NCCN Mountain Lakes Monitoring Strategy: Guidelines to Resolution

By Robert L. Hoffman, U.S. Geological Survey, and Mark H. Huff, National Park Service

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Conversion Factors

Multiply	By	To obtain
meter (m)	3.281	foot (ft)
hectare (ha)	2.471	acre
hectare (ha)	0.003861	square mile (mi^2)

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Abstract

The North Coast and Cascades Network (NCCN) Inventory and Monitoring Program provides funds to its Network Parks to plan and implement the goals and objectives of the National Park Services' (NPS) Inventory and Monitoring (I&M) Program. The primary purpose of the I&M program is to develop and implement a long-term monitoring program in each network. The purpose of this document is to describe the outcome of a meeting held to find solutions to obstacles inhibiting development of a unified core design and methodology for mountain lake monitoring.

Background

The North Coast and Cascades Network (NCCN) Inventory and Monitoring Program provides funds to its Network Parks to plan and implement the goals and objectives of the National Park Services' (NPS) Inventory and Monitoring (I&M) Program. The primary purpose of the I&M program is to develop and implement a long-term monitoring program in each network.

High-elevation mountain lake and pond ecosystems [hereafter mountain lakes] are one of fourteen Vital Signs that the NCCN selected to monitor. In developing a protocol for monitoring mountain lakes from 2002 to 2007, the technical staff and Natural Resource Division Chiefs of NCCN parks could not agree on a single Network protocol design and sampling methods. Consequently, two separate draft protocols were developed: one for Olympic National Park (OLYM) and another for Mount Rainer National Park (MORA) and North Cascades National Park (NOCA).

In November 2007, NCCN hosted a 3-year start up review of the Network. The purpose of the start-up review process is to assess the progress of each of the 32 I&M networks of the NPS. To address this, a panel of U.S. Geological Survey (USGS) scientists, and I&M and USGS program managers were convened for the review. The review panel concluded that, in regards to mountain lake monitoring, using two separate protocols hindered making comparisons across all three parks. The NCCN review panel mandated that a single, unified protocol needed to be developed.

On January 14 and 15, 2008, NCCN mountain lakes protocol staff met with USGS representatives and the NCCN coordinator at Mount Rainier's Nisqually House. Meeting attendees included (1) Science Discussion Oversight Group: Robert L. Hoffman, Group Lead, USGS FRESC Mountain Lake Scientist; Andrea Woodward, USGS FRESC Monitoring Lead; and Mark Huff, I&M Coordination, Facilitator & Mediator; and (2) NPS staff responsible for mountain lakes protocol development and implementation: Barbara Samora (MORA Protocol Lead) and Rebecca Lofgren (MORA); Reed Glesne (NOCA Protocol Lead) and Ashley Rawhouser (NOCA); and Steve Fradkin (OLYM Protocol Lead) and Bill Baccus (OLYM).

The purpose of this document is to describe the outcome of this meeting. In addition, we offer recommendations and insights where deemed appropriate to help clarify outcomes or to further solidify agreements. We acknowledge that substantial collaborative work lies ahead for the mountain lakes protocol staff to develop and merge the existing two draft protocols into a unified product. Documenting the underlying details of melding fundamental differences between these documents was beyond the scope of the charge for this meeting. Rather, our aim was to untangle and find solutions to the major stumbling blocks inhibiting the protocol staff from moving towards developing a unified core design and methodology. Nonetheless, should issues arise associated with techniques and methods, from hereon Hoffman and Huff will assist to arbitrate and finalize decisions.

Purpose of January 2008 Meeting

1. Clarify mountain lake monitoring goal(s) and objective(s).
2. Develop a core design for the mountain lakes protocol for trends to be assessed at the network scale (MORA, NOCA, and OLYM).
3. Develop a supplemental approach linked to the core design that addresses park-scale priorities for status and trends and enhances inference to park-scale and regional issues.

Framework from the NCCN Steering Committee for the January 2008 Meeting

The NCCN Steering Committee provided the following guidance for the meeting:

1. One network-wide protocol.
2. Budget range $80 to $110K.
3. Primary emphasis of Vital Signs monitoring should be ecosystem responses to the following stressors:
   (a) Climate change.
   (b) Atmospheric deposition.
4. Core design should follow:
   a. Set number lakes/park; Steering Committee recommended 15 lakes, 5/park in MORA, NOCA, and OLYM.
   b. One visit annually.
   c. Accessible by foot.
5. Encumbered salaries (about $30,000/year in 2008 dollars) are fixed in the budget.

Five-Step Process of Meeting

1. Develop a core design using the cost constraints; then build upon this for the supplemental design, using the guidance provided.
2. Hoffman and Huff will develop a draft resolution guidance document (*i.e.*, this document).
3. Circulate to mountain lakes protocol development team and NCCN Steering Committee for review, and revise.
4. Circulate for informal peer review through USGS.

5. Finalize resolution guidance report.

Achieving a Common Goal and Objective

Separate goal and objective statements had been proposed for the two draft mountain lakes protocols, which needed (1) to be unified and (2) restated simply and clearly. Hoffman and Huff took input from staff at the meeting on this topic and then crafted the following concise goal and objective statements:

- *Goal*: Monitor the ecological condition of NCCN mountain lakes in the context of climate change and atmospheric deposition.
- *Core Design Objective*: Detect interannual trends in physical, chemical, and biological parameters within and among NCCN mountain lakes to be monitored as part of the core design.
- *Supplemental Design Objective*: Develop a supplemental sampling scheme concordant with the core design that can be implemented as funds become available.

Consensus on a Core Design

The core design has four parts: Design Stratification, Sampling Frequency, Sampling Framework, and Parameters.

1. Design Stratification
    a. Lake size/depth ranges: 0.4 to 6 ha; >2.5 m maximum depth after about August 1.
    b. Elevation range: 1219–1890 m (4,000–6,200 ft).
    c. Relative Precipitation (“wet” to “dry”) gradient in each park.
    d. All lakes would have limited spawning habitat (for example, limited outflow, limited gravel substrates, and lack of nearshore springs). This condition would be a surrogate for low fish density without knowing actual density of fish in a lake. Selected lakes do not necessarily need to have fish present. This habitat criterion is an attempt to include both lakes without fish and lakes with low-density fish populations but to exclude lakes with reproductively successful, high-density fish populations.

2. Sampling Frequency

Sampling will be done one time per year (about early to mid-August to the end of September). This period of time for sampling mountain lakes is when the lakes typically are at "peak productivity," and lake conditions are relatively stable. The period of "peak productivity" could be occasionally missed due to this relatively limited sampling period; however, this limited period of sampling was selected due to fiscal constraints, and because this time period for these mountain lakes is on average the likely period of "peak productivity."

3. Sampling Framework

The core design generally follows a "wet" to "dry" gradient, which is surrogate for a "precipitation" gradient. From the broad perspective, although this environmental pattern is replicated in each park, the results need to be interpreted from this broad "wet" to "dry" perspective, because the gradient of precipitation differs quantitatively and geographically among the parks.

The framework assumes: (1) a balanced design among the three parks, (2) an environmental gradient that partitions the parks into two categories: wet and dry, and (3) three lakes/park per each environmental gradient category. The core design framework to address network-scale inference should then be three parks × two environmental gradient categories × three replicates/category, totaling 18 lake visits/year (table 1).

Table 1. NCCN Mountain Lakes Design Framework.

	"Wet" section	"Dry" section	Total
OLYM (West)	3	3	6
NOCA (North Cascades)	3	3	6
MORA (South Cascades)	3	3	6
Total	9	9	18

4. Parameters

An overarching theme of the stated goal and (core design) objective is to detect lake trends from the "ecosystem perspective" in the context of climate change and atmospheric deposition. To accomplish this integrated approach, water-quality parameters (physical, chemical, and biological) will be collected.

A. Core design water-quality parameters required by the NPS Water Resources Division:

1. Physical Parameters
    a. Water temperature (that is, a continuous profile and profiles taken at surface, top, mid, and bottom).
    b. Water level (accurately measuring this is critical given the relatively shallow depths of these lakes. Even a small fluctuation could have a significant effect on lake volume).
2. Chemical Parameters
    a. pH
    b. Specific conductance
    c. Dissolved oxygen

B. Additional Water-Quality Parameters
    1. Physical Parameters
        a. Water clarity
        b. Surface area
        c. Shoreline length
        d. Maximum depth
        e. Bathymetry
        f. Lake volume
        g. Inlets and outlets (presence-absence, number, location)
        h. Nearshore substrate composition
        i. Large woody debris (presence and photo-documented)
        j. Riparian disturbance (areas of disturbance photo-documented)
    2. Chemical Parameters
        a. Alkalinity and/or acid-neutralizing capacity (ANC)
        b. Anions and cations: including sodium, magnesium, calcium, chlorine, and sulfur (and preferably, as funding is available for analysis, a complete suite for comparing to available atmospheric deposition data)
        c. Nutrients: including nitrogen and phosphorus
        d. Total Dissolved Solids (TDS)
        e. Dissolved Organic Carbon (DOC)
    3. Biological Parameters
        a. Chlorophyll-a
        b. Zooplankton
        c. Macroinvertebrates
        d. Amphibian
        e. Fish

C. Supplemental Measurements
    1. Outlet flow measured annually using the Emap, plastic golf ball method. This should be done when each lake is sampled during the field season.
    2. Nearshore disturbance substrate mapping every 10 years.
    3. Nearshore and riparian disturbance documented annually using photographic reference points.
    4. Amphibian snorkel survey completed in addition to the Visual Encounter Survey to be used for documenting species (that is, especially larval salamander) presence-absence.

Many physical parameters (for example, bathymetry, surface area, shoreline length, and other lake features) can be assessed at relatively long-term intervals (for example, every 10 years) or by using GIS. Others (for example,inlets and outlets, large woody debris, and riparian disturbance) can be documented using photographic reference points.

Because zooplankton and macroinvertebrate species are distributed differently among lakes, network-scales and park-scale inferences of zooplankton and macroinvertebrates needs to be assessed at the community level (for example, species diversity and relative abundance). Zooplankton and macroinvertebrates are useful integrators and indicators of change due to the stressors atmospheric deposition and climate change. Zooplankton and macroinvertebrates inhabit different parts of a lake (that is, shoreline bottom versus water column, respectively), thus each community type may be affected to a different degree by a particular stressor. By monitoring both community types, we can increase our ability to detect trends in biological communities influenced by these major stressors.

Options and Recommendations for Supplemental Sampling

Four options for sampling were identified by participants of the January 2008 meeting to supplement the core design. Recommendations are provided. Some additional useful supplemental measures are proposed to consider.

Options

1. Add lakes visited on a multiple-year rotation (for example, 5-year rotating panel).
2. Add to the number of lakes visited annually.
3. Add more visits/year to core lakes.
4. Add parameters or intensify parameter sampling.

Recommendations are provided as potential add-ons to the single core design if funds are available or additional funding becomes available after the core design is accomplished. Add-ons will be made at the discretion of the individual parks.

1. Because lakes tend to vary chemically and biologically across the park landscapes, NOCA and MORA will add lakes visited on a multiple-year rotation (for example, 5-year rotating panel), within budgetary constraints, to increase diversity of lakes sampled. MORA also proposes to phase in two visits/year to at least two core lakes to capture the melt-out period and associated episodic acidification that may occur due to atmospheric deposition of nitrogen and sulfur compounds.
2. OLYM will continue to sample core lakes twice per year for two additional years to characterize intra-annual variability of physical, chemical, and biological parameters and then switch to once per year sampling of core lakes with the possibility of adding additional lakes to be monitored.
3. There is some concern that one sampling visit per year to core lakes, mid-August through September, will not capture the early season (that is, snowmelt, ice-off) episodic acidic and nutrient (that is, primarily nitrogen) influx into the lakes. Some points to consider include:
    a. Early season sampling can be used to collect surface water samples for the analysis of acid and nitrogen flux from snowmelt. However, snowpack and bulk precipitation sampling at park sampling stations also can be efficient and affordable alternatives for acquiring atmospheric deposition data.
    b. Because the timing of lake ice-in and ice-off can be measured with continuous data loggers, an early season visit is not necessarily required to collect this information.
    c. The biological community in any given mountain lake will go through seasonal succession, and the period of succession can be temporally compacted. However, if the

program can only afford one visit per lake during the ice-melt and snow-free season then the biological community should be sampled during the period of "peak productivity" rather than just after icemelt and snowmelt. If funding becomes available for additional intra-seasonal visits, then the "early" season community can be assessed and intra-annual succession can be documented. This is an important point because sampling lakes more than once a year would be ideal if adequate funding were available to cover this frequency of sampling.

Agreements of the January 2008 Meeting Participants

1. The staff proposed that 18 lakes be sampled in the core design, even though this is more lakes than proposed by the Steering Committee. The design will be balanced (3 parks by 6 lakes; 3 "wet" and 3 "dry") and will likely increase the power of the statistical design (that is, timeliness of detecting trends). This will be reviewed by a biometrician. The group agreed that 15 lakes using the criteria proposed, sampled once per year, costs about $75K in 2008 dollars. For 18 lakes, Hoffman and Huff estimate the cost would be about $82K, assuming costs of roughly $2,500 per lake for adding three lakes—one per park.
2. Sites to be monitored at each park as part of the core program may need to be redrawn.
3. Parks will use the same laboratories for processing water chemistry and biological samples.
4. Each park will complete at minimum a shoreline amphibian Visual Encounter Survey. However, snorkel surveys may be the most effective method for observing larval salamander (for example, *Ambystoma*) species.
5. Mike Adams (USGS FRESC) was consulted about amphibian surveys using a method called Proportion of Area Occupied. He thinks that inference at the park and network levels can not be achieved using this method as part of the core program. He recommends excluding the Proportion of Area Occupied method from the core program protocol.
6. The approximate times of ice-in and ice-off will be measured with continuous data loggers.
7. All lakes sampled as part of the core design will be accessed on foot from trails (or roads). Use of helicopters should be judicious; their use is appropriate only within the supplemental design and only for lakes not visited annually.
8. There is a legacy cost to changing the mountain lakes pre-approved (pilot) protocol design (for example, remove temperature data loggers and access to biometrician). The cost should be built into the budget over the next 2 years.
9. NOCA/MORA Standard Operating Procedures (SOPs) will be used as the starting template, with the expectation to unify these into a single system using an iterative process.
10. There are a limited number of measurement details that differ among the parks. For example, the parks use two different methods for measuring water level that "essentially" provide the same result. The parks will resolve any differences in methodology through the unified SOP writing process. If there is a stalemate, we recommend using the USGS Mountain Lake protocol publication by Hoffman and others (2005) as the benchmark for resolving such differences.
11. Collecting phytoplankton samples, although these can be useful indicators of impacts associated with atmospheric deposition, is problematic because (a) the taxonomy is difficult, (b) taxonomic elucidation is expensive, and (c) the taxonomy is taxonomist dependent—thus requiring that the taxonomist be available for the long-term (which is not

always possible). The parks agreed that phytoplankton samples will not be collected, and that chlorophyll-a samples will be useful surrogates for phytoplankton and diatoms.

Uncertainties

1. We assume that there is an adequate sample of lakes at each park from which to draw a lake sample given the logistical and administrative constraints. However this has not been validated (that is, NOCA and OLYM). Huff will request park GIS staff to assist in validating.
2. Even though the parks agree that sampling macroinvertebrates is an important part of meeting the core design objective, there are some questions regarding the impact sampling may have on the littoral zone of lakes. However, the type of sampling (method and device) can help mitigate potential disturbance. This concern will require further consideration.

Reference Cited

Hoffman, R.L., Tyler, T.J., Larson, G.L., Adams, M.J., Wente, Wendy, and Galvan, Stephanie, 2005, Sampling protocol for monitoring abiotic and biotic characteristics of mountain ponds and lakes: U.S. Geological Survey Techniques and Methods 2-A2, 90 p.