PROTOCOL DEVELOPMENT SUMMARY

Protocol: NCCN Vital Signs Monitoring of Large Lowland Lake Water Quality

Parks where protocol may be implemented: The protocols will be immediately implemented at Lake Crescent within OLYM. Further implementation may proceed at NOCA.

Potential NCCN Large Lowland Lake Population

NOCA	Elevation(m)	Area (ha)	Depth (m)
Chelan		13,500	433
Ross	487	4,726	155
Diablo	367	368	97
OLYM			
Ozette	9	2075	190
Crescent	177	3151	216

Justification:

Lake water quality was ranked 7th as a potential vital sign in the NCCN. While limited in number, large lowland lakes are key aquatic resources in the NCCN parks where they occur. These lakes are susceptible to a wide range of anthropogenic impacts including eutrophication, pollution, shoreline development, hydrological manipulation, exotic species introduction, and global climate change. Because each lake has unique features, a model-based design is advocated rather than an inferential one. For example, Lake Crescent (OLYM) is a deep, oligotrophic lake renowned for its water clarity and supports 2 endemic fish species. Lake Ozette (OLYM) is the 3rd largest lake in Washington State, is a highly humic mesotrophic lake that supports a federally listed (threatened) sockeye salmon stock. And Lake Chelan (NOCA) is the 3rd deepest lake in the U.S.

Monitoring Questions & Objectives:

Large Lake Step-Down Framework

- NCCN Water
  - Streams, Large Rivers, Montane lakes & Ponds
  - Large Lowland Lakes
    - Water Column
      - Physical/Chemical
        - N, P, pH, DO, Ions
        - T, SpCond, Secchi,
      - Biological
        - Zooplankton
        - Primary productivity (Chla)
    - Benthos
      - Bathymetry
    - Littoral
      - Littoral habitat
      - LWD distribution

Monitoring Questions Associated with Step-down Framework

- What is the status and trend of water quality in NCCN?
  - What is the status and trend of large lowland lake water quality in NCCN?
    - What are the temporal and spatial trends in physical/chemical characteristics of the lake water column (pelagic zone)? (*see attached table for physical/chemical parameters and sampling frequency*)
    - What are the temporal and spatial trends in the biological characteristics of the lake water column (pelagic zone)? (*see attached table for biological parameters and sampling frequency*)
      - What are the long-term trends in zooplankton species composition and abundance?
      - What is the natural level of variation in zooplankton species composition and abundance?
      - What are the long-term spatial and temporal trends in lake primary productivity?
    - What is the Bathymetry of a lake?
    - What is the current distribution of littoral habitats in a lake and what is the long-term change in this distribution?
    - What is the current distribution of LWD in a lake and what is the long-term change in this distribution?

Monitoring Objectives:

1. Determine seasonal and inter-annual changes in the horizontal and vertical distribution of physical/chemical characteristics of the lake water column. ***Justification*****:** *The spatial and temporal distribution of physical/chemical water column characteristics respond to a variety of system stressors, from point-source eutrophication to global climate change. Depending upon the type of stressor and basin morphology of the lake, different sections of the lake may be differentially affected. Understanding how these parameters change can provide park managers insight into potential causes, stimulate research to positively identify causes, and ultimately lead to beneficial management activities..*
2. Determine seasonal and inter-annual trends in zooplankton species composition, abundance, and distribution. ***Justification*****:** *Zooplankton communities respond to changes in lake trophic structure, pollution, and climate change. Understanding how zooplankton communities change over time can lead to better interpretation of changes in physical/chemical parameters.*
3. Obtain an accurate bathymetric map of a lake. ***Justification:*** *The number of water column sampling stations per lake is dependent upon the number and size of sub-basins. Separated deep sub-basins may have different physical/chemical and biological dynamics. Knowing the basin morphology of a lake is crucial to developing an appropriate sampling design.*
4. Determine the distribution of littoral habitat types via periodic inventories to determine extent of shoreline modification. ***Justification****: Lake water quality and trophic structure can be affected by shoreline modification. Littoral habitat provides a buffer to terrestrial run-off, along with breeding and nursery habitat for key biota. Knowing the distribution of littoral habitat types and how they are changing over time will lead to more informed management decisions that directly affect lake water quality.*

5. Determine the distribution of LWD on the lake periphery. ***Justification*:** *LWD provides key habitat for lake biota, including fish, that directly affect water quality. Knowing the current distribution of LWD and how it changes over time will inform management decisions that directly affect important lake biota and lake trophic structure.*

Basic Approach:

Because of the limited number of NCCN large lowland lakes and their widely varied characteristics the proposed monitoring design is a model-based rather than an inferential design. Within a lake, all significant basins and sub-basins will be sampled so a probabilistic design is not required to make lake-wide inferences.

The proposed large lowland lake protocol consists of two components, (1) Regular water column physical/chemical and biological monitoring, and (2) Periodic inventorying of littoral habitat and LWD. Details related to sampling design, frequency and parameters are contained in the Table 1 below.

Regular water column monitoring will be conducted at fixed sampling stations located by GPS. The number of stations will be dependent upon the lake basin morphometry. Generally there will be a station in each major sub-basin, or major section of a sub-basin if sub-basins are extensive. Standard physical/chemical sampling will be conducted by taking a vertical profile of the water column with a multi-probe data sonde (e.g. YSI, Hydrolab). Additional chemical sampling will be conducted quarterly by taking epilimnetic, metalimnetic, and hypolimnetic water samples that will be shipped to an analytic laboratory for nutrient and ion analysis. See attached table for specific measurement parameters and sampling frequency.

Zooplankton communities will be sampled taking a vertically integrated sample of the water column during the day from a depth of 1.5 times the average annual secchi depth. This depth will ensure adequate sampling of the euphotic zone. Phytoplankton biomass will be estimated via chlorophyll-a concentration profiles of the water column.

Periodic inventory of lake physical habitat characteristics also will be done. A bathymetric survey resulting in an accurate map will be conducted if such a map doesn't already exist. Once every decade littoral habitats will be boat-surveyed. Once every 5 years the distribution of large woody debris will be mapped.

A preliminary schedule of project-related activities is outlined in Table 2.

Table 1: Vital Signs Monitoring Design for determining the ecological condition of large lowland lakes

Target Population - Lakes OLYM, NOCA: Greater than 50 ha surface area, with boat launch for sampling platform

Two survey types: (1) Regular monitoring, (2) Periodic inventories

Orange denotes WRD required core parameters

Core column denotes striped-down core monitoring program

INDICATORS	Core	Survey Type: Reg Mon	Survey Type: Per Inv	Sampling: # Stations per lake	Sampling: Sampling Frequency	Method	Inference	Response Variables
Biological								
Zooplankton	*	M		2	monthly	vertically integrated 60μm net. 2x mean Secchi	Lake	Species diversity, abundance, timing
Chlorophyll a	*	M		all	monthly	Vetically integrated: Data sonde fluorometry	Lake	Means etc., time series
Physical								
Specific Conductivity	*	m		all	monthly	Vertically intergrated: Data sonde	Lake	
Temperature	*	m		all	monthly		Lake	
Water Clarity (Secchi depth)	*	m		all	monthly	Secchi disk	Lake	Means etc., time series
Lake Level	*	m			continuous/weekly	Pressure transducer/ Staff gauge	Lake	
Bathymetry			i		once	Sonar/GPS	Lake	
Littoral habitat			i		decadal	Boat based survey/ Hi-res aerial photo	Lake	% cover
LWD distribution			i		every 5 yrs		Lake	% cover
Chemical								
Dissolved Oxygen	*	m		all	monthly	Vertically integrated: Data sonde	Lake	Means and stnd dev, Exceedance of criteria
pH	*	m		all				
Turbidity	*	m		all				
Nutrients		m			monthly/quarterly			Means, etc., Exceedance of criteria
-Ammonia	*			all	monthly/quarterly	Vertidially integrated: Data sonde/ Lab sample	Lake	Means and stnd dev
-Nitrate	*			all				
-Total Kjehldahl Nitrogen				2	quarterly	Laboratory water sample	Lake	Means and stnd dev
-Total Phosphorus	*			2				
-Total Dislvd Phosphorous				2				
-Orthophosphate				2				
Anions and Cations		m		2				
Dissolved Organic Carbon		m		2				