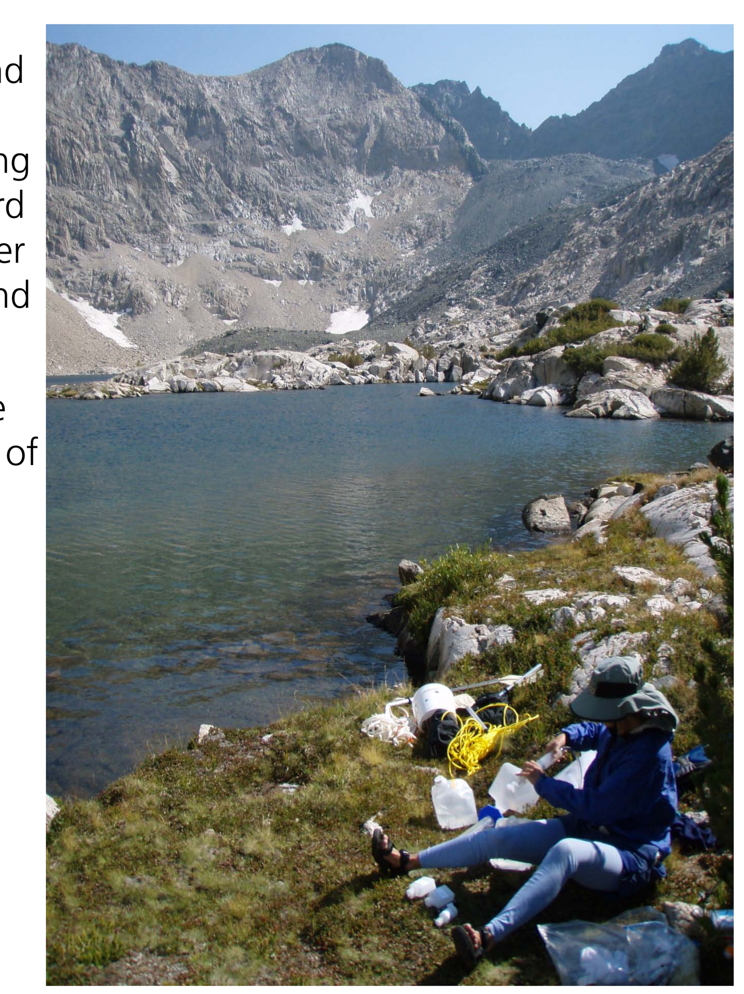
Figure 1: Panel design [(1-0), (1-3)]

Panel Notation (McDonald 2003): The first number is the number of consecutive occasions that a panel will be sampled, and the second is the number of consecutive occasions that a panel is not sampled before repeating the sequence. The [1-0] revisit design is a single panel (panel 1) that is visited every year. Digit pair [1-3] means that members of panels 2-5 are visited for one year, not visited for three years, then visited again for one year, not visited for three years, and so on. The notation for a split panel design, [(1-0), (1-3)], means that units in one panel will be visited every occasion, while units in the four other panels will be visited once every four years.

Field Sampling

Field sampling began in summer 2008. Field and laboratory methods and the Quality Assurance Project Plan are described in the Lake Monitoring Protocol's Standard Operating Procedures (Heard et al. 2007). Two crews, with 2-3 technicians per crew, sampled index sites from May-October and extensive sites in August and September.

Crews collected water chemistry samples at the outlets of all lakes and at mid-lake for a subset of sites (index and panel 1). They conducted shoreline amphibian surveys at all lakes. We gaged outlet flow at index sites only.



Collecting and processing samples (Photos: B. Meadows and R. Thiel)

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