National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Large Lowland Lakes Monitoring Protocol

North Coast and Cascades Network

Natural Resource Report NPS/NCCN/NRR—2013/647

ON THE COVER

Top row: Looking west across the north basin of Lake Crescent, Olympic National Park, towards Barnes Point.
Middle row from left: Nuisance algal blooms at the Lyre river outlet; the endemic freshwater mussel *Anodonta kennerlyi*; roughskin newt (*Taricha granulosa*) in a littoral bed of *Lobelia dortmanna* and *Isoetes occidentalis*.
Bottom row from left: Lake Crescent water column sampling; the Lake Crescent zooplankter *Collotheca pelagica*; tree pollen collected on the surface of the west end of Lake Crescent.
Photographs by: Steven Fradkin

Large Lowland Lake Monitoring Protocol

North Coast and Cascades Network

Natural Resource Report NPS/NCCN/NRR—2013/647

Steven C. Fradkin, Ph.D.

National Park Service
Olympic National Park
600 E. Park Avenue
Port Angeles, WA 98362

April 2013

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics. These reports are of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Report Series is used to disseminate high-priority, current natural resource management information with managerial application. The series targets a general, diverse audience, and may contain NPS policy considerations or address sensitive issues of management applicability.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner. This report received formal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data, and whose background and expertise put them on par technically and scientifically with the authors of the information.

Views, statements, findings, conclusions, recommendations, and data in this report do not necessarily reflect views and policies of the National Park Service, U.S. Department of the Interior. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Government.

This report is available from The North Coast and Cascades Network website (http://science.nature.nps.gov/im/units/nccn/reportpubs.cfm) and the Natural Resource Publications Management website (http://www.nature.nps.gov/publications/nrpm).

Please cite this publication as:

Fradkin, S. C. 2013. Large lowland lake monitoring protocol: North Coast and Cascades Network. Natural Resource Report NPS/NCCN/NRR—2013/647. National Park Service, Fort Collins, Colorado.

NPS 963/120404.April 2013

Contents

Page

Figures vii

Tables ix

Appendices ix

Standard Operating Procedures (SOPs) xi

Revision History Log xiii

Abstract xv

Acknowledgments xvi

1. Introduction 1

2. Background and Objectives 3

    2.1. Background and History 3

    2.2. Rationale for Monitoring Large Lowland Lakes 3

    2.3. Lake Crescent Description 4

    2.4. Measurable Objectives 9

    2.4.1 Monitoring objectives 10

3. Sampling Design 13

    3.1. Rationale for Design Selection 13

    3.2. Site Selection 13

    3.3. Spatial and Temporal Sampling Design 14

    3.4. Description of selected monitoring variables 14

    3.5. Level of change that can be detected 17

4. Field Methods 19

    4.1. Sequence of events during field cycle 19

    4.2. Field Cycle Preparations 19

Contents (continued)

Page

4.3. Permitting and Compliance 20

4.4. Field Methods and Procedures 20

5. Data Management 21

5.1. Project information management overview 21

5.2. Pre-season Preparations for Information Management 22

5.2.1. Project Workspace Setup 22

5.2.2. Project Database Application 22

5.3. Overview of Database Implementation Strategy 22

5.4. Data Entry and Processing 24

5.4.1. Regular Data Backups 24

5.4.2. Data Verification 24

5.4.3. Field Form Handling Procedures 24

5.4.4. Image Handling Procedures 25

5.5. Data Quality Review 25

5.6. Metadata Procedures 26

5.7. Data Certification and Delivery 27

5.8. Data analysis 27

5.9. Reporting and Product Development 27

5.9.1. Report Content 27

5.9.2. Standard Report Format 28

5.10. Identifying and Handling Sensitive Information 28

5.11. Product Delivery, Posting and Distribution 29

5.11.1. Holding Period for Project Data 29

Contents (continued)

Page

5.11.2. Special Procedures for Sensitive Information 29

5.12. Archiving and Records Management 30

5.13. Season close-out 30

6. Personnel Requirements and Training 31

6.1. Safety 31

6.2. Roles and Responsibilities 31

6.3. Qualifications 33

6.4. Training Procedures 33

6.5. Facility and Equipment Needs 34

6.5.1. Essential Equipment 34

6.5.2. Standard monthly sampling field equipment check list 34

6.6. Annual Budget 35

Literature Cited 37

Figures

Page

Figure 1. Location of Lake Crescent within Olympic National Park on the Olympic peninsula of Washington State..... 4

Figure 2. Lake Crescent and its watershed 5

Figure 3. Hypsographic (depth-area) curve for Lake Crescent..... 6

Figure 4. Bathymetric map of Lake Crescent illustrating location of fixed sampling stations 6

Figure 5. Secchi depth data from 2005-2006 illustrating an annual cycle of water clarity measurements. 7

Figure 6. Isothermal variations (ºC) in Lake Crescent from March 1982-March 1983..... 7

Figure 7. Temperature and dissolved oxygen profiles at Station #2 in Lake Crescent during A) stratification (August) and B) destratification (February) periods..... 8

Figure 8. Major water column nutrients (Total N, Total P, Nitrate) at Lake Crescent Station #2 during 2006-2007 in the epilimnion, metalimnion, and hypolimnion..... 9

Figure 9. A conceptual model illustrating system drivers and stressors acting upon NCCN large lake ecosystems processes. 11

Figure 10. Idealized flow diagram of the cyclical stages of project information management, from pre-season preparation to season close-out..... 21

Figure 11. Schematic flow diagram of data flow from the local NCCN copy of NPSTORET to the national enterprise copy of NPSTORET, to the EPA STORET data warehouse..... 23

Tables

Page

Table 1. NCCN Large Lowland Lakes..... 3

Table 2. Threshold levels for selected water quality parameters derived from the Washington Department of Ecology water quality criteria for salmonids spawning, rearing and migration lakes..... 11

Table 3. Lake Crescent monitoring station locations and sampling depths. 13

Table 4. Spatial and temporal sampling design of limnological parameters measured in Lake Crescent (OLYM). 15

Table 5. Sequence of events for the NCCN Large Lowland Lake Protocol during a model calendar year. 19

Table 6. Functional comparison of the working database copy and the master database..... 24

Table 7. Roles and responsibilities for Large Lakes Monitoring in the NCCN. 32

Table 8. Proposed annual budget for implementation of the NCCN Large Lowland Lakes Protocol in Lake Crescent (OLYM). 35

Appendices

Page

Appendix 1: Yearly Project Task List. ..... Appendix 1-1

Appendix 2: Data Forms..... Appendix 2-1

Appendix 3: Lake Crescent Zooplankton Guide. ..... Appendix 3-1

Appendix 4: Job Hazard Analysis and Safety Considerations..... Appendix 4-1

Standard Operating Procedures (SOPs)

Page

SOP 1. Physical/Chemical Water Column Profile.....SOP 1-1

SOP 2. Chlorophyll-*a*: Analytical Laboratory check of YSI Calibration.....SOP 2-1

SOP 3. Water Clarity .....SOP 3-1

SOP 4. Zooplankton Sampling .....SOP 4-1

SOP 5. Alkalinity.....SOP 5-1

SOP 6. Water Chemistry.....SOP 6-1

SOP 7. Lake Level .....SOP 7-1

SOP 8. Recommended Data Analyses.....SOP 8-1

SOP 9. Quality Assurance and Quality Control.....SOP 9-1

SOP 10. Managing Photographic Images .....SOP 10-1

SOP 11. Project Workspace and Records Management .....SOP 11-1

SOP 12. Product Delivery, Posting and Distribution.....SOP 12-1

SOP 13. Revising the Protocol.....SOP 13-1

SOP 14. Field and Laboratory Safety .....SOP 14-1

Revision History Log

Revision Date	Author	Changes Made	Reason for Change
6/1/2006	S. C. Fradkin	Original	
9/21/2006	S. C. Fradkin	Various revisions	Response to admin and peer review
Dec. 2011	J. R. Boetsch	Chapt. 5: Data Management	Update content to current NPS standards
Feb. 2012	S. C. Fradkin	Formatting and minor reorganization	Preparation for publication in NRR series

Abstract

While only five in number, large lowland lakes are vital features within the national parks of the North Coast and Cascades Network (NCCN). These water bodies are vast storehouses of renewable freshwater and serve as valued centers of both ecological and recreational activity. Large lakes are model systems for tracking long-term ecological changes associated with anthropogenic influences. Long-term data collected from these systems grant valuable insights for assessing conditions and evaluating management options. Global climate change and air pollution from nearby urban areas and across the Pacific Ocean affect how these ecosystems function. Their accessibility and recreational opportunity create exposure to human impacts such as increases in nitrogen and phosphorus compounds, road and shoreline development, and fish harvests.

This protocol was designed to track long-term seasonal and annual trends in key physical, chemical, and biological water quality parameters in major lake basins. Water column profiles of parameters are sampled monthly at permanent sampling stations based on GPS locations. Sampled parameters include:

- Temperature, specific conductance, water clarity, lake level
- Alkalinity, pH, ion concentration, dissolved oxygen concentration, dissolved organic carbon
- Nutrients, including nitrogen and phosphorus
- Zooplankton biodiversity and chlorophyll-α concentration

This protocol was designed for primary implementation in Lake Crescent at Olympic National Park, with further implementation planned at other lakes within Olympic National Park and North Cascades National Park Service Complex as funding becomes favorable.

Acknowledgments

Limnological monitoring has a long history, and the construction of this protocol benefited inordinately from the work that others have done in constructing their own monitoring programs. Published protocols of influential programs include Baker et al. (1997), Bade et al. (1998), and Hoffman et al. (2005). Other monitoring programs, especially the Lake Washington program started by W. T. Edmondson and continued by D. E. Schindler, in addition to the Lake Tahoe work group under C. R. Goldman have been most influential. The data management portion of this protocol was crafted by John Boetsch, data manager and ecologist at OLYM. This protocol benefited from early discussions with Stephanie Hampton (NCEAS), Bob Hoffman (USGS-BRD), and Daniel Schindler (Univ. of Washington). Two anonymous reviewers in addition to James Agee (Univ. of Washington), Mike Herold (Washington Dept. of Ecology), Roy Irwin (NPS-WRD), and Penny Latham (NPS-PWR) all provided valuable peer-review input for the revision of this document. Kris Freeman (University of Washington CESU) and Lise Grace (NPS-NOCA) provided valuable editorial and formatting assistance to get this protocol into publishable form.

1. Introduction

This protocol narrative outlines the rationale, sampling design and methods proposed for monitoring large lowland lakes in the North Coast and Cascades Network (NCCN) as part of a larger long-term ecological monitoring program. In 2000, the National Park Service (NPS) initiated an Inventory and Monitoring (I&M) program to track key indicators of ecosystem health, or "vital signs". These indicators are measurable parameters that may provide warning of changes that can impair the long-term stability and character of natural park ecosystems and may also serve as baseline conditions for less impacted systems (NPS 2001). The I&M program is organized nationally around 32 monitoring networks including approximately 270 park units. As one of these networks, the NCCN is composed of 8 NPS units including Olympic National Park (OLYM) and North Cascades National Park Service Complex (NOCA), the only two NCCN units with large lowland lakes.

Since 2000, numerous monitoring workshops and meetings have been conducted in the NCCN to identify key park ecosystem components and core indicators within each ecosystem component, in addition to allocating limited monitoring funding to the development and implementation of monitoring protocols (Weber et al. 2009). As part of this process, large lowland lakes were chosen as one of the park ecosystem components for protocol development. However, due to the limited funding available for protocol implementation within the NCCN and also due to differing priorities placed by network parks on where to allocate limited funding, the NCCN aquatic monitoring group and NCCN technical advisory panel decided to initially implement this protocol only in Lake Crescent within OLYM. This decision was based on the exceptional water quality and unique resident fish populations of the lake, in addition to the high priority OLYM placed on Lake Crescent monitoring, coupled with the presence of appropriate support facilities at the lake and a history of pilot field limnological work (Meyer and Fradkin 2002).

2. Background and Objectives

2.1. Background and History

Prior to the present I&M program, monitoring of large lowland lakes in the NCCN has been sporadic at best (e.g. Meyer and Fradkin 2002), with essentially no substantial time-series data for use in detecting trends in key limnological parameters. In this protocol, large lowland lakes are defined as waterbodies greater than 100 ha surface area. Only five NCCN lakes meet these criteria (Table 1), and all of these lakes are substantially larger than 100 ha and generally exceed 100 m in depth.

Table 1. NCCN Large Lowland Lakes.

Park, Lake	Elevation (m)	Area (ha)	Depth (m)
NOCA			
Chelan	335	13,500	433
Ross	487	4,726	155
Diablo	367	368	97
OLYM			
Ozette	9	3,007	98
Crescent	177	2,030	190

While some sets of lakes may be considered modular ecosystems that are essentially replicate lakes, NCCN large lowland lakes have unique physical and biological characteristics due to their geologic history, landscape setting, and history of anthropogenic manipulation that cause them to behave autonomously (Magnuson and Kratz 2004). For example, Lake Crescent is a deep, clearwater, ultra-oligotrophic system with little watershed disturbance (Meyer and Fradkin 2002), whereas Lake Ozette is a highly humic, mesotrophic system whose watershed has been substantially impacted by logging activity (Meyer and Brenkman 2001). Ross and Diablo Lakes are reservoirs created by hydropower dams, and Lake Chelan is the world's 9th deepest lake at 433 m. Since each of these NCCN lakes is essentially a unique system, the focal scale of this monitoring protocol is at the single lake level rather than at level of many lakes on a landscape.

2.2. Rationale for Monitoring Large Lowland Lakes

Freshwater is a key resource that structures all park ecosystems in the NCCN. While large lowland lakes are found in only two of the eight park units (OLYM and NOCA), and occupy a relatively small portion of the total park areas, these systems are disproportionately important because they represent a large fraction of renewable freshwater and serve as valued centers of recreational, economic and ecological activity (Postel and Carpenter 1997, Wilson and Carpenter 1999). Large lakes are popular visitor destinations due to their aesthetic and natural characteristics. These systems support abundant wildlife, waterfowl, and fish resources that are critical components of natural park ecosystem function. Several of the NCCN large lakes contain endemic and/or federally listed fish species that rely upon lake water quality. For example, Lake Crescent supports the endemic beardslee trout (Meyer and Fradkin 2002), and Lake Ozette supports a federally listed run of sockeye salmon (Meyer and Brenkman 2001).

Large lakes are model systems for tracking long-term ecological changes associated with anthropogenic influences (e.g. Edmondson 1979, Goldman 1981, Stow et al. 1998). Long-term

time series data from these systems can give perspective for assessing conditions and evaluating management options (Magnuson 1990). Lake ecosystems have a rich history of ecological research and have provided fundamental concepts and mechanistic explanations for their function. Examples include contributions towards understanding species diversity (Hutchinson 1959, Hessen et al. 2006), the role of trophic interactions in structuring lake communities (Carpenter 1988), the effects of acidification (Frost et al. 1999, Likens 2004), the effects of nutrient enrichment (Goldman 1988, Edmondson 1991), and the nature of regime shifts (Carpenter 2003). Model large lake monitoring programs include Lake Washington (Edmondson 1979), Lake Tahoe (Goldman 1981), Crater Lake (Larson et al. 1993), Lake Constance, Germany (Gaedke 1998), Lake Lucerne, Switzerland (Buhrer and Ambuhl 2001), and Lake Stechlin, Germany (Koschel and Adams 2003). While large lakes are complex ecosystems, long-term ecological change can be understood based on a finite set of indicators at only a few spatial scales, enabling focus on the role of temporal change (Carpenter 2003).

2.3. Lake Crescent Description

Lake Crescent is a clear, deep ultra-oligotrophic system located in the northwest corner of the Olympic Peninsula of Washington State (Figure 1). Of glacial origin, the lake is situated between the Strait of Juan de Fuca coastal foothills, and the main range of the Olympic Mountains (Meyer and Fradkin 2002). The lake is 17.7 km long, with a surface area of 2,030 ha, and an elevation of 177 m.

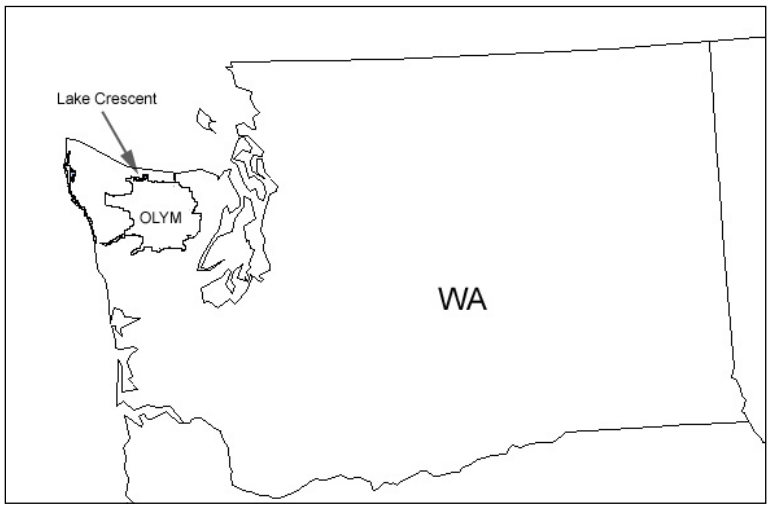


Figure 1. Location of Lake Crescent within Olympic National Park on the Olympic peninsula of Washington State.

Crescent's 10,220 ha watershed is almost entirely within the park boundary, except for a small amount of land at the northwest corner that is managed by the Washington Department of Natural Resources and parcels at the northeast corner that are managed by Green Crow Timber Company (Figure 2). Thirty-two streams flow into the lake, 22 of which are intermittent. Only one stream, the Lyre River which blocks anadromous fish, drains the lake directly to the Strait of Juan de Fuca. U.S. Highway 101 runs along the length of the south shore, while an abandoned railroad grade runs along most of the north lake shore. Approximately 121 houses and cabins, along with 2 resorts and several NPS facilities line the lake shore, most serviced by septic systems (Figure 2). Septic systems are of particular concern since they can contribute to lake

eutrophication at moderate levels of lake development, such as those found on Lake Crescent (Moore et al 2003).

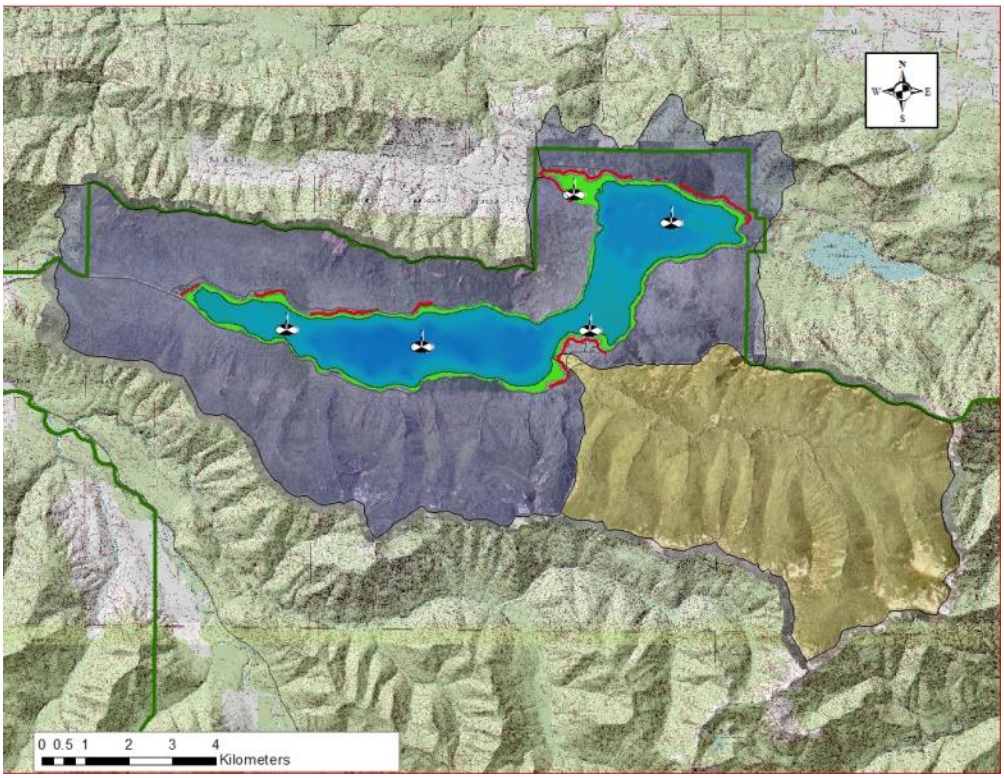


Figure 2. Lake Crescent and its watershed (purple and yellow shaded). The yellow shaded portion of the watershed is the Barnes Creek drainage, responsible for 80% of the stream discharge into the lake. Red linear shoreline features identify areas of lakeshore development. The green line denotes the park boundary.

Lake Crescent is renowned for its exceptional depth and water clarity. The lake has a classic "u"-shaped cross-section typical of glacially-carved lakes, resulting in a very narrow littoral zone around the lake margin. The only littoral habitat of consequence occurs in the Lyre River outlet area, where it provides valuable spawning and rearing habitat for native fish. Approximately 50% of the surface area overlays waters deeper than 95 m (Figure 3). Crescent is composed of two deep basins, separated by earthquake debris and Barnes Point, the alluvial fan of Barnes Creek (Figure 4). The deep area of the west basin is approximately 170 m while that of the east basin is approximately 140 m. The maximum lake depth recorded is in the west basin at 190 m. Characteristic of ultra-oligotrophic lakes, Crescent's water is very clear with an average Secchi depth of 17.7 m (Figure 5).

Crescent is a monomictic lake with summer/fall stratification (Figure 6). Dissolved oxygen levels remain high (> 10 mg/l) year-round throughout the water column of the two deep basins, even during times of stratification (Figure 7). During the period of mixis from fall through spring, water temperature and oxygen concentrations remain relatively constant throughout the water column, suggesting deep wind-driven mixing.

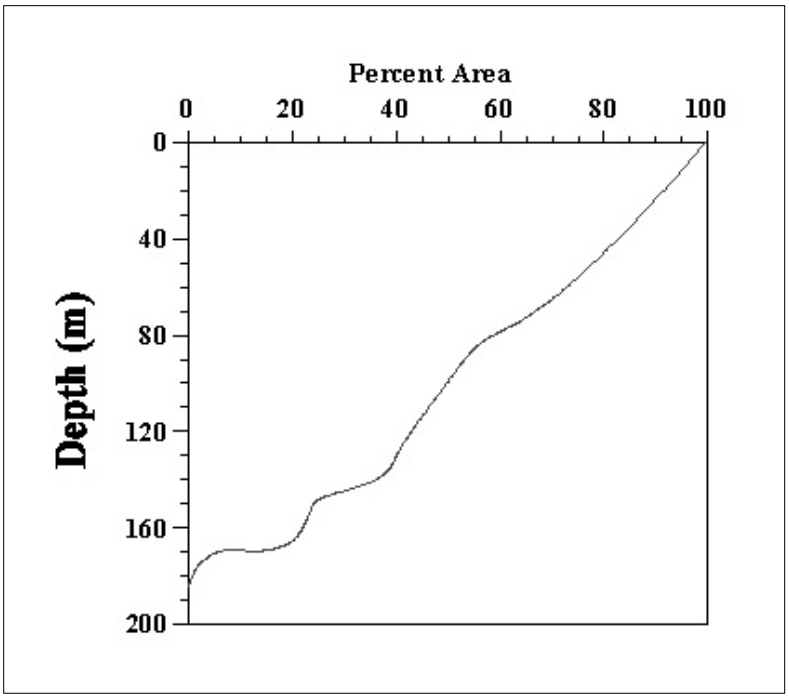


Figure 3. Hypsographic (depth-area) curve for Lake Crescent (modified from Pierce 1984).

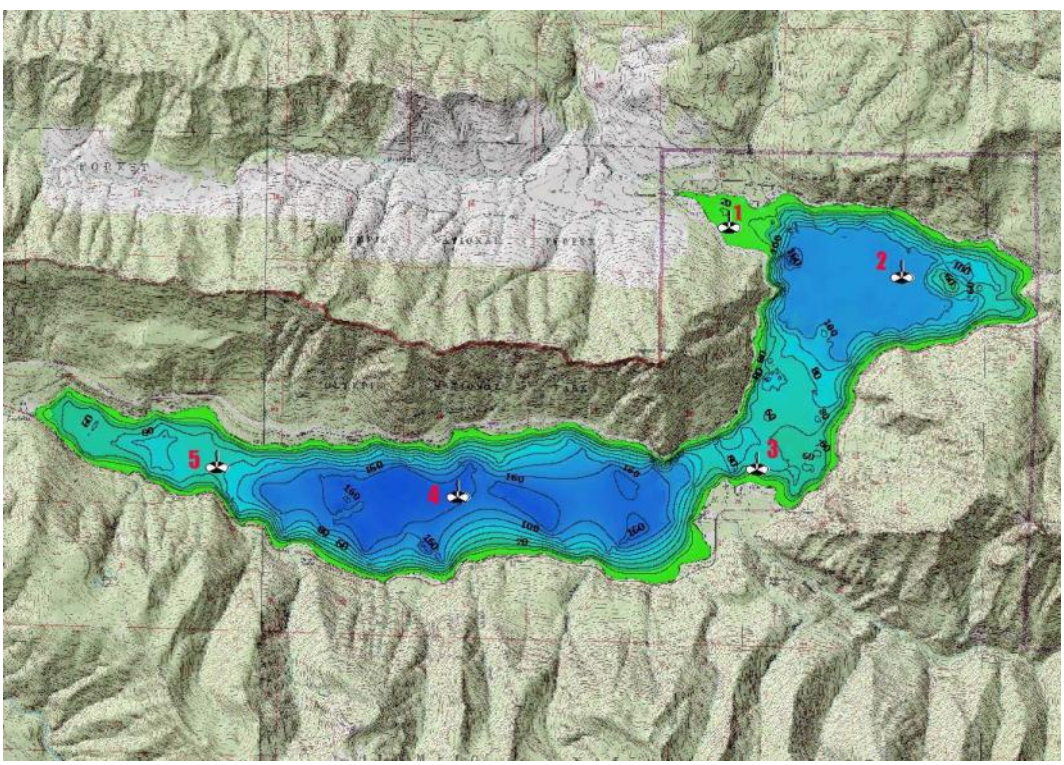


Figure 4. Bathymetric map of Lake Crescent illustrating location of fixed sampling stations (Secchi disk symbols). Contour lines are in 20 m increments.

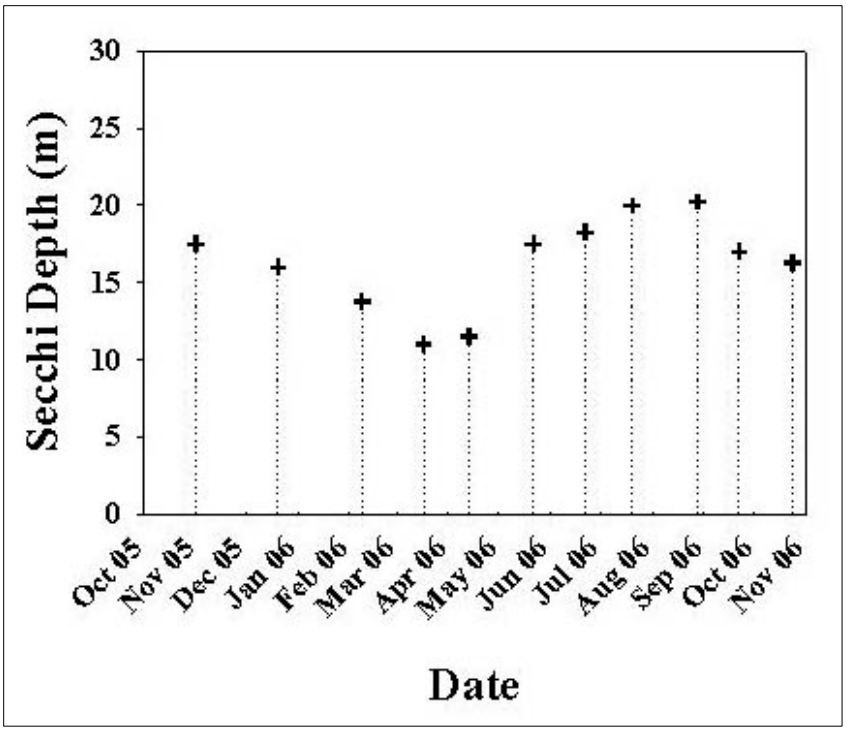


Figure 5. Secchi depth data from 2005-2006 illustrating an annual cycle of water clarity measurements. Average annual Secchi depth in Lake Crescent is 17.7 m.

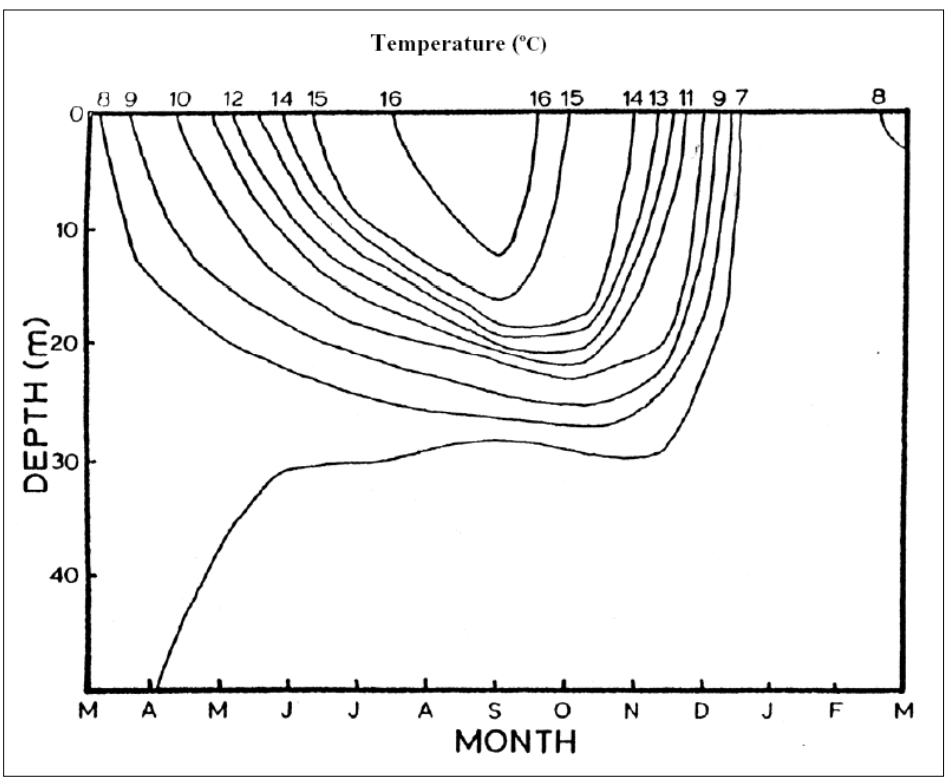


Figure 6. Isothermal variations (ºC) in Lake Crescent from March 1982-March 1983 (modified from Pierce 1984)

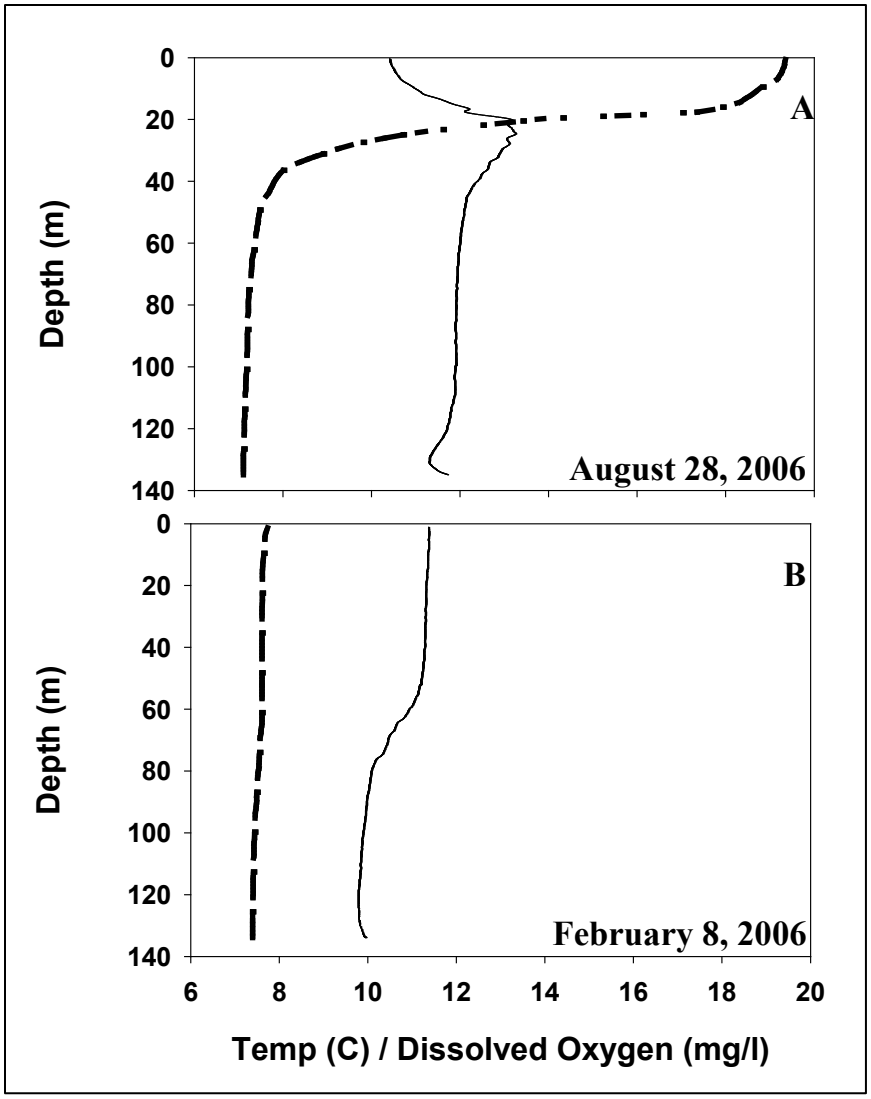


Figure 7. Temperature (dashed line) and dissolved oxygen (solid line) profiles at Station #2 in Lake Crescent during A) stratification (August) and B) destratification (February) periods.

Water column pH ranges from 6.38-8.58 with a mean pH of 7.22 (Hagan and Aho 1989, OLYM unpublished data) and are relatively constant across depth in a manner typical of oligotrophic lakes. Specific conductivity ranges from 100-160 µS/cm (Hagan and Aho 1989, Boyle and Beeson 1991, OLYM unpublished data) and are also relatively constant across depth consistent with oligotrophic lake patterns. Lake Crescent is a reasonably well buffered lake with alkalinities in the 816-1082 µeq/l range.

Typical of ultra-oligotrophic lakes, Crescent is nutrient poor with year-round concentrations of key nutrients, even at great depths during summer stratification (Figure 8). Concentrations of nitrate, a particularly labile form of nitrogen can often be at or below detection limits.

Lake Crescent hosts two endemic forms of trout derived from anadromous rainbow and cutthroat trout when the original lake outlet to the Elwha river was blocked by a series of landslides 10,000 years ago (Meyer and Fradkin 2002, Logan and Schuster 1991). These present day

beardslee (*Oncorhynchus mykiss*) and crescenti trout (*Oncorhynchus clarki*) are distinct forms found nowhere else. Their population health and the water quality of the lake where they evolved and reside are of paramount importance to park management. In addition to these trout, Crescent also contains a population of the pygmy whitefish (*Prosopium coulteri*), a species which is found in only four other deepwater lakes in Washington.

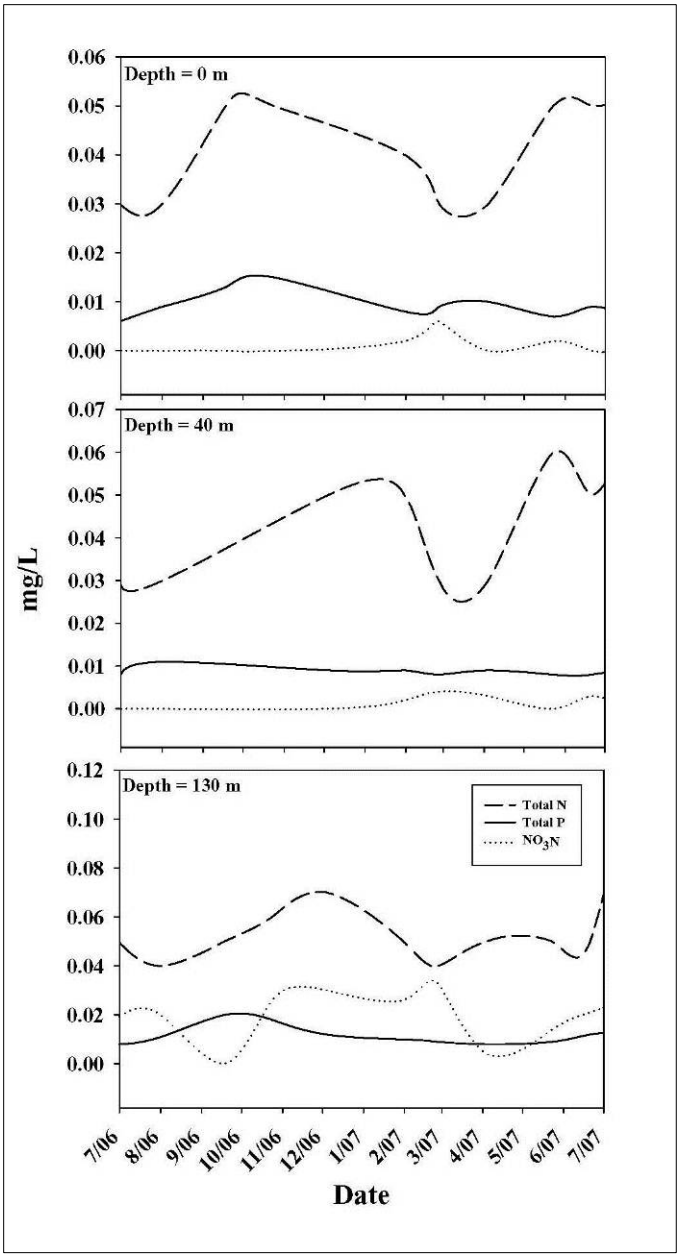


Figure 8. Major water column nutrients (Total N, Total P, Nitrate) at Lake Crescent Station #2 during 2006-2007 in the epilimnion (top panel), metalimnion (middle panel), and hypolimnion (bottom panel).

2.4. Measurable Objectives

The overarching goal of this monitoring program is to detect substantive trends in key ecosystem parameters, or vital signs, that might be associated with anthropogenic stressors. This program is

designed to detect changes in vital signs more as an early warning system, rather than to identify causal agents. The discovery of trends should serve to trigger directed research to identify root causes and determine appropriate management actions.

Large lakes are composed of three major zones, 1) the shallow waters of the littoral zone at the lake margins, 2) the open water of the pelagic zone, and 3) the benthic sediments underneath the pelagic zone (Wetzel 2001). These three zones interact in complex ways with each other and with the lake watershed. Ecosystem processes are in turn profoundly influenced by larger system drivers and anthropogenic stressors. A generalized conceptual model of these relationships appears in Figure 9. This protocol focuses solely upon monitoring parameters of the pelagic zone. The open water column is an area of dynamic processes that are readily measurable using a suite of widely accepted techniques that provide information on lake status and function. While the littoral and benthic zones are vital to the function of lake ecosystems and are affected by a variety of anthropogenic influences, the limited funding available for NCCN large lake monitoring makes monitoring these areas infeasible. As such, the littoral and benthic zones, in addition to costly parameters such as contaminants, are beyond the scope of this protocol and are best addressed by targeted research programs. Fish populations are monitored outside of the I&M program as part of OLYM's natural resource management program.

2.4.1 Monitoring objectives

The essential goal of this protocol is to determine the status and trend of pelagic lake water quality, specifically targeting the temporal and spatial patterns of physical/chemical and key biological parameters. If realized, this goal will provide park managers an understanding of natural levels of variation in these parameters and an ability to detect trends that stray beyond the natural range. The specific monitoring objectives of this protocol are:

1) Characterize seasonal and inter-annual patterns in the vertical distribution of water column physical/chemical characteristics in the major lake basins and sub-basins.
2) Characterize seasonal and inter-annual patterns in pelagic zooplankton species composition and abundance in the major lake basins and sub-basins.
3) Test for trends in physical, chemical and biological time-series data.
4) Where possible, given the inherent limitations of monitoring data to infer causation, use multiple lines of monitoring data to target possible causal factors for management actions and/or to stimulate specific research to determine causation.

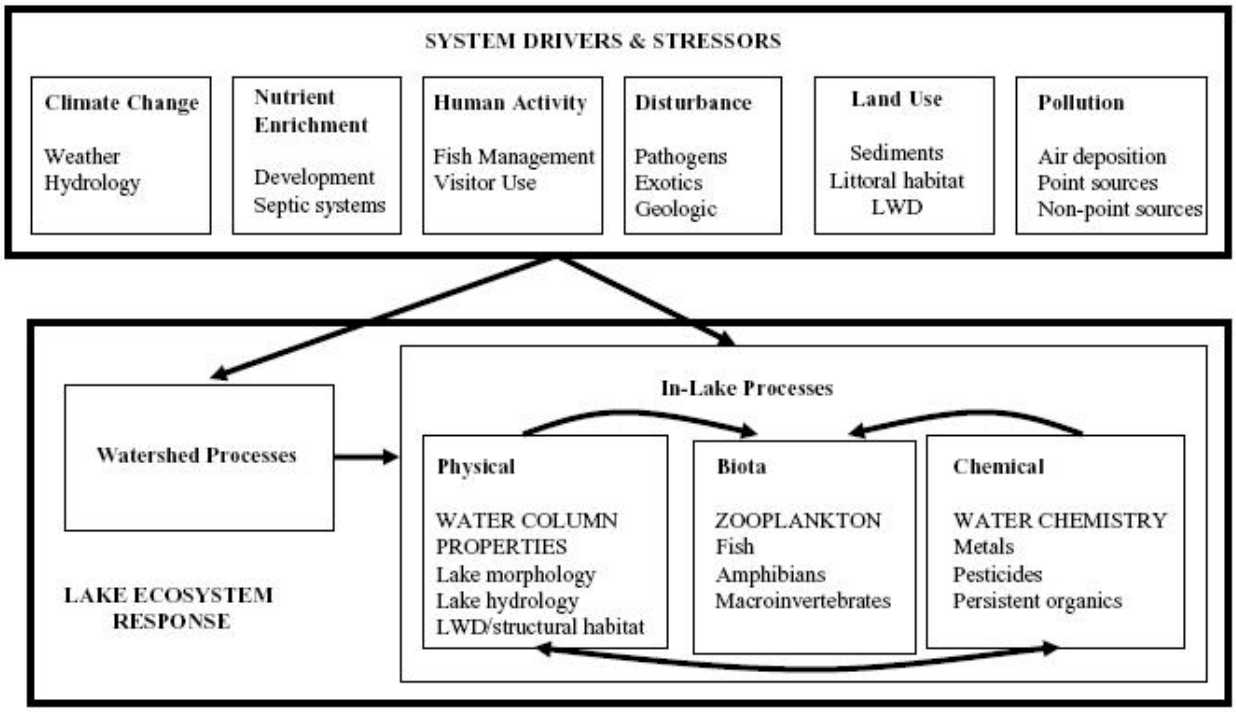


Figure 9. A conceptual model illustrating system drivers and stressors acting upon NCCN large lake ecosystems processes. Ecosystem components appearing in all capital letters in the "In-Lake-Processes" box will be monitored in this protocol.

Physical/chemical water column characteristics respond to a variety of system stressors, from nutrient enrichment to global climate change. Different areas of a lake may be differentially affected by stressors depending upon the basin morphology and type of stressor. Likewise, biological parameters, such as zooplankton, respond to changes in lake trophic structure, pollution and climate. Understanding how these parameters change over time can lead to better interpretations of lake stressors, motivate research to determine causal linkages, and promote informed management actions.

Monitoring results will inform management decisions by identifying problematic conditions that require mitigation (where possible). In particular, when key water quality parameters exceed state water quality thresholds (Table 2), the park management decision apparatus will be triggered.

Table 2. Threshold levels for selected water quality parameters derived from the Washington Department of Ecology water quality criteria for salmonids spawning, rearing and migration lakes. (http://www.ecy.wa.gov/programs/wq/swqs/criteria.html).

Parameter	Threshold	Comments
Dissolved Oxygen	≥8.0 mg/l	Lowest single day value at >40 m depth
Total Phosphorus	<20 μg/l	From epilimnion (1 m depth)
Temperature	≥17.5 ºC	Highest single day value at >40 m depth

3. Sampling Design

3.1. Rationale for Design Selection

Given the unique nature of the finite set of large lowland lakes in the NCCN, the goal of this monitoring protocol is to determine the range of natural variability and detect tends in important characteristics of an individual lake rather than make region-wide comparisons across lakes (Johnson 1999). Hence the sampling design will focus on characterizing the physical, chemical, and biological structure of the lake water column through regular monthly monitoring at a set of fixed stations across the span of major basins and sub-basins within a lake. Other lake monitoring programs have various goals and levels of inference (i.e. region-wide comparisons, mechanistic research questions) specific to their purposes. Programs like these include the USEPA Environmental Monitoring and Assessment Program (EMAP) Surface Waters Program (Baker et al. 1997), and the University of Wisconsin Cascading Trophic Interactions Project (Bade et al. 1998). The "reference-lake" approach of this protocol is similar to the approach used in the University of Washington Lake Washington monitoring program (Edmondson 1991). Lake Crescent was chosen as the reference lake because of its exceptional water quality and endemic fish species (*sensu* Meyer and Fradkin 2002).

3.2. Site Selection

Biological, physical, and chemical parameters will be monitored at a set of fixed sampling stations. The number of fixed sampling stations is dependent upon dependent upon the lake basin morphology and particular areas of interest/concern in a lake (Carlson and Simpson 1996). Generally, fixed stations should be established in each of the major lake basins and sub-basins. Fixed sampling stations are located by GPS. In Lake Crescent (Figure 4, Table 3) five fixed stations have been chosen. Two of the stations are in the two main deep basins (2 and 4), and three are in sub-basins (1, 3, and 5) where some level of shoreline development exists (Figure 2) stimulating interest in potential effects on water column characteristics. Station 1 is near the Lyre river outlet, an area that has a developed shoreline and hosts the only spawning grounds for the endemic beardslee trout. Station 3 is adjacent to Barnes Point, a relatively highly developed area. Station 5 is at the west end of the lake adjacent to the developed north shore road.

Table 3. Lake Crescent monitoring station locations and sampling depths.

Station	UTME	UTMN	Station Depth (m)	Sonde Sampling Depth (m)	Zooplankton Sampling Depth (m)
1	434124.48	5323633.78	20	19	-
2	437244.77	5323246.14	140	135	40
3	441111.64	5323605.07	86	81	-
4	442978.08	5326098.43	165	160	40
5	440747.93	5326739.72	170	165	-

3.3. Spatial and Temporal Sampling Design

The spatial and temporal sampling design and associated Standard Operating Procedures for all monitored parameters are summarized in Table 4.

Briefly, water column sampling is composed of four activities:

1. Monthly vertical physical/chemical water column profiles taken at each sampling station using a multi-parameter data sonde (e.g. YSI 6600 data sonde). All vertical profiles are of the entire water column, except for Chl-a which covers the upper 60 m of the water column due to design limitations of the Chl-a probe.
2. Monthly measures of water clarity (Secchi depth) at each fixed station.
3. Monthly replicate vertically-integrated zooplankton samples from a fixed station in each of the two major lake basins. Zooplankton communities will be sampled during the day by taking 3 replicate vertical hauls using a 63 µm net from 40 m depth (approximately 2 times the average Secchi depth). This depth ensures adequate sampling of the euphotic (sunlit) zone. While daylight sampling of the upper water column in many lakes may miss species that migrate to deeper water during the day, vertical migration behavior of zooplankters in Lake Crescent is relatively weak, with the preponderance of zooplankton biomass residing in the upper 40 m and all identified taxa represented in this zone (Rainey et al. 2007).
4. On a quarterly basis, water samples will be collected from the upper mixed layer of water (epilimnion), the middle water column, and the lower deep water layer (hypolimnion) in each of the two major lake basins. Large lakes have the potential for different nutrient dynamics between distinct basins (George 2006). Given the differences between the two major Crescent basins in both morphology and pattern of shoreline development, it is of interest to OLYM to track each basin versus concentrating on a single basin. The primary goal of this nutrient monitoring is to detect substantial deviations in nutrient levels rather than to conduct a detailed nutrient dynamic analysis. Water samples, along with replicates and field blanks (see **SOP 6: Water Chemistry**) will be analyzed for nutrient, ion, and dissolved organic carbon concentration at an off-site analytical laboratory. Alkalinity will be measured in the NPS Lake Crescent Laboratory.

3.4. Description of selected monitoring variables

Alkalinity is the capacity of water to accept protons, or the concentration of dissolved compounds to shift pH to a more basic level from and acidic level. Alkalinity is a sensitive measure of a lakes buffer capacity and sensitivity to acidification via atmospheric deposition or other means (Likens et al. 1972). Lake Crescent is a well buffered system with an alkalinity of approximately 820 µeq/L. While not currently very susceptible to acidification, Crescent has value as a pristine endpoint in comparison with large lowland lakes in the Cascades that are much more susceptible to acid impacts.

Table 4. Spatial and temporal sampling design of limnological parameters measured in Lake Crescent (OLYM). Asterisks denote NPS Water Resource Division core water quality parameters.

Parameters	SOP	# Stations	Sampling Frequency	Method
Biological				
Zooplankton	1	2	Monthly; 3 reps/station	40 m vertical haul w/60µm net.
Chlorophyll a	2	All	Monthly	Data sonde: Vertical profile
Physical				
*Specific Conductivity	2	All	Monthly	Data sonde: Vertical profile @ stations
*Temperature	2 & 7	All	Monthly/ Continuous	Data sonde: Vertical profile @ stations/ Fixed temp logger: surface @ Lab dock
Water Clarity	3	All	Monthly/ Continuous	Secchi depth
Lake Level	4	1		Pressure transducer/ Staff gauge
Chemical				
*Dissolved Oxygen		All	Monthly	Data sonde: Vertical profile
*pH	2	All	Monthly	Data sonde: Vertical profile
Turbidity	2	All	Monthly	Data sonde: Vertical profile
Alkalinity	6	2	Monthly	Hach digital titrator Model 16900
Anions and Cations	5	2	Quarterly	Water sample profile, offsite lab
Nutrients				
-Ammonia	5	2	Quarterly	Water sample profile, offsite lab
-Nitrate + Nitrite	5	2	Quarterly	Water sample profile, offsite lab
-Total Nitrogen	5	2	Quarterly	Water sample profile, offsite lab
-Total Phosphorus	5	2	Quarterly	Water sample profile, offsite lab
-Orthophosphate	5	2	Quarterly	Water sample profile, offsite lab

Anions and Cations are distinct charged dissolved chemicals that increase the specific conductance of water (Hem 1989). The concentration and relative amount of ions influence both primary and secondary productivity. Their measurement is often used as an indicator of atmospheric deposition of marine and anthropogenic ionic compounds and lake acidification (Wetzel 2001). The concentration and balance of anions/cations is a standard limnological measure that provides great insight into changes in water quality.

Chlorophyll-a is a major photosynthetic pigment used by lake primary producers (e.g. phytoplankton). Measurement of chlorophyll-a concentration in lake water is an accepted surrogate for measuring algal biomass (e.g. Mazumder and Havens 1998). Direct measurement of algal biomass is problematic due to the large number of taxa present in a lake over the course of a year and the requisite taxonomic expertise and sample processing time needed to gather the data. As an oligotrophic lake, Crescent usually has a low standing stock of algal biomass. However, changes in nutrient inputs to Crescent will most likely be first observed in changes in the algal community and its biomass.

Dissolved Oxygen is an essential chemical for the support of key food web constituents (e.g. fish, zooplankton, algae, etc.) that respire aerobically. Lake eutrophication can increase aerobic demand causing low oxygen or anoxic areas that negatively impact aerobic organisms. Dissolved oxygen is a core water quality parameter required to be monitored by the NPS-Water Resources Division (NPS 2002).

Lake Level is a measure of lake hydrology, specifically it is the sum of all water inputs (precipitation, streams, seeps, etc.) and all water outputs (drainage, evaporation, residential water use, etc.). Lake level is a valuable indicator of temporal changes in lake hydrology through climate change and watershed manipulation. Lake level is a core water quality parameter required to be monitored by the NPS-Water Resources Division (NPS 2002).

Nitrogen is one of the essential nutrients in aquatic systems that fuels primary productivity and occurs in several forms that differ in the ability to be used by organisms (Wetzel 2001). Nitrogen enrichment can lead to lake eutrophication. The forms monitored in this protocol are ammonia (NH_3^+), total oxidized nitrogen (Nitrate-NO_3^- and Nitrite-NO_2^-), and total nitrogen. Ammonia and nitrate arise from the decomposition of organic matter decomposition and can accumulate from pollution sources such as fertilizers, animal wastes, septic tanks, and atmospheric deposition. These forms of nitrogen are readily used by primary producers as nutrient sources. Nitrite is a trace, ephemeral form of nitrogen in well-oxygenated systems such as Lake Crescent. As such, the total oxidized nitrogen measure is assumed to mainly measure nitrate. Total nitrogen is the sum of organic nitrogen (in peptides, proteins, etc.), total oxidized nitrogen, and ammonia (Hem 1989). All the nitrogen sources of interest will be measured in these three forms, which are standard lake nutrient measures.

pH is a measure of the acid-base balance of water via the concentration of hydrogen ions. The water ionic composition determines pH, which is altered by atmospheric inputs, terrestrial runoff, and lake biogeochemical processes. pH has the potential to affect aquatic communities and biogeochemical processes (e.g. Likens 2004). pH is a core water quality parameter required to be monitored by the NPS-Water Resources Division.

Phosphorus is a limiting nutrient in lakes and plays an essential role in biological metabolism (Wetzel 2001). Phosphorus enrichment is a common cause of lake eutrophication. The forms monitored in this protocol are total phosphorus (suspended plus dissolved) and orthophosphate, the form directly taken up by primary producers. Anthropogenic sources of orthophosphates come from fertilizers and from septic tanks (Hem 1989). While septic tank inputs are an issue associated with littoral nuisance algal blooms (Rosenberger et al. 2008), the number of tanks is fixed and diminishing as the park buys out in-holders and removes structures. The measurement of phosphorus is a standard measure of lake eutrophication.

Specific Conductance is a temperature-dependent measure of water's ability to conduct an electrical current. It is the reciprocal of resistance. Increases in specific conductivity in a system may be associated with anthropogenic inputs to the system. Specific conductance is a core water quality parameter required to be monitored by the NPS-Water Resources Division (NPS 2002).

Temperature is measured to characterize the ambient environment for aquatic organisms and to determine the pattern of thermal stratification of the water column. Due to density differences

between water masses of different temperatures, the water column can become stratified during the summer and potentially during the winter in some systems. Stratification can lead to the accumulation of nutrients and decreases in dissolved oxygen in the hypolimnion. Spring and fall mixing of the water column can lead to nutrient releases that fuel food web productivity. Temperature is a core water quality parameter required to be monitored by the NPS-Water Resources Division (NPS 2002).

Turbidity is the measure of reduced light transmittance through water as a result of dissolved solids, pigments, algal biomass and suspended sediments. It is an alternate measure of water clarity and can be an indicator of increased primary production or increased sediment loading, both of which in turn are important indicators of changed conditions in Lake Crescent.

Water Clarity (Secchi depth) is a measure of the transparency of water which is a surrogate measure of the cumulative concentrations of dissolved solids, pigments, algal biomass and suspended sediments. All of these factors can be altered by anthropogenic effects. The Secchi depth is a widely used measure of water clarity that measures the maximum depth at which a 20 cm diameter Secchi disk (with alternating black and white quarters) can be observed from the surface (Preisendorfer 1986, Megard 2000, Jassby et al. 2003). Water clarity is important not only for its aesthetic value to park visitors, but the amount of light penetrating into the lake is a major factor regulating aquatic primary production.

Zooplankton are ubiquitous organisms found in the water column of lakes worldwide. They are a central link in lake foodwebs, transferring energy between primary producers and secondary consumers (i.e. fish, salamanders, etc.). Standardized methods exist for their rapid and accurate identification (e.g. Edmondson 1959, Stemberger 1979). Zooplankton species richness, population structure, and abundance have been shown to be valuable indicators of lake ecosystem change due to environmental perturbations (e.g. Edmonson and Litt 1982, Arnott et al. 1998, Hampton 2005, Frost et al. 2006). Additionally, changes in zooplankton body size have the potential to distinguish between changes in water clarity, associated nutrient loading and changes associated with food web alterations (i.e. fish population structure) that affect zooplankton grazing rates (Stemberger and Miller 2003).

3.5. Level of change that can be detected

In this protocol, long-term trends in limnological parameters will be tested using the non-parametric Seasonal Kendall test with a serial correlation correction (Hirsch and Slack 1984, Helsel and Hirsch 2002, McBride 2005). See **SOP 8: Recommended Data Analysis** for a fuller discussion of analytical techniques and the variable subjected to analysis. The probability that a test will detect a trend when one is actually present is known as power. Evaluating the power of a trend provides insight into the limitations of conclusions reached by the trend test. A failure to detect trend could erroneously lead to the conclusion of no trend, when in actuality there may be insufficient data or too much variance to allow trend detection at a specified level of confidence. Unfortunately, for the Seasonal Kendall test, power cannot be calculated (McBride 2005), rather power has to be estimated via Monte-Carlo simulations (e.g. Loftis and Taylor 1989, Mumby 2002). These simulations illustrate that the SKT has higher power than non-parametric techniques when applied to data that even mildly deviate from normality, as limnological data usually do (Loftis and Taylor 1989, Taylor and Loftis 1989, Onoz and Bayazit 2003). The power of the Seasonal Kendall test is dependent upon the length of the time series and sampling

frequency, which essentially increases the sample size (Yue et al. 2002). Monte-Carlo simulations have not been conducted for trend detection in Lake Crescent data to date, because we have not had the opportunity to conduct them and we do not have sufficient data from preliminary monitoring to estimate variability in sample data. After the first 5 years of monitoring, we expect to conduct such simulations to estimate power.

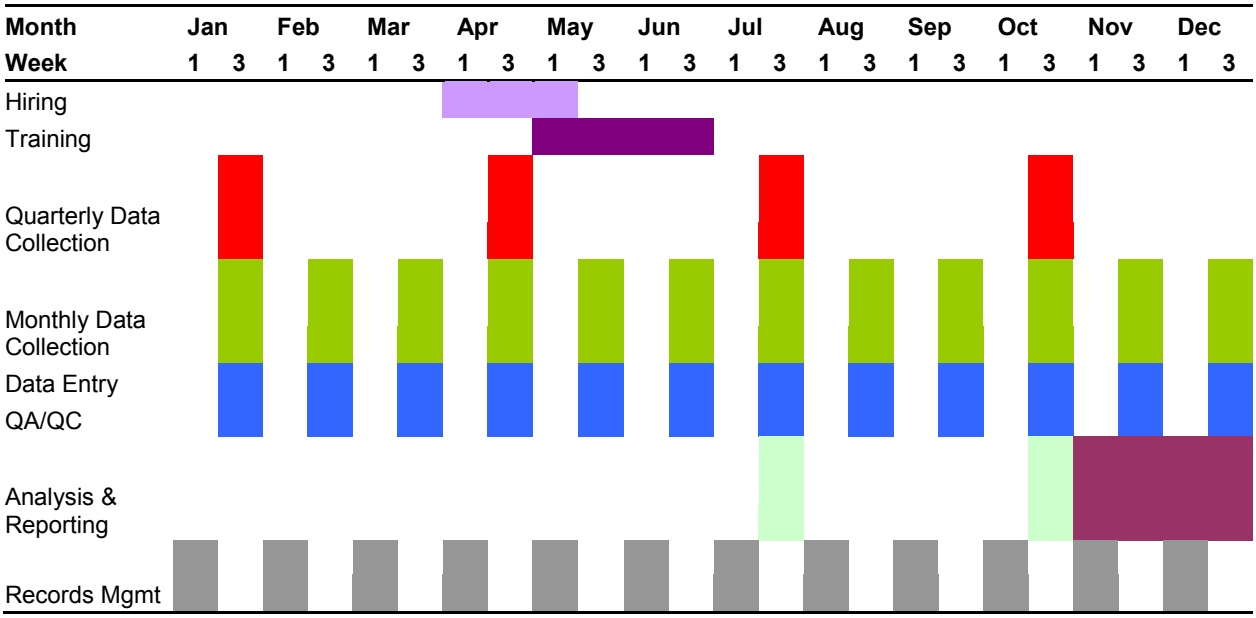
Given the rich literature that exists on limnological and water quality monitoring, it is somewhat surprising that this literature is not replete with examples that determine levels of change that can be detected. Rather, the literature has numerous examples of actual trend testing (e.g. Hampton 2005). A rare example of level of change determination is Warren and Horvatin (2003) who examined nutrient time-series data in Lake Michigan and determined an 80% ability to detect a 20% change at the 90% confidence level over a 17-year period. While the desired minimal level of change that can be detected differs depending upon the parameter under consideration, due to inherent parameter variability (Irwin 2008), we will use the Warren and Horvatin's finding above as the detectable level of change goal for each parameter examined in this NCCN monitoring program. Revised estimates of the minimum levels of detectable change for monitoring parameters in this protocol will be estimated at the 5-year review period based on the observed parameter variability.

4. Field Methods

4.1. Sequence of events during field cycle

Large lowland lake monitoring occurs monthly on a continual basis. As such, there is no field season per se, rather there is a field cycle, whose start, end, analysis and reporting times are largely based on the timing of seasonal technician hiring and a window of opportunity for focused effort based on reduced time commitments to other work not directly associated with this protocol. The annual cycle for program activities appears in Table 5. The cycle begins in April of each year and ends in March of the subsequent year. In April, seasonal technician staff are hired, with training occurring from May through June. Monthly sampling occurs during the 3rd week of every month, and quarterly sampling occurs during the 3rd week of January, April, July, and October. Data entry and records management are conducted shortly after field sampling according to the appropriate Standard Operating Procedures (**Section 2**, see also **Chapter 5: Data Management**). QA/QC procedures are conducted before and after field sampling. Brief quarterly reports will be produced in Jan, April, July and October. The purpose of these quarterly reports is to plot and examine recent data to identify any interesting or anomalous data that might signal a water quality problem or a problem with field or analytical procedures. Annual data analysis will occur from November through December, and the annual report will be produced by April of the following year.

Table 5. Sequence of events for the NCCN Large Lowland Lake Protocol during a model calendar year.



4.2. Field Cycle Preparations

Prior to the beginning of each annual field cycle each of the following activities will occur:

- All field and laboratory equipment will be checked to ensure proper working order according to particular equipment maintenance schedules.

- From May-June all field technician will undergo training on all procedures. This training includes both laboratory and field based training. See **SOP 14: Field and Laboratory Safety**.
- A new project notebook will be prepared that receives all field and laboratory data sheets, calibration logs, probe logs, and trip reports.
- All field equipment will be re-organized and any equipment that need repairing, refurbishing, or replacing will be dealt with.
- Stock will be taken of chemical standards and new standards will be ordered when appropriate.

4.3. Permitting and Compliance

Lake Crescent is not within the congressionally designated wilderness boundary in OLYM. As such, the protocol does not need to undergo a minimum tool analysis to determine appropriate activities in wilderness.

All procedures associated with this protocol fall under a NEPA categorical exclusion for monitoring in parks. Prior to implementation, the park compliance officer will be consulted to ensure that all protocols fall under the categorical exclusion

4.4. Field Methods and Procedures

Field activities consist of a set of monthly and quarterly sampling activities at the 5 fixed permanent stations in Lake Crescent. The design of these activities is summarized in Table 4. Specific methods for each field activity, including quality assurance and quality control (QA/QC) procedures, are found in Standard Operating Procedures (SOPs). Additional QA/QC procedures associated with off-site analytical laboratory analyses can be found at http://www.ccal.oregonstate.edu/qaqc.htm, and other QA/QC information is detailed in SOP 9 (Quality Assurance and Quality Control).

5. Data Management

This chapter describes the procedures for data management, analysis, and report development. Additional details and context for this chapter are provided in the NCCN Data Management Plan (Boetsch et al. 2009), which describes the overall information management strategy for the network. The NCCN website (http://science.nature.nps.gov/im/units/nccn/datamgmt_guide.cfm) also contains guidance documents on various information management topics (e.g., report development, GIS development, GPS use).

5.1. Project information management overview

Project information management may be best understood as an ongoing or cyclic process, as shown in Figure 10. Specific yearly information management tasks for this project and their timing are described in **Appendix 1: Yearly Project Task List**. Readers may also refer to each respective chapter section for additional guidance and instructions.

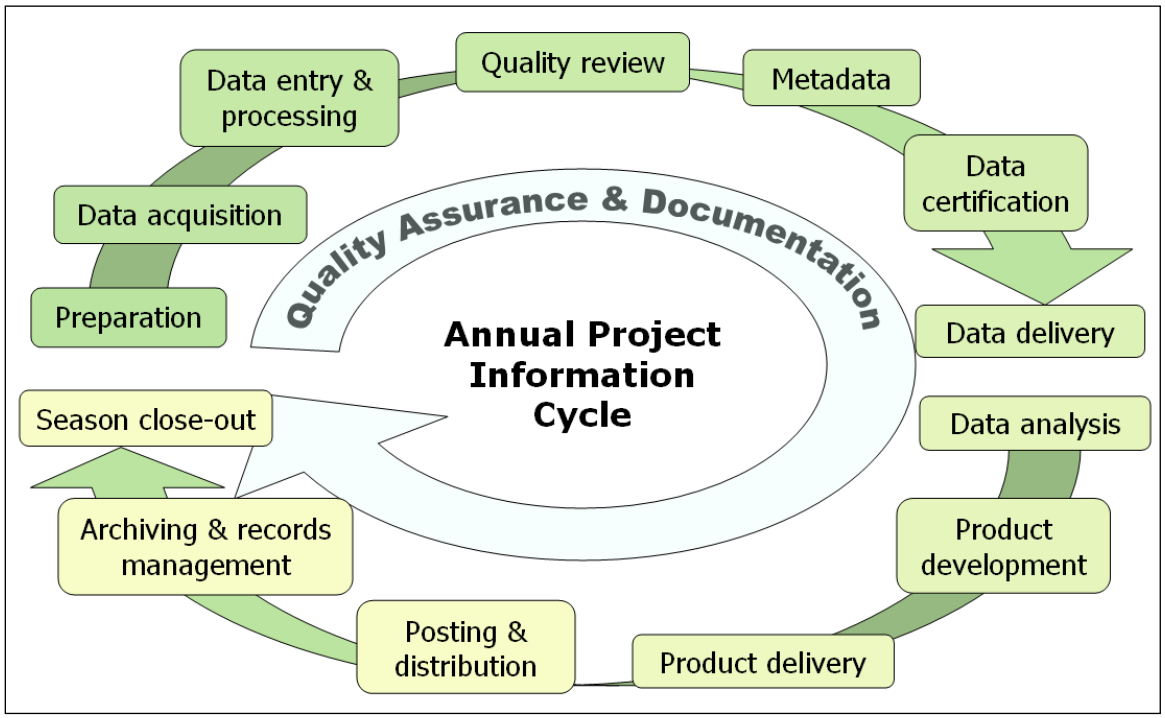


Figure 10. Idealized flow diagram of the cyclical stages of project information management, from pre-season preparation to season close-out. Note that quality assurance and documentation are thematic and not limited to any particular stage.

The stages of this cycle are described in greater depth in later sections of this chapter, but can be briefly summarized as follows:

- *Preparation* – Training, logistics planning, print forms and maps
- *Data acquisition* – Field trips to acquire data
- *Data entry & processing* – Data entry and database uploads, GPS data processing, etc.
- *Quality review* – Data are reviewed for structural integrity, completeness and logical consistency

- *Metadata* – Documentation of the year's data collection and results of the quality review
- *Data certification* – Data are certified as complete for the period of record
- *Data delivery* – Certified data and metadata are delivered for archiving
- *Data analysis* – Data are summarized and analyzed
- *Product development* – Reports, maps, and other products are developed
- *Product delivery* – Deliver reports and other products for posting and archiving
- *Posting & distribution* – Distribute products as planned and/or post to NPS clearinghouses
- *Archiving & records management* – Review analog and digital files for retention (or destruction) according to NPS Director's Order 19. Retained files are renamed and stored as needed.
- *Season close-out* – Review and document needed improvements to project procedures or infrastructure, complete administrative reports, and develop work plans for the coming season

5.2. Pre-season Preparations for Information Management

5.2.1. Project Workspace Setup

A section of the networked file server at OLYM is reserved for this project, and access privileges are established so that project staff members have access to needed files within this workspace. Prior to each season, the Project Lead should make sure that network accounts are established for each new staff member, and that the Data Manager is notified to ensure access to the project workspace and databases. Workspace structure, naming conventions, and additional details are provided in **SOP 6: Project Workspace and Records Management**.

5.2.2. Project Database Application

Prior to the field season, the Data Manager will update the project database application as needed to ensure proper access on the part of the project staff. Refer to **Section 5.3, Overview of Database Implementation Strategy** for additional information about the database design and implementation strategy.

Prior to the onset of each annual cycle season (starting each November 1), the Data Manager will download and implement a blank copy of the working NPSTORET database in the project workspace and proper access on the part of the project staff. This copy will contain the project metadata and monitoring station information, but will not contain any associated event data. Refer to Section 5.3 for additional information about the database implementation strategy.

5.3. Overview of Database Implementation Strategy

All water quality data collected for this monitoring project will be managed according to guidelines from the NPS Water Resources Division (WRD). NPSTORET (http://www.nature.nps.gov/water/infoanddata) and Environmental Protection Agency (EPA) STORET (http://www.epa.gov/storet/) are, respectively, the NPS and national enterprise data warehouses for water quality data. NPSTORET is maintained by WRD and is synchronized with EPA STORET on a regular basis (Figure 11). Instead of developing a customized local application for data storage and manipulation, we have instead decided to implement the desktop version of NPSTORET to manage local data entry, documentation, and transfer. We will transfer

the contents of this local copy at least annually to NPS Water Resource Division for upload to the STORET database (Figure 11).

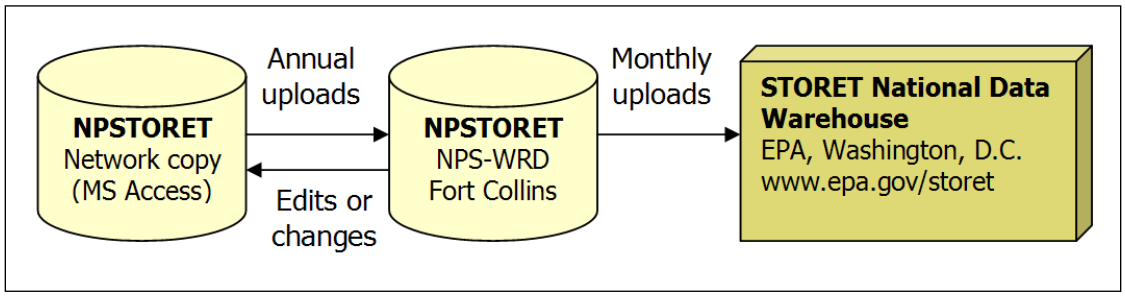


Figure 11. Schematic flow diagram of data flow from the local NCCN copy of NPSTORET to the national enterprise copy of NPSTORET, to the EPA STORET data warehouse

Documentation (including a data dictionary) and guidance for using the desktop version of NPSTORET may be found on the NPS-WRD web page (http://www.nature.nps.gov/water/waterquality/infomgt.cfm). The data dictionary lists data field names and descriptions, data value domains, and required fields. Users are advised to download a copy of the data dictionary for reference while entering data in NPSTORET. The NPSTORET database reflects the design of the EPA STORET database and emphasizes the fields that require data values in order to transfer data to STORET. NPSTORET is based in part on the NPS Natural Resource Database Template (NRDT) model to incorporate standard database elements for quality and consistency.

Two copies of the desktop version of NPSTORET will be maintained locally – one for entering, editing and error-checking data for the current season (i.e., the "working database copy"), and another that contains the complete set of certified data for the monitoring project (i.e., the "master database copy"). Both the working database and the master are identical copies of the NPSTORET desktop database and each has an associated front-end database application ("user interface" with forms, queries, etc.) implemented in Microsoft Access. A functional comparison of these two components is provided in Table 6.

Note: As of January 2013 this protocol has never received funding to be implemented. In case of changes in status, zooplankton data will be entered into the NCCN Mountain Lakes Monitoring database (Glesne et al. 2012).

Prior to data entry for each annual cycle, the project crew will be provided with a working copy of NPSTORET into which they will enter, process, and quality-check data for the current season. Once data for the annual cycle have been certified they will be submitted to NPS Water Resources Division (WRD) staff and uploaded into WRD STORET. After this upload process, a new master database copy will be downloaded and maintained locally – this copy will then be used to inform all reporting and analysis. Refer to the timing described in **Appendix 1: Yearly Project Task List**.

Table 6. Functional comparison of the working database copy and the master database.

Project database functions and capabilities	Working database	Master database
Software platform for back-end data	MS Access 2003	MS Access 2003
Contains full list of sampling locations and metadata	X	X
Portable for remote data entry	X	
Forms for entering and editing current year data	X	X
Quality assurance and data validation tools	X	X
Analysis, summarization and export tools	X	X
Contains certified data for all observation years		X

5.4. Data Entry and Processing

After each field trip, technicians should enter data in order to keep current with data entry tasks, and to identify any errors or problems as close to the time of data collection as possible. The working database application will be found in the project workspace. For enhanced performance, it is recommended that users copy the front-end database onto their workstation hard drives and open it there. This front-end copy may be considered "disposable" because it does not contain any data, but rather acts as a pointer to the data that reside in the back-end working database. Whenever updates to the front-end application are made available by the Data Manager, a fresh copy should be retrieved from the project workspace to the workstation hard drive.

The front-end data entry screens have built-in quality assurance components such as pick lists and validation rules to test for missing data or illogical combinations. Although the database permits users to view the raw data tables and other database objects, users are strongly encouraged only to use these pre-built forms as a way of ensuring the maximum level of quality assurance.

5.4.1. Regular Data Backups

Regular backups of the back-end working database should be made on a periodically during the data entry process – perhaps every day that new data are entered – to save time in case of mistakes or database file corruption. These periodic backup files should be compressed to save drive space, and may be deleted once enough subsequent backups are made. All such backups may be deleted after the data have passed the quality review and been certified.

5.4.2. Data Verification

As data are being entered, the person doing the data entry should visually review the data that have just been entered to make sure that the data on screen match the field form. This should be done for each record prior to moving to the next form for data entry. At regular intervals and at the end of the annual cycle season the Field Lead should inspect the data being entered to check for completeness and identify avoidable errors. The Field Lead may also periodically run the quality assurance tools that are built into the front-end working database application to check for logical inconsistencies and data outliers.

5.4.3. Field Form Handling Procedures

As field data forms are part of the permanent record for project data, they should be handled in a way that preserves their future interpretability and information content. If changes to data on the

forms need to be made subsequent to data collection, the original values should not be erased or otherwise rendered illegible. Instead, changes should be made as follows:

1. Draw a horizontal line through the original value, and write the new value adjacent to the original value with the date and initials of the person making the change.
2. All corrections should be accompanied by a written explanation in the appropriate notes section on the field form. These notes should also be dated and initialed.
3. If possible, edits and revisions should be made in a different color ink to make it easier for subsequent viewers to be able to retrace the edit history.
4. Edits should be made on the original field forms and on any photocopied forms.

These procedures should be followed throughout data entry and data revision. On a four-year basis, data sheets are to be scanned as PDF documents and archived (see the product delivery specifications in **SOP 12: Product Delivery, Posting and Distribution**). The PDF files may then serve as a convenient digital reference of the original if needed.

5.4.4. Image Handling Procedures

This section covers photographic images collected by project staff or volunteers during the course of conducting project-related activities. Images that are acquired by other means – e.g., downloaded from a website or those taken by a cooperating researcher – are not project records and should be filed and named in such a way that they will not be confused with project records.

Care should be taken to distinguish data photographs from incidental or opportunistic photographs taken by project staff. Data photographs are those taken for at least one of the following reasons:

- To document a particular feature or perspective for the purpose of site relocation
- To document a species detection that is also recorded in the data

Data photographs are often linked to specific records within the database, and are stored in a manner that permits the preservation of those database links. Other photographs – e.g., of field crew members at work, or photographs illustrating certain field conditions, etc. – may also be retained but are not necessarily linked with database records. Refer to **SOP 10: Managing Photographic Images** for details on how to handle and manage these files.

5.5. Data Quality Review

After the data have been entered and processed, they need to be reviewed by the Project Lead for structural integrity, completeness and logical consistency. The front-end database application facilitates this process by showing the results of pre-built queries that check for data integrity, data outliers and missing values, and illogical values. The user may then fix these problems and document the fixes. Not all errors and inconsistencies can be fixed, in which case a description of the resulting errors and why edits were not made is documented and included in the metadata and certification report (see **Sections 5.6, Metadata Procedures** and **5.7, Data Certification and Delivery**).

5.6. Metadata Procedures

Data documentation is a critical step toward ensuring that data sets are usable for their intended purposes well into the future. This involves the development of metadata, which can be defined as structured information about the content, quality, condition and other characteristics of a given data set. Additionally, metadata provide the means to catalog and search among data sets, thus making them available to a broad range of potential data users. Metadata for all NCCN monitoring data will conform to Federal Geographic Data Committee (FGDC) guidelines and will contain all components of supporting information such that the data may be confidently manipulated, analyzed and synthesized.

At the conclusion of the field season (according to the schedule in **Appendix 1: Yearly Project Task List**), the Project Lead will be responsible for providing a completed, up-to-date metadata interview form to the Data Manager. The Data Manager and GIS Specialist will facilitate metadata development by consulting on the use of the metadata interview form, by creating and parsing metadata records from the information in the interview form, and by posting such records to national clearinghouses.

An up-to-date metadata record is a required deliverable that should accompany each season's certified data. For long-term projects such as this one, metadata creation is most time consuming the first time it is developed – after which most information remains static from one year to the next. Metadata records in subsequent years then only need to be updated to reflect changes in contact information and taxonomic conventions, to include recent publications, to update data disposition and quality descriptions, and to describe any changes in collection methods, analysis approaches or quality assurance for the project.

Specific procedures for creating, parsing and posting the metadata record are provided in NCCN Metadata Development Guidelines (NCCN 2007). General procedures are as follows:

1. After the annual data quality review has been performed and the data are ready for certification, the Project Lead (or a designee) updates the metadata interview form.
    a. The metadata interview form greatly facilitates metadata creation by structuring the required information into a logical arrangement of 15 primary questions, many with additional sub-questions.
    b. The first year, a new copy of the NCCN Metadata Interview form (available at: http://science.nature.nps.gov/im/units/nccn/datamgmt_guide.cfm) should be downloaded. Otherwise the form from the previous year can be used as a starting point, in which case the Track Changes tool in Microsoft Word should be activated in order to make edits obvious to the person who will be updating the XML record.
    c. Complete the metadata interview form and maintain it in the project workspace. Much of the interview form can be filled out by cutting and pasting material from other documents (e.g., reports, protocol narrative sections, and SOPs).
    d. The Data Manager can help answer questions about the metadata interview form.
2. Deliver the completed interview form to the Data Manager according to the product delivery instructions in **SOP 12: Product Delivery, Posting and Distribution**.
3. The Data Manager (or GIS Specialist for spatial data) will then extract the information from the interview form and use it to create and update an FGDC- and NPS-compliant

metadata record in XML format. Specific guidance for creating the XML record is contained in NCCN Metadata Development Guidelines (NCCN 2007).

4. The Data Manager will post the record and certified data to the NPS Data Store, and maintain a local copy of the XML file for subsequent updates.
5. The Project Lead should update the metadata interview content as changes to the protocol are made, and each year as additional data are accumulated.

5.7. Data Certification and Delivery

Data certification is a benchmark in the project information management process that indicates that: 1) the data are complete for the period of record; 2) they have undergone and passed the quality assurance checks (Section 5.5); and 3) they are appropriately documented and in a condition for archiving, posting and distribution as appropriate. Certification is not intended to imply that the data are completely free of errors or inconsistencies that may or may not have been detected during quality assurance reviews.

To ensure that only quality data are included in reports and other project deliverables, the data certification step is an annual requirement for all tabular and spatial data. The Project Lead is the primary person responsible for completing an NCCN Project Data Certification Form, available at: http://science.nature.nps.gov/im/units/nccn/datamgmt_guide.cfm. This brief form should be submitted with the certified data according to the timeline in **Appendix 1: Yearly Project Task List**. Refer to **SOP 12: Product Delivery, Posting and Distribution** for specific instructions.

5.8. Data analysis

The timing of analysis tasks and the schedule for deliverables are detailed in **SOP 12: Product Delivery, Posting and Distribution** and **Appendix 1: Yearly Project Task List**. Recommendations on routine data summaries, analyses to detect change, and methods for long-term trends are summarized in **SOP 8: Recommended Data Analysis**.

5.9. Reporting and Product Development

5.9.1. Report Content

A summary report will be produced annually, with a more detailed report produced every five years. The annual report will:

- List project personnel and their roles.
- List the schedule of completed field sampling.
- Provide a summary history of the number and types of samples taken (broken down by sampling station and date).
- Provide a graphical summary of physical/chemical profile data for each parameter by sampling station.
- Provide a summary history and results of all water samples shipped to the off-site analytical laboratory for analyses, including any data quality concerns and/or deviations from standard operating procedures that may have affected data quality and/or interpretability.
- List all zooplankton species detected in the lake during the current year.
- Provide summary and trend results for dominant zooplankton species.

- Identify any apparent spatial patterns in physical/chemical and zooplankton data across the lake sub-basins.
- Identify any data quality concerns and/or deviations from standard operating procedures that affect data quality and/or interpretability.

Recommended analyses and graphical examples are provided in **SOP 8: Recommended Data Analysis.**

A more in depth trend analysis and report will be generated every five years, as a full set of five annual cycles are completed allowing better trend analysis. In addition to the above, the annual report will include trend analyses for each physical/chemical parameter and for zooplankton species abundance and biomass. Analyses will also be conducted to determine whether physical/chemical and biological patterns differ between lake sub-basins. The report will also evaluate operational aspects of the monitoring program, such as changes to standard operating procedures and/or the sampling design.

5.9.2. Standard Report Format

Annual reports and trend analysis reports will use the NPS Natural Resource Publications templates, which are pre-formatted Microsoft Word template documents based on current NPS formatting standards. Annual reports will use the Natural Resource Technical Report (NRTR) template. Trend analysis and other reports may require the Natural Resource Report (NRR) template if they include management implications or other content requiring an additional level of peer review. These templates and documentation of the NPS publication standards are available at: http://www.nature.nps.gov/publications/NRPM/index.cfm.

5.10. Identifying and Handling Sensitive Information

Note: At present we do not anticipate this project collecting any sensitive information. If this changes, a new SOP will be added with detailed instructions.

Certain project information related to the specific locations of rare or threatened taxa may meet criteria for protection and as such should not be shared outside NPS except where a written confidentiality agreement is in place prior to sharing. Before preparing data in any format for sharing outside NPS – including presentations, reports, and publications – the Project Lead should consider whether or not the resulting information might put protected resources at risk. Information that may convey specific locations of sensitive resources may need to be screened or redacted from public versions of products prior to release.

Although it is the general NPS policy to share information widely, the NPS also realizes that providing information about the location of park resources may sometimes place those resources at risk of harm, theft, or destruction. This can occur, for example, with regard to caves, archeological sites, tribal information, and rare plant and animal species. Therefore, information will be withheld when the NPS foresees that disclosure would be harmful to an interest protected by an exemption under the Freedom of Information Act (FOIA). The National Parks Omnibus Management Act, Section 207, 16 U.S.C. 5937, is interpreted to prohibit the release of information regarding the “nature or specific location” of certain cultural and natural resources in the national park system. Additional details and information about the legal basis for this policy

are in the NPS Management Policies (NPS 2006) and in Director's Order 66 (available at: http://home.nps.gov/applications/npspolicy/DOrders.cfm).

These guidelines apply to all NCCN staff, cooperators, contractors, and other partners who are likely to acquire or otherwise have access to information about protected NPS resources. The Project Lead has primary responsibility for ensuring adequate protection of sensitive information related to this project.

The following are highlights of our strategy for protecting this information:

- *Protected resources*, in the context of the NCCN Inventory and Monitoring Program, include species that have State- or Federally-listed status, and other species deemed rare or sensitive by local park taxa experts.
- *Sensitive information* is defined as information about protected resources that may reveal the "nature or specific location" of protected resources. Such information must not be shared outside the National Park Service, unless a signed confidentiality agreement is in place.
- In general, if information is withheld from one requesting party, it must be withheld from anyone else who requests it, and if information is provided to one requesting party. without a confidentiality agreement, it must be provided to anyone else who requests it
- To share information as broadly as legally possible, and to provide a consistent, tractable approach for handling sensitive information, the following shall apply if a project is likely to collect and store sensitive information:
    - Random coordinate offsets of up to 2 km for data collection locations, and
    - Removal of data fields likely to contain sensitive information from released data set copies.

5.11. Product Delivery, Posting and Distribution

Refer to **SOP 12: Product Delivery, Posting and Distribution** for the complete schedule for project deliverables and instructions for packaging and delivering them. Upon delivery products will be posted to NPS websites and clearinghouses (e.g., IRMA, NPSpecies, NPS Data Store) as appropriate.

5.11.1. Holding Period for Project Data

To permit sufficient time for priority in publication, certified project data will be held upon delivery for a period not to exceed two years after data certification. After the 2-year period has elapsed, all certified, non-sensitive data will be posted to the NPS Data Store. Note: This hold only applies to raw data, and not to metadata, reports or other products which are posted to NPS clearinghouses immediately after being received and processed.

5.11.2. Special Procedures for Sensitive Information

Products that have been identified upon delivery by the Project Lead as containing sensitive information will normally be revised into a form that does not disclose the locations of protected resources – most often by removing specific coordinates and only providing coordinates that include a random offset to indicate the general locality of the occurrence. If this kind of measure is not a sufficient safeguard given the nature of the product or the protected resource in question, the product(s) will be withheld from posting and distribution.

If requests for distribution of products containing sensitive information are initiated by the NPS, by another federal agency, or by another partner organization (e.g., a research scientist at a university), the unedited product (i.e., the full data set that includes sensitive information) may be shared only after a confidentiality agreement has been established between NPS and the agency, organization, or person(s) with whom the sensitive information is to be shared. Refer to **Section 5.10, Identifying and Handling Sensitive Information** for more information.

5.12. Archiving and Records Management

All project files should be reviewed and organized by the Project Lead on a regular basis (e.g., annually in January). Unneeded draft documents and other intermediate files should be deleted to conserve space and maintain a clear and unambiguous record for future project staff. See **SOP 11: Project Workspace and Records Management** for more details. Decisions on what to retain and what to destroy should be made following guidelines stipulated in NPS Director's Order 19 (available at: http://home.nps.gov/applications/npspolicy/DOrders.cfm), which provides a schedule indicating the amount of time that the various kinds of records should be retained.

Because this is a long-term monitoring project, good records management practices are critical for ensuring the continuity of project information. Files will be more useful to others if they are well organized, well named, and stored in a common format. Details for handling project files are described in **SOP 11: Project Workspace and Records Management**. In addition, files containing sensitive information must be stored in a manner that will enable quick identification. Refer to **Section 5.10, Identifying and Handling Sensitive Information**.

5.13. Season close-out

At the end of the annual cycle in March of every year that the monitoring project has been implemented, the Project Lead and Data Manager will meet to discuss the year's activities, and to document any needed changes to the field sampling protocols, to the database structure or front-end application, or to any of the SOPs associated with the protocol.

6. Personnel Requirements and Training

6.1. Safety

Personal safety is the number one priority at all times in the field and laboratory. At no time are staff expected to participate in operations that appear dangerous or risky. The operation of boats and sampling gear in the field can be potentially dangerous. Constant vigilance is required to ensure personal safety. All field personnel are required to participate in an annual field safety training program that covers standard safe field practices. All boat operators must pass the National Park Service Motorboat Operations Certification Course. A minimum of two staff will be on each boat-based sampling event. All staff must demonstrate swimming proficiency and **must** wear personal floatation devices while working on a boat. Training in Operational Leadership will be required for any staff leading or overseeing field work. Training in defensive driving will be required for all staff who could potentially operate motor vehicles while on duty.

6.2. Roles and Responsibilities

The primary roles associated with implementation of this protocol include: NPS Lead, Project Lead, Field Lead, Technicians, and Data Manager. Specific responsibilities associated with these roles are found in Table 7 and the information management task list associated with these roles and responsibilities is found in **Appendix 1. Yearly Project Task List**. Briefly, NPS laboratory analyses are conducted by either the Technician or the Field Lead. Offsite water chemistry analyses are conducted by a certified analytical laboratory (Oregon State University Cooperative Chemical Analytical Laboratory, CCAL). Data analysis and reporting are the responsibility of the Project Lead. Note that a single individual can play multiple roles during project implementation.

Table 7. Roles and responsibilities for Large Lakes Monitoring in the NCCN.

Role	Responsibilities	Name / Position
NPS Lead	• Project oversight and administration • Track project objectives, budget, requirements, and progress toward meeting objectives • Facilitate communications between NPS and cooperator(s), logistics planning • Coordinate and ratify changes to protocol	Steven Fradkin, Coastal Ecologist, OLYM
Project Lead	• Project operations and implementation • Oversee QA/QC program • Certify each season's data for quality and completeness • Complete reports, metadata, and other products according to schedule • Maintain and archive project records	
Data Analyst	• Zooplankton identification • Perform data summaries and analysis, assist interpretation and report preparation	
Field Lead	• Train and ensure safety of field crew • Plan and execute field visits • Acquire and maintain field equipment • Examine raw data immediately after collection • Oversee data collection and entry, verify accurate data transcription into database • Complete a field season report	
Technicians	• Collect, record, enter and verify data • Water sample processing	Biological Science Techs, GS-5/6
Data Manager	• Consultant on data management activities • Facilitate check-in, review and posting of data, metadata, reports, and other products to national databases and clearinghouses according to schedule • Install updates to NPSTORET database application • Provide database training as needed	John Boetsch, Data Manager, OLYM*
GIS Specialist	• Consultant on spatial data collection, GPS use, and spatial analysis techniques • Facilitate spatial data development and map output generation • Work with Project Lead and Data Analyst to analyze spatial data and develop metadata for spatial data products • Primary steward of GIS data and products	Roger Hoffman, GIS Specialist, OLYM*
Network Program Manager	• Review of annual reports for formatting and completeness	NCCN Network Program Manager
Park Managers	• Review reports, data and other project deliverables	OLYM Natural Resource Managers
Park Curator	• Receive and archive copies of annual reports, 5-year analysis report, and other publications • Facilitate archival of other project records (e.g., original field forms, etc.)	Park Curators and Collections Managers at OLYM

* These individuals act as coordinators and primary points of contact for this project. Their responsibility is to facilitate communication among network and park staff and to coordinate the work which may be shared among various staff to balance work load and to enhance the efficiency of operations. Refer to the NCCN Data Management Plan (Boetsch et al. 2009) for additional explanation of shared data stewardship.

6.3. Qualifications

Due to budget constraints, for the foreseeable future, the Project Lead and the Field Lead role will be covered by the same person. This protocol requires that the Project Lead be a full time aquatic ecologist with specific training in limnology. If zooplankton identification is to be conducted "in-house", as it is for the Lake Crescent implementation, the Field Lead must have demonstrated expertise in taxonomic identification. For Lake Crescent, the Project and Field Lead is Dr. Steven Fradkin, who holds an M.S. and Ph.D. in limnology. Dr. Fradkin specialized in zooplankton ecology and has over 16 years' experience identifying zooplankton.

The biological technician will devote five pay periods (2.5 months) per year to the large lake program spread over the course of an annual sampling cycle. The technician will work the rest of the year either on otherwise-funded aquatic programs, especially during the summer field season, or will work intermittently (i.e. during the winter). Historically OLYM has had great success in recruiting and retaining key technicians for 2-3 year periods, allowing for overlap between successive key technicians. Technicians must have at least a B.S degree with training and experience in aquatic ecology.

6.4. Training Procedures

A comprehensive and well-designed training program is critical to the success of this project, as it will maximize observer consistency within and between years. Up to three weeks should be allowed for the training period to maximize the likelihood that the Technician will be qualified to conduct all of the monitoring components at the end of the training session, and to allow ample time for any required meetings between the Technician, Field Lead, Project Lead, Data Manager, and GIS Specialist. Additional training time will be required to participate in and complete required general park training sessions (e.g., computer training, ethics, all-park safety training, etc.).

The Technician must go through a training period (May-June) with the Field Lead. The technician training will include the following:

- A program overview with a discussion of goals, objectives and standard operation procedures.
- Required readings. The Technician will be given a copy of the protocol and other reference materials for review.
- Boat instructions: The Technician will take the DOI Motorboat Operator Certification Course.
- Hands-on laboratory instruction: The Technician will be shown how to operate and calibrate all laboratory equipment.
- Hands-on field instruction: The Technician will be shown how to conduct all field SOPs.
- Safety (e.g., first aid and CPR, the GAR Model of NPS Operational Leadership, defensive driving, backcountry travel, etc. See SOP 14: Field and Laboratory Safety, and Appendix 4: Job Hazard Analysis)
- Forms: The Technician will be shown the proper way to fill out all field and laboratory forms.

- Data Entry: The Technician will be shown the proper method for entering data into the database, in addition to demonstration of all data QA/QC procedures.

The Technician will work directly with the Field Lead until the Field Lead is satisfied that the technician is capable of operating independently.

6.5. Facility and Equipment Needs

This protocol requires a rudimentary lab facility, certain essential field and lab equipment, and an identified analytical laboratory for water chemistry analysis. The Lake Crescent Laboratory at OLYM is directly on the shoreline of the north basin of Lake Crescent approximately a half mile from the Lyre River outlet. The lab has a wet-lab room for processing water samples, in addition to a microscopy room for sample identification. The lab also has a dock on the lake where the sampling platform (a 17-ft. Boston whaler) is permanently stationed. Below is a list of equipment needed for this protocol that is present at the Lake Crescent Lab. Equipment for each SOP also appears as part of specific SOPs (Section 2).

6.5.1. Essential Equipment

- A multi-probe data sonde (e.g. YSI 6600 w/ DO, pH, conductivity, temperature, turbidity and chl-a probes)
- Sampling platform (e.g. 17-ft. Boston Whaler boat)
- Davit with steel line and hand crank for deploying and retrieving sampling gear
- GPS/Sonar unit (e.g. Lowrance LC-X16$_{ci}$) for locating permanent stations
- Personal floatation devices
- Vertically integrating zooplankton sampler (e.g.60 um plankton net, Clark-Bumpus sampler etc.)
- Van-Dorn water sampler (e.g. 8-liter model)
- Dissecting microscope (e.g. Zeiss Stemi-2000C)
- Compound microscope (e.g. Nikon E400)
- Folsom plankton splitter
- Ward counting well
- Multi-tally counter
- Hensen-Stempel pipett (1-2 ml)
- Stand-alone Nalgene filtration units (500 ml) with hand pump
- Hach Digital Titrator and alkalinity kit
- Secchi Disk and marked line

6.5.2. Standard monthly sampling field equipment check list

- YSI 6600 (with DO, pH/ORP and conductivity/temperature probes installed)
- Water proof cable cap for YSI 6600
- Bulkhead cup and field cage for YSI 6600
- Davit with steel line and hand crank
- Lowrance LC-X16$_{ci}$ GPS/Sonar unit
- Personal Flotation Devices
- Clark-Bumpus Zooplankton sampler w/messenger
- 8 liter Van-Dorn water sampler w/ messenger

- Rope marked in meters
- Weight and carabiners
- Large Lake Monitoring Field form
- Field clipboard
- Limnology field note book
- Lugol's solution
- Coolers with ice packs
- 1000 ml previously labeled water sample jars
- 125 ml previously labeled zooplankton sample jars
- Squirt bottle
- Sharpie pens and pencil

6.6. Annual Budget

The annual budget for the NCCN Large Lowland Lakes Monitoring Program as implemented at Lake Crescent/OLYM appears in Table 8. These costs are based on fiscal year 2012 NPS personnel services costs and CCAL laboratory costs.

Table 8. Proposed annual budget for implementation of the NCCN Large Lowland Lakes Protocol in Lake Crescent (OLYM).

Personnel: Lake Sampling	Job Component	# of Pay Periods	NCCN Cost*	OLYM Contribution
Personnel				
GS-5 seasonal technician	Data collection , sample processing	3	$3,875	
GS-5 seasonal technician	QA/QC, data analysis, data management	2	$2,584	
GS-12 Project Lead Limnologist	QA/QC, data analysis, reporting	2		$6,330
Services				
Water Analysis - nutrients, ions: (24 field samples, 4 replicates, 4 field blanks, 4 filter blanks) 36 samples * $181/sample =			$6,516	
Supplies and Equipment:				
Probes, standard solutions, sampling bottles, misc. field gear			$1,190	
Gasoline for boat				$300
	Total =		$14,165	$6,630

Literature Cited

Arnott, S. E., J. J. Magnuson, and N. D. Yan. 1998. Crustacean zooplankton species richness: single- and multiple-year estimates. Canadian Journal of Fisheries and Aquatic Sciences 55:1573–1582.

Bade, D., J. Houser, and S. Scanga, editors. 1998. Methods of the cascading trophic interactions project. Fifth edition. Center for Limnology, University of Wisconsin, Madison.

Baker, J. R., D. V. Peck, and D. W. Sutton, editors. 1997. Environmental monitoring and assessment program Surface waters: Field operations manual for lakes. EPA/620/R-97/001. U.S. Environmental Protection Agency, Washington D.C. Available at http://www.epa.gov/emap/html/pubs/docs/groupdocs/surfwatr/field/97fldman.html (accessed 25 March 2011).

Boetsch, J. R., B. Christoe, and R. E. Holmes. 2009. Data management plan for the North Coast and Cascades Network Inventory and Monitoring Program (2005). Natural Resource Report NPS/NCCN/NRR—2009/078. National Park Service, Fort Collins, Colorado.

Boyle, T. P., and D. R. Beeson. 1991. Trophic status and assessment of non-point nutrient enrichment of Lake Crescent Olympic National Park. Technical Report NPS/PNRWR/NRTR-91/01. Water Resources Division, National Park Service, Seattle, Washington.

Buhrer, H., and H. Ambuhl. 2001. Lake Lucerne, Switzerland, a long term study of 1961–1992. Aquatic Science 63:1–15.

Carlson, R. E., and J. Simpson. 1996. A coordinator's guide to volunteer lake monitoring methods. North American Lake Management Society, Madison, Wisconsin.

Carpenter, S. R. 1988. Complex interaction in lake communities. Springer-Verlag. New York

Carpenter, S. R. 2003. Regime shifts in lake ecosystems: Pattern and variation. *In* O. Kinne, editor. Excellence in ecology. Book 15. International Ecology Institute, Oldendorf/Luhe, Germany.

Edmondson, W. T., editor. 1959. Freshwater biology. Second edition. John Wiley and Sons, New York, New York.

Edmondson, W. T. 1979. Lake Washington and the predictability of limnological events. Archiv Fur Hydrobiologie 13:234–41.

Edmondson, W. T. 1991. The uses of ecology: Lake Washington and beyond. University of Washington Press, Seattle, Washington.

Edmondson, W. T., and A. H. Litt. 1982. Daphnia in Lake Washington. Limnology and Oceanography 27:272–293.

Forbes, A., and D. Stewart. 2002. Center for Limnology guide to the preservation of research specimens. Center for Limnology, University of Wisconsin, Madison, Wisconsin.

Frost, T. M., J. M. Fisher, J. L. Klug, S. E. Arnott, and P. K. Montz. 2006. Trajectories of zooplankton recovery in the Little Rock Lake whole-lake acidification experiment. Ecological Applications 16:353–367.

Frost, T. M., P. K. Montz, T. K. Kratz, T. Badillo, P. L. Brezonik, M. L. Gonzalez, R. G. Rada, C. J. Watras, K. E. Webster, J. G. Wiener, and others. 1999. Multiple stresses from a single agent: Diverse responses to the experimental acidification of Little Rock Lake, Wisconsin. Limnology and Oceanography 44:787–794.

Gaedke, U. 1998. Functional and taxonomical properties of the phytoplankton community of large and deep Lake Constance: Interannual variability and response to re-oligotrophication (1979–1993). Archiv Fur Hydrobiologie Special Issues Advances in Limnology 53:119–141.

George, D. G. 2006. The spatial distribution of nutrients in the south basing of Windermere. Freshwater Biology. 11:405–424.

Glesne, R. S., S. C. Fradkin, B. A. Samora, J. R. Boetsch, R. E. Holmes and B. Christoe. 2012. Protocol for long-term monitoring of mountain lakes in the North Coast and Cascades Network: Version July 3, 2012. Natural Resource Report NPS/NCCN/NRR—2012/549. National Park Service, Fort Collins, Colorado.

Goldman, C. R. 1981. Lake Tahoe: Two decades of change in a nitrogen deficient oligotrophic lake. Plenary lecture. Verhandlungen der Internationalen Vereinigung für Theoretische und Angewandte Limnologie 21:45–70.

Goldman, C. R. 1988. Primary productivity, nutrients, and transparency during the early onset of eutrophication in ultra-oligotrophic Lake Tahoe, California-Nevada. Limnology and Oceanography 33:1321–1333.

Hagen, T. A., and J. Aho. 1989. Lake Crescent water quality status report 1984-1989. Unpublished report. Olympic National Park, Port Angeles, Washington.

Hampton, S. E. 2005. Increased niche differentiation between two *Conochilus* species over 33 years of climate change and food web alteration. Limnology and Oceanography 50:421–426.

Helsel, D., R., and R. M. Hirsch. 2002. Statistical methods in water resources. USGS Techniques of water investigations. Book 4, Chapter A3. U.S. Geological Survey, Reston, Virginia. Available from http://water.usgs.gov/pubs/twri/twri4a3/ (accessed 27 March 2011).

Hem, J. D. 1989. Study and interpretation of the chemical characteristics of natural water. Third edition. U.S. Geological Survey Water-Supply Paper 2254. U.S. Geological Survey, Reston, Virginia.

Hessen, D. O, B. A. Faafeng, V. H. Smith, V. Bakkestuen, and B. Walseng. 2006. Extrinsic and intrinsic controls of zooplankton diversity in lakes. Ecology 87:433–443.

Hirsch, R. M., and J. R. Slack. 1984. A non-parametric trend test for seasonal data with serial dependence. Water Resources Research 20:727–32.

Hoffman, R. L., T. J. Tyler, G. L. Larson, M. J. Adams, W. Wente, and S. Galvan. 2005. Sampling protocol for monitoring abiotic and biotic characteristics of mountain ponds and lakes. U.S. Geological Survey Techniques and Methods 2-A2. U.S. Geological Survey, Reston, Virginia. Available from http://pubs.usgs.gov/tm/2005/tm2a2/ (accessed 27 March 2011).

Hutchinson, G. E. 1959. Homage to Santa-Rosalia or why are there so many kinds of animals. American Naturalist 93:145–159.

Irwin, R. 2008. Draft part B lite QA/QC review checklist for aquatic vital sign monitoring protocols and SOPs, National Park Service, Water Resources Division, Fort Collins, Colorado. Available at http://www.nature.nps.gov/water/Vital_Signs_Guidance/Guidance_Documents/PartBLite.pdf (accessed 27 March 2011).

Jassby, A. D., J. E. Reuter, and C. R. Goldman. 2003. Determining long-term water quality change in the presence of climate variability: Lake Tahoe (U.S.A). Canadian Journal of Fisheries and Aquatic Sciences 60:1452–1461.

Johnson, R. K. 1999. Regional representativeness of Swedish reference lakes. Environmental Management 23(1):115–124.

Koschel, R., and D. D. Adams, editors. 2003. Lake Stechlin: An approach to understanding an oligotrophic lowland lake. Advances in Limnology 58.

Koste, W. 1978. Rotatoria. Die Rädertiere Mitteleuropas. Borntraeger, Berlin, Stuttgart.

Larson, G. L., C. D. McIntire, and R. W. Jacobs, editors. 1993. Crater Lake limnological studies final report. Technical Report NPS/PNROSU/NRTR-93/03. National Park Service, Pacific Northwest Region, Seattle, Washington.

Likens, G. E. 2004. Some perspectives on long-term biogeochemical research from the Hubbard Brook Ecosystem Study. Ecology 85:2355–2362.

Likens, G. E., F. H. Bormann, and N. M. Johnson. 1972. Acid rain. Environment 14:33–40.

Loftis, J. C., and C. H. Taylor. 1989. Detecting acid precipitation impacts on lake water quality. Environmental Management 13(5):529–538.

Logan, R. L., and R. L. Schuster. 1991. Lake divided: The origin of Lake Crescent and Lake Sutherland, Clallam County, Washington. Washington Geology 19:38–42.

Magnuson, J. J. 1990. Long-term ecological research and the invisible present. BioScience 40:495–501.

Magnuson, J. J., and T. K. Kratz, editors. 2004. Lake in the landscape. Oxford University Press, London.

Mazumder, A., and K. E. Havens. 1998. Nutrient chlorophyll Secchi relationships under contrasting grazer communities of temperate versus subtropical lakes. Canadian Journal of Fisheries and Aquatic Sciences 55:1652–1662.

McBride, G. B. 2005. Using statistical methods for water quality management: Issues, problems and solutions. Wiley-Interscience, Hoboken, New Jersey.

Megard, R. O. 2000. Diagnosis of light attenuance with Secchi disks. Archiv Fur Hydrobiologie Special Issues Advances in Limnology 55:169–178.

Meyer, J., and S. Brenkman. 2001. Status report on the water quality of Lake Ozette and potential human-related impacts on salmonids. Olympic National Park, Natural Resource Management Division, Port Angeles, Washington.

Meyer, J., and S. C. Fradkin. 2002. Summary of fisheries and limnological data for Lake Crescent, Washington. Olympic National Park, Natural Resource Management Division, Port Angeles, Washington.

Moore, J. W., D. E. Schindler, M. D. Scheuerell, D. Smith, and J. Frodge. 2003. Lake eutrophication at the urban fringe, Seattle region, USA. Ambio 32:13–18.

Mumby, P. J. 2002. Statistical power of non-parametric tests: a quick guide for designing sampling strategies. Marine Pollution Bulletin 44:85–87.

National Park Service (NPS). 2001. Park Vital Signs Monitoring – A commitment to Resource Protection. National Park Service, National Resource Program Center, Fort Collins, Colorado. Available at http://www.cnr.uidaho.edu/css496/Vital_signs_brochure.pdf.

National Park Service. 2002. Recommendations for core water quality parameters and other key elements of the NPS vital signs program water quality monitoring component. Freshwater Workgroup Subcommittee. Fort Collins, Colorado.

National Park Service. 2006. Management policies. Available at: http://www.nps.gov/policy/mp/policies.html (accessed 14 January 2013).

North Coast and Cascades Network (NCCN). 2007. Metadata development guidelines. USDI National Park Service. Available at http://science.nature.nps.gov/im/units/nccn/datamgmt_guide.cfm (accessed 13 January 2013).

Oakley, K. L, L. P. Thomas, and S. G. Fancy. 2003. Guidelines for long-term monitoring protocols. Wildlife Society Bulletin 31(4):1000–1003.

Onoz, B., and M. C. Bayazit. 2003. The power of statistical tests for trend detection. Turkish Journal Engineering and Environmental Science. 27:247–251.

Pierce, B. E. 1984. The trouts of Lake Crescent, Washington. MS thesis, Colorado State University, Fort Collins, Colorado.

Postel, S., and S. R. Carpenter. 1997. Freshwater ecosystem services. Pages 195–214 *in* G. Daily, editor. Nature's Services. Island Press, Washington, D.C.

Preisendorfer, R. W. 1986. Secchi disk science: Visual optics of natural waters. Limnology and Oceanography 31:909–926.

Rainey, J. D., S. C. Fradkin, and W. V. Sobczak. 2007. Zooplankton diel vertical distributions in Lake Crescent, a deep oligotrophic lake in Washington (USA). Journal of Freshwater Ecology 22:469–476.

Rosenberger, E. E., S. E. Hampton, S. C. Fradkin, and B. P. Kennedy. 2008. Effects of shoreline development on the nearshore environment in large deep oligotrophic lakes. Freshwater Biology 53:1673–1691.

Sanden, P., and B. Hakansson. 1996. Long-term trends in Secchi depth in the Baltic sea. Limnology and Oceanography 41:346–351.

Stemberger, R. S. 1979. A guide to rotifers of the Laurentian Great Lakes. EPA 600/4-79-021. U. S. Environmental Protection Agency, Cincinnati, Ohio. Available from http://nepis.epa.gov (accessed 3 April 2013).

Stemberger, R. S., and E. K. Miller. 2003. Cladoceran body length and Secchi disk transparency in northeastern U.S. lakes. Canadian Journal of Fisheries and Aquatic Sciences 60:1477–1486.

Stow, C. A., S. R. Carpenter, K. E. Webster, and T. M. Frost. 1998. Long-term environmental monitoring: Some perspectives from lakes. Ecological Applications 8:269–276.

Taylor, C. H., and J. C. Loftis. 1989. Testing for trend in lake and ground water quality time series. Water Resources Bulletin 25:715-726.

Warren, G. J., and P. J. Horvatin. 2003. Great lakes monitoring results: Comparison of probability and deterministic sampling grids. Environmental Monitoring and Assessment 81:63–71.

Weber, S., A. Woodward, and J. Freilich. 2009. North Coast and Cascades Network vital signs monitoring report (2005). Natural Resource Report NPS/NCCN/NRR—2009/098. National Park Service, Fort Collins, Colorado.

Wetzel, R. G. 2001. Limnology: Lakes and river ecosystems. Academic Press. London.

Wilson, M. A., and S. R. Carpenter. 1999. Economic valuation of freshwater ecosystem services in the United States: 1971–1997. Ecological. Applications 9:772–783.

Yue, S., P. Pilon, and G. Cavadias. 2002. Power of the Mann-Kendall and Spearman's rho tests for detecting monotonic trends in hydrological series. Journal of Hydrology 259:254–271.

Standard Operating Procedures

The eastern basin of Lake Crescent (OLYM), with Lake Sutherland in the background.

Standard Operating Procedure (SOP) 1. Physical/Chemical Water Column Profile

Revision History Log

Revision Date	Author	Changes Made	Reason for Change
9/21/2006	S.C. Fradkin	Minor editorial changes, chl-a calibration check by analytical lab	Response to peer review

Introduction

This SOP covers the usage of a multi-parameter data sonde to collect vertical profile data from the water column at each sampling station. Parameters measured using this device include: temperature, specific conductivity, dissolved oxygen, pH, turbidity, and chlorophyll-a.

Equipment Needed

Calibration materials**:**

- YSI 6600 EDS data sonde
- YSI 650 MDS multi-parameter display/datalogger system (optional)
- Sonde calibration cup
- Rinsing bucket
- Kimwipes
- Parafilm
- Distilled water (dH_2O)
- Calibration standards
  - pH 7, ph 10
  - Conductivity (1000 µS/cm)
  - Turbidity (0, 10 NTU)
  - Nitrate & Ammonium (1, 10 mg/l)

YSI 6600 Multi-probe Data-sonde Calibration

General Considerations

- The calibration cup should be rinsed with dH_20, then with a small amount of calibration standard prior to calibration of each probe.

- During calibration, receiving an error message *"Out of Range Error, Calibrate Anyway?"* should serve as a flag that something is wrong with sonde, probes, or calibration solution. **Never accept the "calibrate anyway" option**. When faced with this error message, select "no", then attempt to recalibrate with fresh calibration solution. If error message persists, clean probe according to the YSI manual specifications and recalibrate. If error still persists, call YSI technical support at 1-800-897-4151.
- Calibrate sensors in the order listed in this SOP.
- Temperature sensor requires no calibration.
- The Field Lead will examine all data immediately after collection to detect errors associate with equipment malfunction.

General Calibration Procedure

1. Secure 6600 to stand and attach to MDS 650 unit or to PC.
2. Immerse probes into desired calibration solution and attach calibration cup to the sonde.
3. On PC run Ecowatch program, or connect to sonde via MDS 650 unit.
4. Select **sonde** from menu.
5. From Main Menu select **2-Calibrate.**
6. Select the number next to the parameter that you want to calibrate and press **Enter.**
7. Input the Units of the calibration standard and press **Enter.**
8. A real time calibration screen will appear. When the readings have stabilized for over 30 sec., press **Enter** to accept the calibration.
9. Press **Enter** to return to the calibration screen and continue with the next calibration.

Conductivity Probe Calibration

1. Add 300 ml of 1 mS/cm conductivity standard to the calibration cup and secure to data sonde. Rotate data sonde to an upside down position so the conductivity sensor is immersed in the calibration standard.
2. Gently rotate to remove any bubbles from the conductivity sensor.
3. Wait one minute for temperature equilibrium.
4. From the Calibrate menu, select **1-Conductivity,** and then **1-SpCond** .
5. Enter **1 ms/cm at 25° C** for the calibration standard, then press **Enter.**
6. Wait for the calibration readings to stabilize for 30 sec. then press **Enter** to start the calibration of the next sensor.

<u>Dissolved Oxygen Probe Calibration</u>

1. Place approx. 3 mm of dH2O in the bottom of the calibration cup. Lightly twist calibration cup onto only the first few threads of the data sonde.
2. Wait 10 min. for the air in the calibration cup to become saturated.

3. From the Calibrate Menu, select **2-Disssolved Oxy**, then 1**-DO%**.
4. Enter current barometric pressure in mm of Hg (Inches of Hg x 25.4 = mm Hg). **Make sure that the barometric pressure readings are not corrected to sea level for Lake Crescent measurements**.
5. Press **Enter** and wait for the calibration readings to stabilize for 30 sec. then press **Enter** to start the calibration of the next sensor.

Depth and Level Calibration

1. From the Calibrate Menu, select **3-Pressure-Abs.** Input **0.0** and press **Enter**.
2. Press **Enter** and wait for the calibration readings to stabilize for 30 sec. then press **Enter** to start the calibration of the next sensor.

pH Probe Calibration

Note: Before proceeding, wrap DO probe tip in parafilm!!!

1. Add 300 ml of pH 7.0 buffer to the calibration cup and secure to data sonde. Wait 1 min. for temperature equalization.
2. From the Calibrate Menu, select **4-ISE1 pH** then press **2-2-Point.** Press **Enter** then input **7** for the value of the buffer and press **Enter**.
3. Wait for the PC to calibrate the pH sensor to 7.0. When finished press **Enter**.
4. Rinse the pH sensor in dH2O and dry with a kimwipe.
5. Add 300 ml of pH 10.0 buffer to the calibration cup and secure.
6. Press **Enter** and input 10 as the value of the second buffer.
7. Press **Enter** and wait for the calibration readings to stabilize for 30 sec. then press **Enter** to start the calibration of the next sensor.

Turbidity Probe Calibration

1. Add 300 ml of dH2O to the calibration cup and secure to data sonde.
2. From the Calibrate Menu, select **8-Turbidity**, then **2-2-Point.**
3. Input the value **0.00 NTU** at the prompt and press **Enter**.
4. Activate the wiper by pressing **3-Clean Optics**.
5. Wait for the calibration readings to stabilize for 30 sec. then press **Enter** to start the calibration of the 10 NTU standard.
6. Dump the dH2O from the calibration cup, dry all the sensors carefully with a kimwipe, then add 130 ml of the 10 NTU standard to the calibration cup and secure to 6600 data sonde.
7. Input the value **5.00 NTU** at the prompt and press **Enter**.
8. Wait for the calibration readings to stabilize for 30 sec. then press **Enter** to return to the calibration menu.

Chlorophyll Probe Calibration

Note: This calibration uses a secondary calibration compound, Rhodamine WT in place of Chlorophyll-a, due to the difficulty in obtaining a reliable Chlorophyll-a standard. Purified Chlorophyll-a is unstable, expensive, and infeasible to work with using the YSI 6600 sonde and fluorometric Chlorophyll probe.

1. Add 130 ml of dH2O to the calibration cup and secure to data sonde.
2. From the Calibrate Menu, select **9-Chlorophyll**, then **2-2-Point.**
3. Input the value **0.00 μg/l** at the prompt and press **Enter**.
4. Activate the wiper by pressing **3-Clean Optics.**
5. Wait for the calibration readings to stabilize for 30 sec. then press **Enter** to accept.
6. Dump the dH2O from the calibration cup, dry all the sensors carefully with a kimwipe.
7. Add 5 ml of the stock Rhodamine WT solution (100 mg/l) to 995 ml, of dH_20. Mix, and allow time to let it come to room temperature (20 ºC). This solution is now 0.5 mg/l.
8. Add 300 ml of the 0.5 mg/l Rhodamine WT standard at room temperature to the calibration cup and secure to sonde.
9. Input the value **118 μg/l** at the prompt and press **Enter.**
10. Activate the wiper by pressing ”Clean Optics”. After wiping, wait 30 secs. for stabilization and press **Enter**.
11. Wait for calibration readings to stabilize for 30 sec. then press **Enter** to return to calibration menu.

<u>Chlorophyll Probe Calibration Check</u>

Chlorophyll-measurements by in-situ fluorometers provide only an estimate of the chlorophyll in environmental whole water because they measure fluorescence of pigments that reside in cells packaged in phytoplankton rather than purified extracts, such as are analyzed in the laboratory. Rather than obtaining true quantitative concentrations in the environment, the proposed in vivo probe method should provide reliable estimates that track changes in environmental chlorophyll concentrations. As such twice a year during periods of expected productivity (spring/April and fall/October), the chlorophyll probe calibration via the secondary standard (above) will be checked in a side-by-side comparison with in-situ probe measurements at the 10 m depth and of the quantitative analysis of the chlorophyll concentration of 2 liters of water collected from 10 m depth. The collection and choice of analytical lab of the chlorophyll sample is outlined in SOP 2. Quantitative chlorophyll concentrations will be used to post-calibrate the probe data during each six-month period if the concentrations vary greater than 10% from the probe values.

Multi-Parameter Data Sonde Deployment

General Considerations

- After calibration, remove field cable and **affix cable port screwcap.**
- The data sonde is deployed at all fixed stations.

- At each station two sonde casts are taken due to different depth limits of probes (Table SOP 1.1).
- The first cast with Chl-a and turbidity probes installed is deployed to a max depth of 60 m.
- The second cast with Chl-a and turbidity probes removed is deployed to a max depth of 200 m (usually within 5 m of the lake bottom).
- Prior to deployment in water make sure the sonde is securely fastened to the cable with a locked carabiner.
- Prior to sonde deployment make sure that cable and attachments appear sound. Bent deformed steel cable can snap due to stress articulation on a single point.

Table SOP 1.1. YSI Sonde Probe Depth limits.

Probe	Depth
Chl-a	61 m
Turbidity	61 m
DO/pH/SpCond	200 m

1. Attach armed sonde and 10-lb weight to cable and swing davit overboard.
2. Let out line dropping sonde to target maximum depth (dependent upon probes installed and bathymetry). Monitor depth using boat's sonar display.
3. Arrest sonde descent at target depth. Using the hand crank raise the sonde at 5-m intervals allowing the sonde to stay approximately 2 minutes at each depth.
4. Bring sonde into boat and adjust probe array according to sample schedule.

Data Files Nomenclature

On both the sonde and computer after downloading from the sonde, all data files are named after the following convention.

Name = L**XMMDDYY**

Where X	=	C (for Crescent)
MM	=	Month (two digit)
DD	=	Day (two digit)
YY	=	Year (two digit)

Data Downloading

1. Download data file from Sonde to PC file (excel spreadsheet).
2. Clip out up cast data from file and store in separate named interim data file with separate worksheet for each station/cast.
3. Review each worksheet for quality control, with particular eye towards data completeness (appropriately timed records, values within acceptable ranges).
4. Upload interim data into NPStoret.
5. Enter initials and date for appropriate QA/QC fields on the Limnological Field Form.

Standard Operating Procedure (SOP) 2.
Chlorophyll-*a*: Analytical Laboratory check of YSI Calibration

Revision History Log

Revision Date	Author	Changes Made	Reason for Change
9/21/2006	S.C. Fradkin	New SOP	Response to peer review

Introduction

Chlorophyll-*a* (Chl-a) is a major photosynthetic pigment used by lake primary producers (e.g. phytoplankton). Measurement of chlorophyll-a concentration in lake water is an accepted surrogate for measuring algal biomass. Vertical profiles of Chl-a in this protocol are measured via in-situ fluorometry as outlined in SOP 1: Physical/Chemical Water Column Profiles, however periodic checks of in-situ fluorometry against laboratory quantitative analysis of Chl-a are required to validate the standard calibration of the in-situ Fluorometer. This protocol outlines the validation procedure. Part of this SOP is modified from Hoffman et al. (2005).

Equipment Needed

- Van Dorn water sampler
- 2 1-liter Nalgene bottles
- 0.45 µm membrane filter
- Nalgene polysulfone filtration apparatus
- Sample cooler with ice
- Sharpee
- Aluminum foil
- Peristaltic pump apparatus.

Procedures

1. Collection of the water for Chlorophyll-a concentration sample
    a. Water to be filtered for samples should be collected at the depth of 10 meters at Station #2 using an 8-liter Van Dorn sampling bottle.
    b. Whole water is transferred from the Van Dorn to two 1-liter Nalgene bottles that are immediately put on ice in the dark (i.e. a cooler) and transported to the lab.
2. Laboratory filtration of the Chlorophyll-a samples

a. Place new 0.45 μm membrane filter into the filtering apparatus using forceps.
b. Pour 25-30 ml of distilled water into top of the filter chamber and swirl to rinse sides of chamber and discard water. Repeat.
c. Invert the water sample gently several times to re-suspend any settled algae, then filter exactly 2000 ml of sample water.
d. Discard filtered water.
e. Pump pressure gauge should not register higher than 5 PSI (or 10 inches of Hg).
f. After filtering the 2000 ml of water, pump filter dry, then remove filter from filtering apparatus, fold in eighths with forceps, and place into a pre-labeled foil-wrapped micro centrifuge tube.
g. Label microcentrifuge tube with black sharpee: Lake, Date, Chl-a, depth
h. The microcentrifuge should be wrapped in aluminum foil, placed into the freezer until mailed to the analytical laboratory.

3. Processing of Chlorophyll-a sample by analytical lab
   a. Total chlorophyll-a concentration is determined by the CCAL analytical lab by the fluorometric procedure descried and outlined in APHA (1998).
   b. Ship frozen chlorophyll-a samples on dry ice via overnight mail to:

Cooperative Chemical Analytical Laboratory
Oregon State University
3200 Jefferson Way
Corvallis, OR 97331

Literature Cited

APHA. 1998. Standard methods for the examination of water and wastewater. American Public Health Association, Washington, D.C.

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

Standard Operating Procedure (SOP) 3.
Water Clarity

Revision History Log

Revision Date	Author	Changes Made	Reason for Change
9/21/2006	S.C. Fradkin	Minor editorial changes, additional explanations	Response to peer review

Introduction

Water Clarity in this SOP is measured as Secchi depth, the depth at which a 20-cm diameter disk with alternating black and white quarters can be observed from the surface (Megard 2000). Seasonal changes in Secchi disk transparency values correspond to sediment inflows, phytoplankton blooms, and grazing pressure. The Secchi depth is measured at all fixed sampling stations.

Equipment Needed

- Secchi disk
- Marked line (in meters)
- Aqua-tube
- 5 lb lead weight

General Notes

- Secchi depth will be measured between 10:00 am and 2:00 pm to standardize light conditions.
- Secchi depth will not be measured when adverse lake conditions (e.g. large swells, waves, etc.) make Secchi depth measurement infeasible. Under such conditions Secchi depth will be measured the next day that conditions are conducive to measurement.
- The Field Lead will examine Secchi depth data immediately after it is collected to ensure accuracy.
- Secchi depths will be taken by the same staff member during each sampling event.

Procedures

1. Use an aqua-tube for viewing the Secchi disc in the water. An aqua-tube is a tube with a clear Plexiglas bottom that allows the observer to view underwater without interference from surface glare.

2. Attach a 5-lb weight to the Secchi disc bottom to keep the line straight at depth.
3. Lower Secchi disc on attached line marked in meters on the shaded side of the boat until the point where the disc is no longer visible. Note the depth.
4. Lower the disc beyond this point. And slowly raise the disc until it just reappears. Note this depth.
5. Record the average of the two depth measurements as the Secchi depth.

Literature Cited

Megard, R. O. 2000. Diagnosis of light attenuance with Secchi disks. Archiv Fur Hydrobiologie Special Issues Advances in Limnology 55:169–178.

Standard Operating Procedure (SOP) 4. Zooplankton Sampling

Revision History Log

Revision Date	Author	Changes Made	Reason for Change
6/1/2006	S.C. Fradkin	Original	

Introduction

This SOP details the collection, processing and identification of zooplankton from Lake Crescent. Methods in the SOP are adapted from Downing and Rigler (1984) and Bade et al. (1998) and Wetzel and Likens (2000).

Equipment Needed

- Dissecting microscope
- Ward Counting Wheel (Wildco #1810-E80)
- Borogov counting chamber (Wildco #1810-B10) as alternate to Ward Counting Wheel
- 1,2 ml Hensen-Stempel pippette (Wildco #1806-D52)
- 150 ml Ehrlenmeyer flask
- Acid Lugol's solution (see recipe below)
- Water rinse bottle
- 53 µm filter cup
- Tally counter bank (5-7 counters)
- 2 fine probes (insect pins embedded in glass rod for manipulating organisms)
- NPS-OLYM Zooplankton enumeration form (see **Appendix 2:Data Forms**)
- Excel spreadsheet ZOOP_ALIQUOT.XLS

General Considerations

- Standard zooplankton samples will be fixed with acid Lugol's solution. Samples thus fixed are stable for at least 6 months if refrigerated. Formalin is not used in these samples because it is highly carcinogenic, requires working in a fume hood, and worker exposure to it should be minimized.
- Formalin is used only to fix voucher specimen samples. In these samples a 5% sugar formalin solution is used. Samples thus fixed can be kept unrefrigerated for many years.
- All zooplankton identifications will be made consistent with the following taxonomic keys: Brandlova et al. (1972), Brooks (1957), Edmondson (1959), Koste (1978), Sandercock and Scudder (1994), Stemberger 1979, Thorp and Covich (1991).

Sample Collection

- Zooplankton are sampled monthly in Lake Crescent during the 3rd week of the month.
- Zooplankton sampling should occur within ± 2 hrs of noon to minimize variation associated with vertically migrating species.
- Record zooplankton sampling and depth of each replicate on the Large Lake Monitoring Field Form (see **Appendix 2: Data Forms**).
- Zooplankton samples are collected via a vertical haul using a 64 μm mesh net deployed to approximately twice the mean annual lake Secchi depth. In Lake Crescent, a Clarke-Bumpus zooplankton sampler fitted with a 64 μm net is deployed to a depth of 40 m. The closed sampler is deployed to depth and opened via a messenger or "go-devil". Once opened, the sampler is retrieved at a steady pace (~0.5 m/s)
- Zooplankton are further concentrated in the cod end and rinsed into a previously labeled sample bottle.
- The sample is fixed in the field with acid Lugol's solution, using approximately 2 ml of liquid (enough to make the sample look like strong tea). The sample is then stored for transport back to the laboratory.
- Three (3) replicate zooplankton samples are collected from each of two sampling stations (Stations #2 and #4).
- A single qualitative vertical haul from 40 m is collected from the last station sampled for immediate laboratory examination. Notes should be made in the zooplankton journal on the observed sample species composition and relative abundance.
- When the colonial rotifer *Conochilus* is present in the plankton, mean colony size will be determined by counting the number of individuals per colony from 10 colonies randomly chosen from the qualitative live-sample directly upon return to the laboratory. Each colony will be isolated in separate wells in a 24-well tissue-culture plate with ethanol added to dissociate them and all individuals will then be counted (Gilbert and Burns 2000).
- Once at the laboratory all samples are transferred to the dedicated sample refrigerator

Sample Labeling

Each sample will be labeled with the following unique identifier:

XyymmddS#R#

Where X = Lake (C for Crescent)
yy = year (2 digit)
mm = month (2 digit)
dd = day (2 digit)
S# = Station #
R# = Replicate #

Sample Processing

Use the *Zooplankton Enumeration Form* (**Appendix 2: Data Forms**) to record species and counts.

Use Excel spreadsheet ZOOP_ALIQUOT.XLS to examine the standard error criterion for determining number of aliquots to count.

1. Concentrate sample using a 64 µm sieve and bring to a standard volume (e.g. 20, 50 or 100 ml) depending upon the abundance of organisms in the sample.
2. Thoroughly mix sample (in 150 ml Ehrlenmeyer flask) and draw an aliquot (1 or 2 ml) using a wide-bore Hensen-Stempel pipet.
3. Place aliquot in Ward Counting Wheel and enumerate all organisms under 25X on the dissecting microscope using the labeled bank of click-counters.
4. Continue counting aliquots until the standard error of the total number of organisms per aliquot is less than 10% of the mean (standard error = standard deviation/ $\sqrt{n}$, where n = number of grid squares counted). Count a minimum of 3 aliquots and ensure that at least 150 of the dominant taxon are counted. After each aliquot, enter the total number of organisms counted into the ZOOP_ALIQUOT.XLS spreadsheet to determine when enough aliquots have been sampled.
5. Examine the entire sample in a glass Petri dish to count all *Leptodora* or other large, mobile zooplankton. Counts for the organisms are qualitative, since the capture device is inadequate to quantitatively estimate their abundance.
6. Record all counts on the *Zooplankton Enumeration Form*.
7. Save the first 20 daphnids encountered from each sample. Photograph each using the stage micrometer. Identify each daphnid to species and use Image-Pro Express software to measure the length of each.
8. Upon completion of sample processing, enter all count data into the ZOOPLANKTON.MDB *Access* database to calculate zooplankton densities. Store

Acid Lugol's Recipe

Below is the standard recipe for Acid Lugol's solution (Edmondson 1959, Forbes and Stewart 2002). Lugol's should be stored refrigerated (5ºC) in an amber or foil-wrapped bottle to protect from light degradation.

- 10 g iodine
- 20 g potassium iodide
- 20 g glacial acetic acid
- 200 ml distilled water

Literature Cited

Bade, D., J. Houser, and S. Scanga, editors. 1998. Methods of the cascading trophic interactions project. Fifth edition. Center for Limnology, University of Wisconsin, Madison.

Brandlova, J., Z. Brandl, and C. H. Fernando. 1972. The Cladocera of Ontario with remarks on some species and distribution. Canadian Journal of Zoology 50: 1373–1403.

Brooks, J. L. 1957. The systematics of North American *Daphnia*. Memoirs of the Connecticut Academy of Arts and Sciences 13:1-180.

Downing, J. A., and F. H. Rigler (eds.). 1984. A manual on methods for the assessment of secondary productivity in fresh waters. Second edition. Blackwell Scientific Publications. Oxford, England.

Edmondson, W. T. (ed.). 1959. Freshwater biology. 2nd edition. John Wiley and Sons. New York, New York.

Gilbert, J. J., and C.W. Burns. 2000. Day and night vertical distributions of Conochilus and other zooplankton in a New Zealand reservoir. Verh. Int. Ver. Limnol 27:1909-1914.

Koste, W. 1978. Rotatoria. Die Rädertiere Mitteleuropas. Borntraeger, Berlin, Stuttgart, Germany.

Sandercock, G. A., and G. G. E. Scudder. 1994. An introduction and key to the freshwater calanoid copepods (Crustacea) of British Columbia. Department of Zoology, University of British Columbia, Vancouver, B.C.

Stemberger, R. S. 1979. A guide to rotifers of the Laurentian Great Lakes. EPA 600/4-79-021. U. S. Environmental Protection Agency, Cincinnati, Ohio. Available from http://nepis.epa.gov (accessed 3 April 2013).

Thorp, J. H., and A. P. Covich. 1991. Ecology and classification of North American freshwater invertebrates. Academic Press. San Diego, California.

Wetzel, R. G., and G. E. Likens. 2000. Limnological analyses, Third Edition. Springer-Verlag, New York, New York.

Standard Operating Procedure (SOP) 5. Alkalinity

Revision History Log

Revision Date	Author	Changes Made	Reason for Change
9/21/2006	S.C. Fradkin	Minor addition of pH meter and QA/QC detail.	Response to peer review

Introduction

This SOP measures alkalinity in the lab with a Hach Digital Titrator (model 16900) using the Phenolphthalein and Total Method. This method measures alkalinity in the range of 10 to 4000 mg/L as $CaCO_3$. The SOP below and SOP 9 (Quality Assurance and Quality Control) are modified slightly from the Hach Digital Titrator manual (catalog number 16900-08).

Equipment Needed

- 8 liter Van Dorn bottle
- 500 ml amber wide-mouth Nalgene HDPE bottles
- 1 liter Nalgene bottles
- pH meter (i.e. Orion 200)
- Hach alkalinity kit and reagents as follows:

Description	**Unit**	**Cat. No**
Digital Titrator	each	16900-01
Flask, Erlenmeyer, 250-mL	each	505-46
Cylinder, graduated, 100-mL	each	508-42
Reagents	**Unit**	**Cat. No**
Alkalinity Reagent Set (about 100 tests)		22719-00
Includes: (1) 942-99, (1) 943-99, (1) 14388-01, (1) 14389-01		
Bromcresol Green-Methyl Red Powder Pillows	100/pkg	943-99
Phenolphthalein Powder Pillows	100/pkg	942-99
Sulfuric Acid Titration Cartridge, 1.600 N	each	14389-01
Sulfuric Acid Titration Cartridge, 0.1600 N	each	14388-01
Water, deionized	4 L	272-56

Collection of the Water Sample

1. Water samples in Lake Crescent will be collected in each of the deep water basins (Stations 2 and 4). Water samples will be collected in the epilimnion, metalimnion and hypolimnion at 1 m, 40 m and 140 m depths respectively
2. Water samples will be collected using a horizontal Van-Dorn water sampler.
3. Prior to collection, the collection bottle should be washed profusely with water from the collection site.
4. Once the Van Dorn bottle is deployed to depth, a weighed messenger attached to the line will trigger the device closed. The water-filled device is then retrieved to the surface, where approximately 1 liter is decanted into acid-washed Nalgene HDPE bottles and stored in a cooler for transport back to the laboratory on shore.

NPS laboratory Processing of Unfiltered Water Samples for Alkalinity

This procedure is adapted from the Hach Digital Titrator manual (catalog number 16900-08).

1. Select the sample volume and Sulfuric Acid (H2SO4) Titration Cartridge corresponding to the expected alkalinity concentration as mg/L calcium carbonate (CaCO3) from Table SOP 5.1.
2. Insert a clean delivery tube into the titration cartridge. Attach the cartridge to the titrator body. See *General Description, Step-by-Step* for assembly instructions, if necessary.
3. Turn the delivery knob to eject a few drops of titrant. Reset the counter to zero and wipe the tip.
4. Use a graduated cylinder or pipet to measure the sample volume from Table SOP 5.1. Transfer the sample into a clean 250-mL Erlenmeyer flask. Dilute to about the 100-mL mark with deionized water, if necessary.

Table SOP 5.1. Titration sample volumes and cartridge selection.

Range (mg/L as CaCO3)	Sample Volume (mL)	Titration Cartridge (H2SO4)	Catalog Number	Digit Multiplier
10–40	100	0.1600	14388-01	0.1
40–160	25	0.1600	14388-01	0.4
100–400	100	1.600	14389-01	1.0
200–800	50	1.600	14389-01	2.0
500–2,000	20	1.600	14389-01	5.0
1,000–4,000	10	1.600	14389-01	10.0

5. Add the contents of one Phenolphthalein Indicator Powder Pillow and swirl to mix. ***Note:*** *A solution of one pH 8.3 Buffer Powder Pillow and one Phenolphthalein Powder Pillow in 50 mL of deionized water is recommended as a comparison for determining the proper end point color .**Note:** Four drops of Phenolphthalein Indicator Solution may be substituted for the Phenolphthalein Indicator Powder Pillow.*

6. If the solution turns pink, titrate to a colorless end point. Place the delivery tube tip into the solution and swirl the flask while titrating with sulfuric acid. Record the number of digits required. ***Note:*** *If the solution is colorless before titrating with sulfuric acid, the Phenolphthalein (P) Alkalinity is zero; proceed with step 8.*
7. Calculate: Digits Required x Digit Multiplier = mg/L CaCO3 P Alkalinity.
8. Add the contents of one Bromcresol Green-Methyl Red Indicator Powder Pillow to the flask and swirl to mix. ***Note:*** *Four drops of Methyl Purple Indicator Solution may be substituted for the Bromcresol Green-Methyl Red Indicator Powder Pillow. Titrate from green to a gray end point (pH 5.1 using the Orion 200 pH Meter).* ***Note:*** *Four drops of Bromcresol Green-Methyl Red Indicator Solution may be substituted for the Bromcresol Green-Methyl Red Indicator Powder Pillow.*
9. Continue the titration with sulfuric acid to a light greenish blue-gray (pH 5.1), a light violet-gray (pH 4.8), or a light pink (pH 4.5) color, as required by the sample composition; see Table SOP 5.2. Record the number of digits required. ***Note:*** *A solution of one Bromcresol Green-Methyl Red Powder Pillow and one pillow of the appropriate pH buffer in 50 mL of deionized water is recommended as a comparison for judging the proper end point color. If the pH 3.7 end point is used, use a Bromphenol Blue Powder Pillow instead of a Bromcresol Green-Methyl Red and titrate to a green end point.*
10. Calculate: Total Digits Required x Digit Multiplier = mg/L as CaCO3 Total (T or M) Alkalinity ***Note:*** *Carbonate, bicarbonate and hydroxide concentrations may be expressed individually using the relationships shown in Table SOP 5.3.* ***Note:*** *meq/L Alkalinity = mg/L as CaCO3 ÷ 50.*

Table SOP 5.2. pH endpoints for different alkalinity waters.

Sample Composition	End Point
Alkalinity about 30 mg/L	pH 4.9
Alkalinity about 150 mg/L	pH 4.6
Alkalinity about 500 mg/L	pH 4.3
Silicates or Phosphates present	pH 4.5
Industrial waste or complex system	pH 4.5

Sampling and Storage

Collect samples in clean plastic or glass bottles. Fill completely and cap tightly. Avoid excessive agitation or prolonged exposure to air. Samples should be analyzed as soon as possible after collection but can be stored at least 24 hours by cooling to 4 ºC (39 ºF) or below. Warm to room temperature before analyzing.

Alkalinity Relationship Table

Total alkalinity primarily includes hydroxide, carbonate and bicarbonate alkalinities. The concentration of these alkalinities in a sample may be determined when the phenolphthalein and total alkalinities are known (see Table SOP 5.3).

Table SOP 5.3. Alkalinity relationships

Row	Result of Titration	Hydroxide is equal to:	Alkalinity is equal to:	Carbonate Alkalinity
1	Phenolphthalein Alkalinity = 0	0	0	Total Alkalinity
2	Phenolphthalein Alkalinity equal to Total Alkalinity	Total Alkalinity	0	0
3	Phenolphthalein Alkalinity less than one half of Total Alkalinity	0	2 times the Phenolphthalein Alkalinity	Total Alkalinity minus two times Phenolphthalein Alkalinity
4	Phenolphthalein Alkalinity equal to one half of Total Alkalinity	0	Total Alkalinity	0
5	Phenolphthalein Alkalinity greater than one half of Total Alkalinity	2 times the Phenolphthalein minus Total Alkalinity	2 times the difference between Total and Phenolphthalein Alkalinity	0

To use Table SOP 5.3 follow these steps:

a. Does the phenolphthalein alkalinity equal zero? If yes, use Row 1.

b. Does the phenolphthalein alkalinity equal total alkalinity? If yes, use Row 2.

c. Multiply the phenolphthalein alkalinity by 2.

d. Select Row 3, 4, or 5 based on comparing the result of *step c* with the total alkalinity.

e. Perform the required calculations in the appropriate row, if any.

f. Check your results. The sum of the three alkalinity types will equal the total alkalinity.

For example:

A sample has 170 mg/L as CaCO3 phenolphthalein alkalinity and 250 mg/L as CaCO3 total alkalinity. What is the concentration of hydroxide, carbonate and bicarbonate alkalinities?

The phenolphthalein alkalinity does not equal 0 (it is 170 mg/L); see *step a*.

The phenolphthalein alkalinity does not equal total alkalinity (170 mg/L vs. 250 mg/L); see *step b*.

The phenolphthalein alkalinity multiplied by 2 = 340 mg/L; see *step c*.

Because 340 mg/L is greater than 250 mg/L, select Row 5; see *step d*.

The hydroxide alkalinity is equal to: (see *step e*).

340 – 250 = 90 mg/L hydroxide alkalinity

The carbonate alkalinity is equal to:

250 – 170 = 80
80 x 2 = 160 mg/L carbonate alkalinity

The bicarbonate alkalinity equals 0 mg/L.

Check: (see *step f*).

90 mg/L hydroxide alkalinity + 160 mg/L carbonate alkalinity +
0 mg/L bicarbonate alkalinity = 250 mg/L

The above answer is correct; the sum of each type equals the total alkalinity.

Quality Assurance/Quality Control Procedure

The accuracy of this Hach Alkalinity procedure is ±5% or 1 mg/l while the precision is ±3% or 0.6 mg/l.

Accuracy Check

Standard Additions Method

This accuracy check should be performed when interferences are suspected or to verify analytical technique.

1. Snap the neck off an Alkalinity Standard Solution Voluette® Ampule, 0.500 N.
2. Use a TenSette® Pipet to add 0.1 mL of standard to the sample titrated in Steps 6 or 9. Resume titration back to the same end point. Record the number of digits needed.
3. Repeat, using two more additions of 0.1 mL. Titrate to the end point after each addition.
4. Each 0.1 mL addition of standard should require 25 additional digits of 1.600 N titrant or 250 digits of 0.1600 N titrant.

Interferences

- Highly colored or turbid samples may mask the color change at the end point. Use a pH meter for these samples.
- Chlorine may interfere with the indicators. Add one drop of 0.1N Sodium Thiosulfate to eliminate this interference.

Summary of Method

The sample is titrated with sulfuric acid to a colorimetric end point corresponding to a specific pH. Phenolphthalein alkalinity is determined by titration to a pH of 8.3, as evidenced by the color change of phenolphthalein indicator, and indicates the total hydroxide and one half the

carbonate present. M (methyl orange) or T (total) alkalinity is determined by titration to a pH between 3.7 and 5.1, and includes all carbonate, bicarbonate and hydroxide.

Standard Operating Procedure (SOP) 6.
Water Chemistry

Revision History Log

Revision Date	Author	Changes Made	Reason for Change
9/21/2006	S.C. Fradkin	Addition of bottle labeling, filter blanks and misc. QA/QC detail.	Response to peer review

Introduction

This SOP measures describes the sampling and NPS laboratory processing of water samples prior to being shipped off to the offsite analytical laboratory for water chemistry analysis. The chemical parameters measured in these samples are: ammonia, nitrate + nitrite, total nitrogen, total phosphorus, orthophosphate, in addition to cations (sodium, potassium, calcium, magnesium) and anions (chloride, sulfate).

Equipment Needed

- 8-liter Van Dorn bottle
- 500 ml amber wide-mouth Nalgene HDPE bottles
- 1-liter Nalgene bottles
- Whatman GF/F filters
- 0.5 N hydrochloric acid Bath
- Ample deionized water

Standard Operating Procedure

A. Preparation of filters, Amber wide-mouth Nalgene high-density polyethylene (HDPE) bottles, and filtration apparatus.

   a. Sample bottle labeling

      i. Each sample bottle will be labeled with the following unique identifier:

         XyymmddS#D#ff

         Where X = Lake (C for Crescent)

         yy = year (2 digit)

         mm = month (2 digit)

         dd = day (2 digit)

         S# = Station #

D# = depth (m)
ff = filtered/unfiltered (FF or UF)

b. Filters
   i. Prepare a relatively contaminant-free space for cleaning and drying the cleaning supplies, sample-collection, and sample-processing equipment. This space should also be free of methanol and other organic compounds that potentially could contaminate apparatus to be used for the collection of dissolved organic carbon samples.
   ii. The 0.7 µm glass-fiber filters (Whatman GF/F) used to filter water for the analysis of nutrients should be pre-washed and dried in a drying oven at 60º C before use.
   iii. Pre-washed filters should always be handled with clean forceps.

c. Amber wide-mouth Nalgene HDPE bottles
   i. Bottles should be acid washed prior to use. Bottles should be filled with 0.5 N hydrochloric acid and allowed to sit for 24 hours. Lids and filtering equipment should be soaked for 24 hours in 0.5 N hydrochloric acid. The bottles are then emptied and filled with deionized water and allowed to sit for 24 hours. Lids and filtering equipment are soaked in deionized water for 24 hours. The deionized water rinse is repeated. Bottles are then emptied, lids and filtering equipment are removed from their soaking tub, and rinsed continuously for 8 minutes with deionized water. Bottles, lids and filtering equipment are allowed to air-dry.
   ii. Lids should be secured to bottles and not opened until used in the field.

B. Collection of the water sample
   a. Water samples in Lake Crescent will be collected in each of the deep water basins (Stations 2 and 4). Water samples will be collected in the epilimnion, metalimnion and hypolimnion at 1 m, 40 m and 140 m depths respectively
   b. Water samples will be collected using a horizontal Van-Dorn water sampler.
   c. Once the Van Dorn bottle is deployed to depth, a weighed messenger attached to the line will trigger the device closed. The water-filled device is then retrieved to the surface. The collection bottle should be rinsed profusely with water from the collection depth prior to filling with 1 liter of sample water. The samples are then stored in a cooler for transport back to the laboratory on shore.

C. Laboratory processing filtered water for water chemistry:
   a. Once back at the laboratory, water collected for water chemistry is filtered through a pre-washed 0.7 µm glass-fiber filter (Whatman GF/F), using a 500 ml stand-alone Nalgene polysulfone filtering setup with a hand pump.
   b. Always place the filter (rough side up) in the filtering apparatus using clean forceps.

c. Before processing the sample, pour 25-30 ml of sample into the top chamber of the stand-alone filtering unit. Swirl to rinse sides of chamber and discard water. Repeat.

d. Pour another 25-30 ml of sample into top chamber of filtering apparatus and, using the hand pump, filter water into the lower chamber of filtering apparatus. Swirl to rinse bottom chamber and discard. Repeat.

e. **Never pour or rinse the bottom chamber of the stand-alone unit with unfiltered water. Use only filtered water to rinse the bottom chamber and sample collection bottle.**

f. Fill the top chamber with 250-500 ml of sample water and pump water through the filter. When water has been filtered, pour a small amount (i.e. 25-30 ml) of the filtered water into an acid-washed 250 or 500 ml wide-mouth amber HDPE sample storage bottle. Rinse bottle and discard water. Repeat.

g. Fill sample bottle leaving enough air to allow expansion of water as it freezes.

h. Immediately freeze sample bottle and store frozen until samples are shipped on dry ice to the off-site laboratory for processing (within 7 days of collection).

i. Take filter apparatus apart and discard filter.

j. Acid wash filter apparatus.

D. Field Blanks and Duplicates

a. On each quarterly sampling date a replicate sample will be collected for nutrient and anion/cation analysis.

b. On each quarterly sampling date a field blank will also be collected for nutrient and anion/cation analysis. Field blank samples will be used to test for possible contamination of samples from collection, processing, cleaning, storage, and analysis procedures. Field blank samples are deionized water that contain no detectable nutrient concentrations. The blank water is processed through the sampling equipment and handled and analyzed in the same manner as the field samples.

c. On each quarterly sampling a filter blank will be collected for nutrient and anion/cation analysis. Filter blank samples will be used to test for the possibility of contaminated filters. Filter blank samples are deionized water that contains no detectable nutrient concentrations. Deionized water is filtered in the lab without passing through the sampling equipment.

Standard Operating Procedure (SOP) 7.
Lake Level

Revision History Log

Revision Date	Author	Changes Made	Reason for Change
6/1/2006	S.C. Fradkin	Original	

Equipment Needed

- Instrumentation Northwest PS-9805 Submersible Pressure/Temp Transducer
- Campbell Scientific CR10X datalogger
- Staff gage

Instrumentation

Lake level will be automatically recorded using a submergible pressure transducer attached to a Campbell Scientific CR10X datalogger.

The pressure transducer is attached to a fixed object (such as a piling) in the lake at a submerged depth well below the lowest lake level. This level is then surveyed in to a permanent reference marker on the shoreline for long term reference. As an additional reference point, a permanent staff gage is mounted adjacent to the transducer with the zero mark at the same level as the transducer.

Lake level data will be recorded by the datalogger at 5 minute intervals and stored as averaged hourly values. While the instrument has resolution and accuracy to 0.1 mm, data will be recorded and analyzed at a resolution of .01 meters.

Lake level data will be manually recorded by Park staff on a weekly basis, using the reference staff gage. This will allow for QA/QC of transducer values over time and ensure some data continuity in the case of an instrument failure.

Table SOP 7.1. Lake level and temperature/sensor performance standard: Instrumentation Northwest PS-9805 submersible pressure/temperature transducer.

Parameter	Units	Accuracy	Depth Range	Resolution
Lake Level	0.01 m	+/-0.03 m*	0 to 3.52 m	0.1 mm
Water Temperature	ºC	+/-0.3º C	-5º C to 70º C	0.1º C

*Accuracy based on instrument rating of +/-0.1% FSO (full span operation is 5 PSI or 3.54 meters)

Instrument Maintenance

A site visit to inspect instrumentation will occur every 3 months. This will include

- Collect and archive all uncollected data.
- Monitor lake level as recorded by instrument and compare to the reference staff gage.
- Inspect the desiccant tube on the transducer cable. If desiccant is no longer bright blue (i.e. saturated), desiccant is replaced to ensure moisture does not foul pressure measurements.

Instrument Calibration

To compensate for instrument drift, the transducer will be factory calibrated every 2 years. If small scale drift is found during shorter periods, an offset value based on the permanent reference may be calculated and used to correct the lake level value.

The CR10x Datalogger will be factory calibrated every 4 years.

Standard Operating Procedure (SOP) 8. Recommended Data Analyses

Revision History Log

Revision Date	Author	Changes Made	Reason for Change
9/21/2006	S.C. Fradkin	Addition of info on trend testing and response variables of measured parameters	Response to peer review

Introduction

This SOP discusses the approach that will be used in data handling, summary analyses and analyses of trends in the limnological data collected for this protocol. Issues associated with the statistical analysis of limnological time series have been considered in both the water resources and the ecological literature (Stow et al. 1998). While some have argued the utility of distribution-based parametric analyses for limnological data (Carpenter et al. 1989), a large literature exists recommending the use of non-parametric analyses, given that most limnological time series deviate from the normal distribution (Reckhow et al. 1993, Jassby 1996, Griffith et al. 2001, Helsel and Hirsch 2002, McBride 2005). This protocol will use non-parametric analyses for long-term trend analyses.

Data Handling: Censored Data and Outliers

Censored Data

Chemical compounds in water frequently occur in concentrations that are not detectable using many standard analytical methods. This inability to quantify chemical concentrations and low levels of certain physical attributes leads to the reporting of data as “less than” values, rather than actual values. For example, in ultra-oligotrophic Lake Crescent, nitrate and other nutrients are often present in the water column at very low levels leading to non-detects (Meyer and Fradkin 2002). These “censored” data are generally not analyzable using parametric statistics; however they can be analyzed by non-parametric procedures that convert values to ranks (McBride 2005).

Measurement quality objectives and Method Detection Limits (MDLs) for the analytical procedures used in this protocol are detailed in SOP 9 (Quality Assurance and Quality Control). Censored data will be managed according the following rules:

- Values below the MDL will be entered into the database as less than the MDL value (<MDL) and flagged as not detected (ND)
- Values above the MDL will be entered into the database as the measured value.

Outlier Data

An outlier is an observation that lies outside of the overall pattern of a distribution of many observations. While outlier observations can often be valid data, outliers are frequently the result of errors, such as equipment error, measurement error, transcription error, or other human error. In this protocol, identified outlier data will be examined to determine whether there is a clear source of error to explain the observation. If such errors are verified, these data will be flagged in the database and removed from any subsequent analyses. Otherwise, outlier data will remain in trend analyses. The non-parametric analyses used in this protocol are resistant to outliers (see below).

Exploratory Data Analyses

Exploratory data analyses will be used to summarize data for the annual report (see **SOP 12: Product Delivery, Posting and Distribution** for the reporting schedule). Exploratory analyses for parameters will consist of computations of descriptive statistics and graphical analyses.

Descriptive Statistics

Measures of Central Tendency

These measures are useful for assessing the average or center value of a group of samples. Standard measures to be determined included: mean, median.

Measures of Dispersion

These measures provide insight into the variability of observations around the center of the distribution. For trend detection the power to detect trends generally decreases with increases in variability. Standard measures of dispersion to be determined include: standard deviation, standard error, variance, coefficient of variation, 95% confidence intervals.

Graphical Analyses

Box-whisker Plots:

These plots are useful for comparing the central value, dispersion and symmetry between different data groups (e.g. stations, months, years). Boxes depict the range of values from the 25th to the 75th percentile, while the line inside is the median (50th percentile). Vertical lines from the box extend up to 1.5 box lengths to the highest and lowest values. Values beyond this are considered outliers. An example appears below in Figure SOP 8.1.

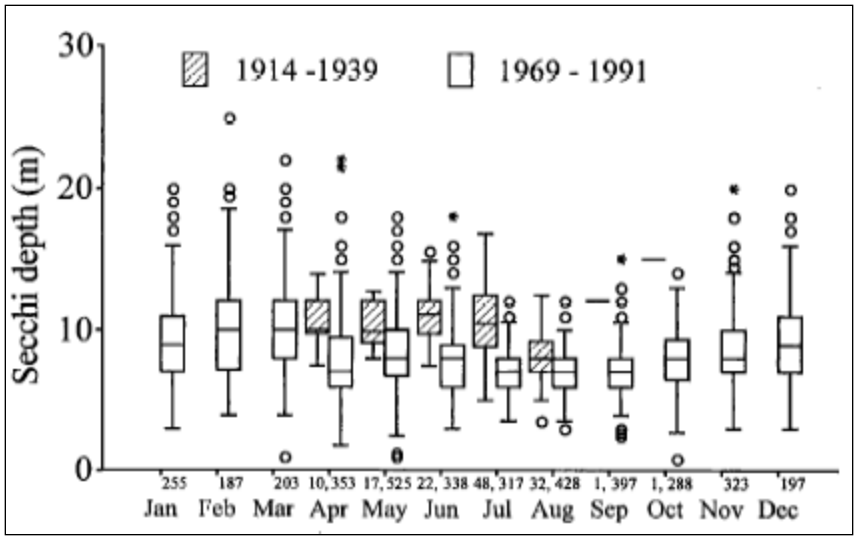


Figure SOP 8.1. Example box-and-whisker plot depicting Secchi depth vs. month comparing two time periods in the Baltic sea (modified from Sanden and Hakansson 1996).

Bivariate Plots

These graphical displays are useful for visually assessing the relationship of a parameter (individual value or mean) vs. time. In the example below (Figure SOP 8.2), a potential trend in decreasing Secchi depth in Lake Tahoe is apparent over the 33-year time series.

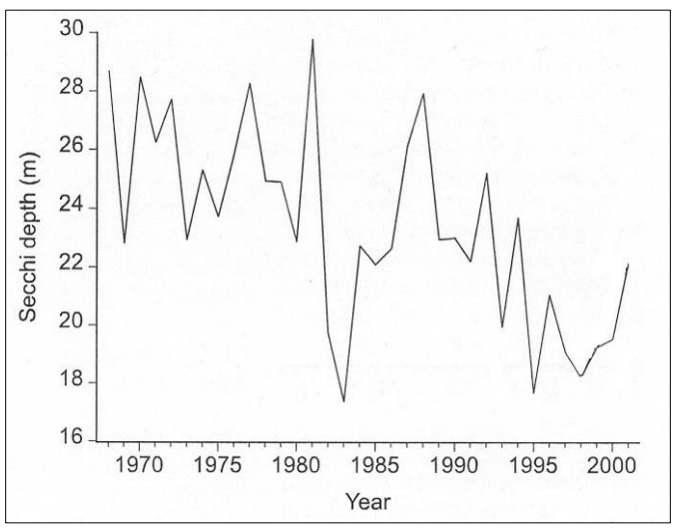


Figure SOP 8.2. Example bivariate plot depicting mean June-September Secchi depth in Lake Tahoe from 1968–2001 (modified from Jassby et al. 2003).

Isopleth Plots

These plots display a parameter (e.g. temperature, chlorophyll-a concentration, etc.) as a function of depth and time. These plots are particularly useful for examining patterns in vertical profile data over time. In the Lake Crescent temperature example below (Figure SOP 8.3), summer stratification of the water column is apparent from July through October.

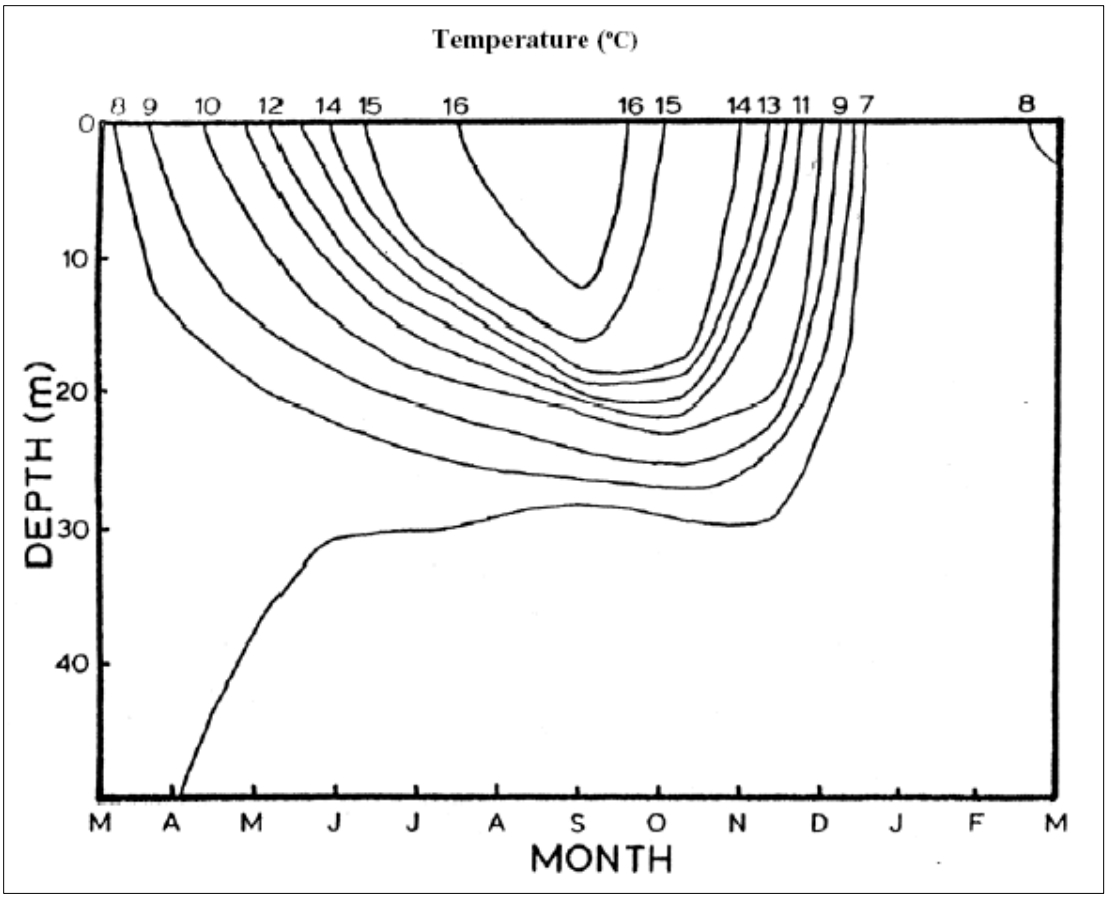


Figure SOP 8.3. Example isopleth diagram illustrating temperature profiles over a year from March 1982 to March 1983 in Lake Crescent, OLYM (modified from Pierce 1984).

Long-term Trend Detection

Routine trend analyses will be conducted on data every 5 years to detect directional change in parameters over time. Trend detection will largely be employed to detect gradual (monotonic) trends, however exploratory data analyses will be employed to determine when testing for abrupt changes is appropriate. In general, trend detection is a function of data variability, sample size, and the responsiveness of indicator parameters (Irwin 2008).

Trend testing of physical/chemical parameters will be conducted on both a seasonal (quarterly) and annual basis. Monthly samples within seasons will be averaged to better estimate seasonal conditions. Seasonal analyses are of interest to determine whether changes are occurring during distinct periods, such as during summer stratification. Annual analyses are of interest to determine long-term trends with seasonality factored out.

For zooplankton, trends in species richness, community species abundance (i.e. correspondence analysis) and the abundance of dominant zooplankton taxa (i.e. *Daphnia rosea*, *Diaptomus tyrelli*, *Conochilus sp.*) will be analyzed.

Monitoring parameters with the specific response variables to analyze in this protocol appear in Table SOP 8.1.

Table SOP 8.1. NCCN Large Lowland Lake monitoring parameters and associated analytic response variables.

Parameters	Response Variable
Biological	
Zooplankton	Species Richness Community Species Abundance Dominant Species Abundance (#/l)
Chlorophyll-a	Mean Concentration (μg/l)
Physical	
Specific Conductivity	Mean Concentration (μS/cm)
Temperature	Mean Temperature (ºC)
Water Clarity	Mean Secchi Depth (m)
Lake Level	Mean Level (m)
Chemical	
Dissolved Oxygen	Mean Concentration (ug/l)
pH	Mean pH
Turbidity	Mean NTU
Alkalinity	Mean Concentration (μeq/l)
Anions and Cations	
Nutrients	Mean Concentration (μg/l)
Ammonia	
Nitrate + Nitrite	
Total Nitrogen	
Total Phosphorus	
Orthophosphate	

Trend Testing for Individual Stations

Lakes exhibit cycles in physical/chemical and biological processes associated with climatic seasonality. Such seasonality is often manifested by changes in water temperature, nutrient profiles, and zooplankton species succession, etc. (Wetzel 2001). Seasonal changes may induce variability that interferes with the detection of longer-term systematic changes. The effect of seasonality must be accounted for in the time series analysis.

The class of non-parametric tests based on the Mann-Kendall test is widely used for trend testing (McBride 2005). These rank-based tests are advantageous because they 1) don't assume normality, 2) are resistant to outliers, and 3) admit censored data because only ranks are used. The basic Mann-Kendall test estimates a robust trend line that is the median slope for the set of lines joining all possible pairs of points in a time series.

The Seasonal Kendall test is a modification of the Mann-Kendall test that accounts for seasonality. In this test the Mann-Kendall test is applied to each season (e.g. month or quarter) separately and then results are combined for an overall test (Hirsch et al. 1982). Thus, each individual season may show insignificant positive trends, yet the overall Seasonal Kendal test

can be significant. Like the Mann-Kendall test, the Seasonal Kendall test is robust to non-normality, outliers, and censored data, and offers higher power by removing short-term variability that would otherwise be viewed as environmental noise. One unfortunate possibility with the Seasonal Kendal test is that trends of the opposite sign in different seasons have the potential to cancel each other out, suggesting that no trend exists. This possibility can be mitigated through careful examination of how seasons are grouped, especially through graphical exploration of seasonal data and through scientific understanding of ecological system.

When seasons are influenced by the previous sequence of seasons, as is often the case for limnological data, such serial dependence must be corrected for by taking into account any covariance among seasons using the Modified Seasonal Kendall test (Hirsch and Slack 1984, McBride 2005).

In this protocol the Modified Seasonal Kendall test will be used to test for monotonic trends in limnological time series data at each station in Lake Crescent. If monotonic trends are detected, the Sen Slope estimator will be used to determine the magnitude of trend. This estimator computes the slope between each pair of points in the data set and uses the median slope as the estimator of magnitude (McBride 2005).

When exploratory data analyses suggest that it is appropriate to test for abrupt changes between two time periods, the Mann-Whitney test will be used to test for significant change. If a significant change is determined, the Hodges-Lehmann estimator will be used to determine the magnitude of the change (Helsel and Hirsch 2002).

Trend Testing for Multiple Stations

Potential lake-wide trends, based on all of the sampling stations within the lake, will be tested for using an additional variant of the Seasonal Kendall Test, referred to as the Spatial Kendall test (Jassby 1996). The Spatial Kendall test is essentially the Seasonal Kendall test where stations are used in place of seasons. Thus, where the Seasonal Kendall test applies the Mann-Kendall test to each season and then the results are combined for an overall test, the Spatial Kendall test applies the Mann-Kendall test to each station and the results are combined for an overall lake-wide test.

Literature Cited

Carpenter, S. R., T. M. Frost, D. Heisey, and T. K. Kratz. 1989. Randomized intervention analysis and the interpretation of whole-ecosystem experiments. Ecology 70:1142–1152.

Griffith, L. M., R. C. Ward, G. B. McBride, and J. C. Loftis. 2001. Data analysis considerations in producing ‘comparable’ information for water quality management purposes. Technical Report 01-01. National Water Quality Monitoring Council, USGS, Reston, Virginia.

Helsel, D., R., and R. M. Hirsch. 2002. Statistical methods in water resources. USGS Techniques of water investigations. Book 4, Chapter A3. U.S. Geological Survey, Reston, Virginia. Available from http://water.usgs.gov/pubs/twri/twri4a3/ (accessed 27 March 2011).

Hirsch, R. M., and J. R. Slack. 1984. A non-parametric trend test for seasonal data with serial dependence. Water Resources Research 20:727–32.

Hirsch, R. M., J. R. Slack, and R. A. Smith. 1982. Techniques of trend analysis for monthly water quality data. Water Resources Research 18(1):107–121.

Irwin, R. 2008. Draft part B lite QA/QC review checklist for aquatic vital sign monitoring protocols and SOPs, National Park Service, Water Resources Division, Fort Collins, Colorado. Available at http://www.nature.nps.gov/water/Vital_Signs_Guidance/Guidance_Documents/PartBLite.pdf (accessed 27 March 2011).

Jassby, A. D. 1996. Methods for analysis of spatial and temporal patterns. A special study of the San Francisco Estuary Regional Monitoring Program. RMP Contribution 18. Available at http://www.sfei.org/rmp/reports/patterns/patterns.html.

Jassby, A. D., J. E. Reuter, and C. R. Goldman. 2003. Determining long-term water quality change in the presence of climate variability: Lake Tahoe (U.S.A). Canadian Journal of Fisheries and Aquatic Sciences 60:1452–1461.

McBride, G. B. 2005. Using statistical methods for water quality management: Issues, problems and solutions. Wiley-Interscience, Hoboken, New Jersey.

Meyer, J., and S. C. Fradkin. 2002. Summary of fisheries and limnological data for Lake Crescent, Washington. Olympic National Park, Natural Resource Management Division, Port Angeles, Washington.

Pierce, B. E. 1984. The trouts of Lake Crescent, Washington. MS thesis, Colorado State University, Fort Collins, Colorado.

Reckhow, K. J., K. Kepford, and W. W. Hicks. 1993. Methods for the analysis of lake water quality trends. EPA 841-R-93-003. Environmental Protection Agency, Washington, D.C.

Stow, C. A., S. R. Carpenter, K. E. Webster, and T. M. Frost. 1998. Long-term environmental monitoring: Some perspectives from lakes. Ecological Applications 8:269–276.

Wetzel, R. G. 2001. Limnology: Lakes and river ecosystems. Academic Press. London.

Standard Operating Procedure (SOP) 9. Quality Assurance and Quality Control

Revision History Log

Revision Date	Author	Changes Made	Reason for Change
Jan 2009	S.C. Fradkin	---	Original
Jan 2010	S.C. Fradkin	Minor clarifications	Peer-review revisions

Introduction

Ensuring that high quality data are collected, analyzed and archived is of vital importance to NPS long-term ecological monitoring. This SOP describes procedures for quality assurance and quality control (QA/QC) for the Large Lowland Lakes Monitoring Protocol. Many aspects of QA/QC for this protocol are discussed in the protocol narrative and also in descriptions of specific SOPs.

Target Population, Representativeness and Completeness

The target population for this protocol is that of a single large lowland lake, Lake Crescent (OLYM). Using standard procedures detailed in this section, limnological parameters will be monitored at monthly or quarterly intervals at 5 deep water stations in Lake Crescent. The 5 stations were non-randomly chosen to represent each major deepwater basin (2 stations) and each major sub-basin (3 stations). From these 5 stations, vertical profile data will be used to characterize the water column of the lake. There is no *a-priori* reason to suspect that the water column of these fixed stations acts any differently from the water column overlaying deep water anywhere else in the respective lake basins. This protocol examines only the pelagic zone of the lake, thus any conclusions drawn from these data will have direct relevance only to the pelagic zone and not to the littoral zone or benthic sediments. In summary, the target population of this protocol is the pelagic zone on Lake Crescent, and is representative of only Lake Crescent, although data may have relevance to phenomena observed in other large lowland lakes of the Pacific Northwest. The completeness of the data is defined by the limitations of the spatial and temporal nature of the data collection, i.e. monthly sampling at fixed stations as opposed to continuous sampling at a multitude of random stations.

Data Comparability

Upon NPS acceptance for implementation, changes or alterations to sampling procedures and methods will be kept to a minimum to assure comparability of data over the long term (i.e. >30 yrs). If new sampling procedures are implemented, these will be phased in for a concurrent period with the old sampling procedures so that conversions or correlations between data from the two procedures can be determined.

While this program is not specifically designed to be comparable with other monitoring programs, it is desirable to have its data be comparable to similar data collected in other programs for comparative purposes and for use in regional/national surveys. As such, it is crucial to ensure consistency in both field and laboratory methods. Different procedures and analytical labs can produce different results, thus we have chosen sample collection and analysis methods that are standard methods and are similar or identical to other NPS monitoring programs in the region. We have also chosen a stable, tested analytical lab (CCAL) that is used by NCCN research programs, other NCCN long term monitoring programs (e.g. Hoffman et al. 2005), and by research programs of other regional agencies (e.g. USGS-WRD) and academic programs (Oregon State University). The water chemistry methods used here are similar to those used by other NPS long-term monitoring programs (e.g. Hoffman et al. 2005) and research programs by other agencies (e.g. USGS-WRD). Thus data from this protocol may be used in broader scale analyses.

Measurement Quality Objectives

The analytical laboratory that will be processing all off site water chemistry analyses for this protocol is the Oregon State University Cooperative Chemical Analytical Laboratory (CCAL). SOPs and associated QA/QC procedures, including the practical range of determination and the method detection limit, for each procedure performed by this laboratory can be found at http://www.ccal.oregonstate.edu/qaqc.htm.

As part of a joint research project between OLYM and the USGS-WRD to construct a nutrient budget of Lake Crescent, 181 total nitrogen (TN) samples, 173 total phosphorus (TP) samples, and 166 nitrate samples were analyzed by the CCAL lab during 2006-2007. Of these samples, 9.4% of the TN and 6.9% of the TP samples were below the CCAL Method Detection Limit (MDL). For nitrate, a highly labile nutrient in oligotrophic systems, 49% of the samples were below the MDL. Monitoring data from Lake Crescent is expected to be similar to the 2006-2007 data. This low to moderate level of censored data should not hamper our ability to conduct trend analyses (Helsel 2005, McBride 2005).

For parameters measured in the field or in the OLYM laboratory, the measurement quality objectives appear in Table SOP 9.1.

Table SOP 9.1. Measurement quality objectives for parameters measured at OLYM.

Parameter	Instrument	Measurement Systematic Error	Method Detection Limit (MDL)	Practical Range of Determination
Chlorophyll-a	YSI 6025 probe		0.10	0 to 400 mg/l
Conductivity	YSI 6560 probe	± 0.5%	0.001 mS/cm to 0.1 mS/cm	0 to 100 mS/cm
Depth	YSI 6600 sonde	± 0.3 m	0.001 m	0 to 200 m
Dissolved Oxygen	YSI 6562 probe	± 2.0%	0.01 mg/l	0 to 50 mg/l
pH	YSI 6561 probe	± 0.2 units	0.01 units	0 to 14 units
Temperature	YSI 6560 probe	± 0.15ºC	0.01ºC	-5 to 45ºC
Turbidity	YSI 6026 probe	± 2 NTU	0.10 NTU	0 to 1,000 NTU
Alkalinity	Hach Digital	± 1%		10–4,000 as mg/L $CaCO_3$
Lake Level	InstNW PS-9805	± 0.03 m	0.10 mm	0 to 3.52 m
Temperature	InstNW PS-9805	± 0.3ºC	0.01ºC	-5 to 70ºC

Literature Cited

Helsel, D. R. 2005. Non-detects and data analysis: Statistics for censored environmental data. Wiley, New York, New York.

Hoffman, R. L., T. J. Tyler, G. L. Larson, M. J. Adams, W. Wente, and S. Galvan. 2005. Sampling protocol for monitoring abiotic and biotic characteristics of mountain ponds and lakes. U.S. Geological Survey Techniques and Methods 2-A2. U.S. Geological Survey, Reston, Virginia. Available from http://pubs.usgs.gov/tm/2005/tm2a2/ (accessed 27 March 2011).

McBride, G. B. 2005. Using statistical methods for water quality management: Issues, problems and solutions. Wiley-Interscience, Hoboken, New Jersey.

Standard Operating Procedure (SOP) 10. Managing Photographic Images

Revision History Log

Revision Date	Author	Changes Made	Reason for Change
6.1.2006	J. Boetsch S.C. Fradkin	Original	
Feb 2012	J. Boetsch S.C. Fradkin	Changes to post-season cleanup procedure	Update and Clarification

Introduction

This SOP describes procedures for downloading, processing and naming photographic images collected by project staff or volunteers during the course of conducting project-related activities. Images that are acquired by other means – e.g., downloaded from a website or those taken by a cooperating researcher – are not project records and should be stored separately and named in such a way that they can be readily identified as non-NPS images and not be mistaken for project records.

To effectively manage potentially hundreds of images requires a consistent method for downloading, naming, editing and documenting. The general process for managing project images is as follows:

A. Prepare image workspace – set up the folder directory structure for images prior to acquisition.
B. Acquire images.
C. Download and process images.
    1. Download the files from the camera
    2. Rename the image files according to convention
    3. Copy and store the original, unedited versions
    4. Review and edit the photos; delete unneeded or poor quality photos
    5. Move the files into appropriate folders for storage
D. Deliver image files for final storage.

Data Photos Defined

Care should be taken to distinguish data photographs from incidental or opportunistic photographs taken by project staff. Data photographs are those taken for the following reasons:

- To document a particular feature or perspective for the purpose of site relocation
- To capture site characteristics and possibly to document gross structural changes over time

- To document a species detection that is also recorded in the data

Data photographs are often linked to specific records within the database, and are stored in a manner that permits the preservation of those database links. Other photographs – e.g., showing field crew members at work, or documenting the morphology of a particular species – may also be retained but are not necessarily linked with database records.

Image Workspace Setup

Prior to each season, the Project Lead (or a designee) should create a new set of image folders beginning with the new season year, under the Images section of the project workspace and seasonal workspaces (refer to **SOP 11: Project Workspace and Records Management**). The workspace subfolders are as follows:

[Year]	The appropriate year – 2011, 2012, etc.
[Park code]	Arrange files by park – OLYM, etc.
1_Originals	Unedited versions of image files
[Download date]	Arranged by download date to preserve file names
2_Processing	Temporary processing workspace
[Site_code]	Arranged by site, for images taken at a site
[Capture date]	Arranged by date, for images not taken at a site
3_Data	Data images
[Site_code]	Arranged in subfolders by site
4_Miscellaneous	Non-data images taken by project staff
[Site_code]	Arranged by site, for images taken at a site
[Capture date]	Arranged by date, for images not taken at a site
5_Not_NPS	Images acquired from other sources

This folder structure permits data images to be stored and managed separately from non-record and miscellaneous images collected during the course of the project. This structure also provides separate space for image processing and storage of originals. For additional information about the project workspace, refer to **SOP 11: Project Workspace and Records Management**.

In all cases, folder names should follow these guidelines:

- No spaces or special characters in the folder name.
- Use the underbar ("_") character to separate words in folder names.
- Try to limit folder names to 20 characters or fewer.
- Date names should be formatted as YYYYMMDD.

Image Acquisition Standards

Capture images at an appropriate resolution that balances space limitations with the intended use of the images. Although photographs taken to facilitate future navigation to the site do not need to be stored at the same resolution as those that may be used to document gross environmental change at the site, it may be more efficient to capture all images at the same resolution initially. A recommended minimum raw resolution is 1600 x 1200 pixels (approximately 2 megapixels). Higher resolutions may be available but are undesirable from the perspective of data storage and information content.

Download and Processing Procedures

1. Under the appropriate "Originals" subfolder, create a subfolder for the download date (e.g., 20120715). Other suffixes may be used to distinguish downloads when multiple sites or parks are downloaded on the same date.
2. Download the raw, unedited images from the camera into the new subfolder. Depending on the operating system used by the person downloading, it may be possible to greatly reduce the time and effort it takes to rename the images in subsequent steps.
   - Plug in the camera to the USB port and turn the camera on.
   - From the Start menu, select All Programs > Accessories > Scanner and Camera Wizard (or select this option if a dialog box appears upon plugging in the camera).
   - Follow screen prompts until reaching the 'Picture Name and Destination' screen. You will be able to select name prefix/suffix, image format, and photo destination.
     - For name prefix, use the naming conventions indicated later in this SOP.
     - For image file format, select the default (JPG).
     - For photo destination, browse to the appropriate "Originals" subfolder.
3. Copy the images to the “Processing” folder and set the contents under "Originals" as read-only by right clicking in Windows Explorer and checking the appropriate box. These originals serve as backups in case of unintended file alterations (e.g., incorrect names applied, file deletion, loss of resolution, or loss of image metadata upon rotation).
4. Finish renaming the images in the "Processing" folder according to convention (refer to the image naming standards section).
   - If image file names were noted on the field data forms, be sure to update these to reflect the new image file name prior to data entry. Field form annotations should be done in a different color ink from the original notation, after first drawing a line through the original entry (for more information, refer to **Section 5.4, Data Entry and Processing**).
   - Renaming may be most efficiently done as a batch using image processing software such as Microsoft Office Picture Manager, which allows a standard prefix or suffix to be added to the camera file name. After batch renaming, a descriptive component may be added manually to each file name.
5. Process the images in the "Processing" folder, using the edit features built into image software programs such as ThumbsPlus or Microsoft Office Picture Manager. At a minimum, the following processing steps should be performed on all image files:
   - Delete photographs of poor quality – e.g., out of focus, poor lighting conditions, etc. Low quality photographs might be retained if the subject is highly unique, or the photo is an irreplaceable data photo.
   - Duplicates should also be deleted unless they provide unique information. Other non-data photographs should be evaluated for their potential long-term value.
   - Rotate images to make the horizon level.
   - Remove 'red eye' glare in photographs of people.
   - Crop non-data images to remove edge areas that grossly distract from the subject.
6. Optional processing steps may include enhancing contrast or brightness, or resizing images to make them small enough for use in documents or on the web. These steps are not recommended for data photos.

7. When finished processing the current download, move the image files that are to be retained to the appropriate folder – i.e., data images to the appropriate "Data" subfolder, other images under the appropriate "Miscellaneous" folder.
8. Photos of potential interest to a greater audience should be uploaded to the NCCN Digital Library.
9. Delete files from the "Processing" folder between downloads to minimize the chance for accidental deletion or overwriting of needed files.

Image File Naming Standards

In all cases, image names should follow these guidelines:

- No spaces or special characters in the file name
- Use the underbar ("_") character to separate file name components
- Try to limit file names to 30 characters or fewer, up to a maximum of 50 characters
- Park code and year should either be included in the file name (preferred), or specified by the parent folders in the directory structure
- Dates should be formatted as YYYYMMDD, as this leads to better sorting than other date naming conventions

The image file name should consist of the following parts:

1. The date on which the image was taken (formatted as YYYYMMDD)
2. Site location
3. Optional file name components:
    - A brief descriptive word or phrase indicating the content of the image
    - A sequential number if multiple images were captured of a given subject
    - Time of image acquisition (formatted as HHMM)

Examples:

- 20090621_BarnesCrk_turbidity_plume.jpg (documents a plume of turbid water entering Lake Crescent from Barnes Creek)
- 20100518_training_004.jpg (4th photo taken during training on May 18, 2010)

Post-season Cleanup Procedures

At the end of the season, field crew members should organize images within the seasonal workspace and notify the Project Lead, after making sure that all processing folders are empty.

After each season, the Project Lead (or a designee) should:

1. Review the seasonal workspace folders to make sure that all images are properly named and filed and accounted for.
2. The "Processing" folder should be empty and may be deleted.
3. Files in the "Not_NPS" folder may be refiled as appropriate.
4. The contents of the "Originals" folder may be deleted once all desired files are accounted for. Originals of data images may be retained as desired, depending on the size of the files and storage limitations. If storage space is limiting, originals may be stored on a local hard drive or external drive.

5. Copy the entire contents of the "Images" subfolder from the seasonal workspace to the main project workspace, and delete the images subfolders from the seasonal workspace.
6. Set the images in the project workspace to read-only to prevent unintended changes.

Standard Operating Procedure (SOP) 11. Project Workspace and Records Management

Revision History Log

Revision Date	Author	Changes Made	Reason for Change
Mar 2009	J. Boetsch	---	Original
Feb 2012	J. Boetsch S.C. Fradkin	Clarifications and updates	Peer-review revisions and updates to current standards

Overview

This SOP describes how and where project files and records are managed by project staff. Workspace structure, naming conventions, and procedures for handling project files are included.

NCCN File Workspace

NCCN has a centralized file system and project workspaces available for use by field crews and project staff at: \\inpolymfs\parkwide\NCCN. This will help avoid the problem of NCCN projects having several versions of files on different servers around the network. These folders are set up so that park and network staff members at the network parks all have read privileges throughout the directory structure. Project leads and a few other individuals associated with each project have full privileges for their project folder so they can manage their own permissions. These workspaces are intended to be a more familiar and convenient way of storing information, as an adjunct to the NCCN SharePoint site. The Project Lead will decide what is to be stored locally in these project workspaces as opposed to on the team SharePoint site. Examples of files kept in these project workspaces include: working files for project field crews, GPS downloads, GIS map files, database files, and other project records.

The NCCN workspace is organized as follows under four main folders: Libraries, Projects, Temp, and Workspace. Project staff members will primarily be working in one or more of the project folders under Projects, and may wish to make desktop shortcuts to one or more of the project subfolders by right-clicking on the desired folder and selecting Send To > Desktop (create shortcut).

Project staff members should create a network shortcut to the project workspace by going to the Desktop in Windows Explorer and adding a new network place under My Network Places. Project staff located at OLYM will typically already have this path available to them via a mapped drive (e.g., the I:\ drive); however, they should still create this network shortcut where multiple parks are concerned for the sake of communications and consistency among parks. Performance is the main rationale for using network shortcuts instead of mapped drives at other parks.

Instructions for creating a network shortcut to the NCCN workspace:

1. Open an instance of Windows Explorer. One way is from the Start menu, go to: All Programs > Accessories > Windows Explorer. Another is to open My Documents, My Computer, or any other folder browser shortcut.
2. Navigate to the Desktop, and then to My Network Places.
3. Double-click the Add Network Place option to open the setup wizard.
4. Choose the option to specify the network location, then under network address, type in: \\inpolymfs\parkwide\NCCN
5. When prompted for a name for the network place, enter "NCCN" (or something similarly brief and meaningful).
6. This network place shortcut should now be available each time you log in to that particular computer, and can be accessed when navigating within most Windows software.

Project Workspace

A section of the NCCN workspace is reserved for this project. The recommended file structure within this workspace is shown in Figure SOP 11.1.

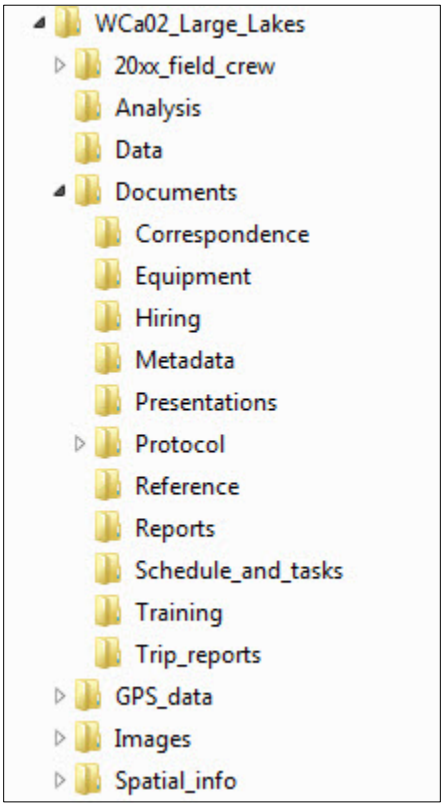


Figure SOP 11.1. Recommended file structure for project workspace. Note: The workspace folder name includes 'WCa02', the NCCN project code.

Each major subfolder is described as follows:

- Analysis – Contains working files associated with data analysis.

- Data – Contains the front-end database application file for the season. The back-end database for the project is maintained in Microsoft SQL Server. Database exports and other intermediate summary information can be stored here as well; these files are most effectively managed within subfolders named by calendar year.
- Documents – Contains subfolders to categorize documents as needed for various stages of project implementation. Additional folders and subfolders may be created as needed to arrange information in a way that is useful to project staff.
- GPS data – Contains GPS data dictionaries, and raw and processed GPS data files. This folder contains subfolders to arrange files by year. Each of these subfolders also contains the project code to make it easier to select the correct project folder within the GPS processing software.
- Images – For storing images associated with the project. This folder has subfolders named by calendar year to make it easier to identify and move files to the project archives at the end of each season. Refer to **SOP 10: Managing Photographic Images** for more details.
- Spatial info – Contains files related to visualizing and interacting with GIS data.
    - GIS data – New working shapefiles and coverages specific to the project.
    - GIS layers – Pointer files to centralized GIS base themes and coverages.
    - Map documents – Map composition files (.mxd).

Seasonal Workspace

In addition to these permanent folders, a temporary seasonal workspace is established at the beginning of each field season (e.g., "2012_field_crew"). This temporary workspace provides a place for field crew members to create and modify files while limiting access privileges for the remainder of the project workspace. Subfolders are created for Images and GPS data to allow field crew members to process incoming files as needed. Temporary workspaces may also be established on other servers to provide local access to crews stationed at other parks. At the end of the season, files in these temporary workspaces are then filed in the appropriate permanent folder(s).

Folder Naming Standards

In all cases, folder names should follow these guidelines:

- No spaces or special characters in the folder name.
- Use the underbar ("_") character to separate words in folder names.
- Try to limit folder names to 20 characters or fewer.
- Dates should be formatted as YYYYMMDD (this leads to better sorting than other date naming conventions).

File Naming Standards

Unless otherwise specified, file names should follow these guidelines:

- No spaces or special characters in the file name.
- Use the underbar ("_") character to separate file name components.
- Try to limit file names to 30 characters or fewer, up to a maximum of 50 characters.

- Dates should be formatted as YYYYMMDD.
- Correspondence files should be named as YYYYMMDD_AuthorName_subject.ext.

Workspace Maintenance Procedures

Prior to each season, the Project Lead should:

1. Make sure that network accounts are established for each new staff member, or reactivated for returning staff members. By default, the IT staff puts new user accounts into a group that has read-only access to all files.
2. Create new folders named by year under the Images and GPS data sections.
3. Create the seasonal workspace, with subfolders for Images and GPS data.
4. Add user logins for the seasonal crew members to the seasonal workspace, with modify privileges. This can be done by right-clicking on the seasonal workspace folder, selecting Properties > Security, then adding users one at a time and checking the box in the Allow column for Modify privileges.
5. Provide the Data Manager with a list of user logins that need modify access to the project workspace and database.

After each season, the Project Lead should:

1. Review the workspace organization and clean up any temporary files and subfolders that are no longer needed.
2. Move files from the seasonal workspace folders into the appropriate permanent folder(s), and archive or delete the seasonal workspace folders as desired. See **SOP 10: Managing Photographic Images** for specific instructions for images.
3. Compare older files against the retention schedule in NPS Director's Order 19 (available at: http://home.nps.gov/applications/npspolicy/DOrders.cfm). Dispose of files that are beyond their retention schedule if they are no longer needed. As a long-term project, many files associated with this project are likely to be scheduled for permanent retention. This makes it all the more imperative to clean out unneeded files before they accumulate and make it harder to distinguish the truly useful and meaningful ones.
4. Convert older files to current standard formats as needed to maintain their usefulness.
5. Identify files that may contain sensitive information (as defined in Section 5.10 of the narrative). Such files should be named and filed in a way that will allow quick and clear identification as sensitive by others.
6. Post final documents and files to the NCCN Digital Library for long-term storage. See **SOP 12: Product Delivery, Posting and Distribution**.
7. Send analog (non-digital) materials to the park collections for archiving.

Standard Operating Procedure (SOP) 12. Product Delivery, Posting and Distribution

Revision History Log

Revision Date	Author	Changes Made	Reason for Change
Mar 2009	J. Boetsch	---	Original

This SOP provides a schedule, product specifications, and instructions for delivering completed data sets, reports and other project deliverables for long-term storage. Details are also provided on posting products to websites and clearinghouses, and on responding to data requests.

Product Delivery Schedule and Specifications

Table SOP 12.1. Schedule and instructions for project deliverables.

Deliverable Product	Primary Responsibility	Target Date	Delivery Instructions
Field season report	Field Lead	December 15 of the same year	Upload digital file in Microsoft Word format to the NCCN Digital Library.
Digital photographs	Project Lead	December 15 of the same year	Organize, name and maintain photographic images in the project workspace according to **SOP 10: Managing Photographic Images**.
Certified working database	Project Lead	December 15 of the same year; data are not published until two years after the certification date	Refer to the section in this SOP on delivering certified data and related materials.
Certified geospatial data	Project Lead with GIS Specialist		
Data certification report	Project Lead		
Metadata interview form	Project Lead		
Full metadata (parsed XML)	Data Manager and GIS Specialist	March 15 of the following year	Upload the parsed XML record to the NPS Data Store [1].
Annual I&M report	Project Lead	Apr 1 of the following year	Refer to the section in this SOP on reports and publications.
5-year analysis report	Project Lead and Data Analyst	Every 5 years by April 30 of the following year	
Other publications	Project Lead and Data Analyst	As completed	
Field data forms	Project Lead	April 30 of the following year	Scan original, marked-up field forms as PDF files and store in the project workspace. Hard copy originals go to the Park Curator for archiving 5 years after data collection.

Table SOP 12.1. Schedule and instructions for project deliverables (continued).

Deliverable Product	Primary Responsibility	Target Date	Delivery Instructions
Other records	Project Lead	Review for retention every January	Retain or dispose of records following NPS Director's Order 19 [2]. Organize and send analog files to Park Curator for archiving. Digital files that are slated for permanent retention should be uploaded to the NCCN Digital Library.

[1] The NPS Data Store is an internet clearinghouse of documents, data and metadata on natural and cultural resources in parks. It is a primary component of the NPS Integrated Resource Management Applications (IRMA) portal (http://irma.nps.gov).

[2] NPS Director's Order 19 provides a schedule indicating the amount of time that the various kinds of records should be retained. Available at: http://home.nps.gov/applications/npspolicy/DOrders.cfm

NCCN Digital Library

The NCCN Digital Library is a document management system maintained in a Microsoft SharePoint environment at: http://sharenrss/im/networks/NCCN/default.aspx. The primary purpose of this system is to maintain important digital files – such as reports, protocol documents, and select project images – within a content management system, and to make them available to NCCN and NPS users. NCCN users may view, post and edit documents within this system; other NPS users have read-only access to these files, except where information sensitivity may preclude general access.

To enable discovery and long-term usability of key documents, certain information about each file needs to be filled in as files are uploaded, for example:

- Document title
- Project code (e.g., "WCa02" for Large Lakes Monitoring)
- Park(s) to which the file(s) apply; multiple parks may be selected for each upload
- Document type (e.g., formal report, database, protocol, etc.)
- Date of publication or last revision
- Author name(s)
- Sensitivity: Sensitive, NPS Only, or Public. Sensitive files will not be viewable without permission. For a definition of sensitive information, see **Section 5.10, Identifying and Handling Sensitive Information**.
- Description - Document abstract, additional authors and credits, special use instructions, etc.

For project staff without access to the NPS intranet, files may be sent by email or CD/DVD to the Project Lead or Data Manager for upload, along with the above information in a text file or accompanying email.

Park Collections

The collections at OLYM will serve as the park of record for the Large Lakes Monitoring Project. Voucher specimens, hardcopy field forms, and printouts of annual reports, technical

reports, and other publications will be filed there. In addition, other hard copy project records should be reviewed and organized on an annual basis (or at the conclusion of a project), and sent to park collections for long-term storage.

The Project Lead should contact the Park Curator during the project planning if voucher specimens will be collected. All specimens must be labeled with NPS accession and catalog numbers, and with advance notice the Park Curator can help to provide these numbers ahead of time so they can be included in label printouts. Specimen label information will be entered by the Park Curator into the ANCS+ database. The Park Curator will help to decide which and how many specimens can be maintained at the park versus sent to another institution or collection. Collected materials remain NPS property even if they later reside in a non-NPS collection (e.g., university herbarium).

Delivering Certified Data and Related Materials

Data certification is a benchmark in the project information management process that indicates that the data: 1) are complete for the period of record; 2) have undergone and passed the quality assurance checks; and 3) are appropriately documented and in a condition for archiving, posting and distribution as appropriate. To ensure that only quality data are included in reports and other project deliverables, the data certification step is an annual requirement for all tabular and spatial data.

NPSTORET and EPA STORET (http://www.epa.gov/storet) are, respectively, the NPS and national enterprise data warehouses for water quality data. NPSTORET is maintained by NPS-Water Resources Division (WRD) and is synchronized with EPA STORET on a regular basis. NPSTORET is also available as a desktop database for local use. We refer to this local version as either the 'working database' or the 'master project database' depending on whether or not it includes certified data from previous seasons.

The following deliverables should be delivered as a package:

- *Certified geospatial data* – GIS themes in ESRI coverage or shapefile format. Refer to NCCN GIS Development Guidelines (NCCN 2007a) and NCCN GIS Product Specifications (NCCN 2007b) for more information.
- *Data certification report* – A brief questionnaire in Microsoft Word that describes the certified data product(s) being delivered. A template form is available on the NCCN website at: http://science.nature.nps.gov/im/units/nccn/datamgmt_guide.cfm.
- *Metadata interview form* – The metadata interview form is a Microsoft Word questionnaire that greatly facilitates metadata creation. It is available on the NCCN website at: http://science.nature.nps.gov/im/units/nccn/datamgmt_guide.cfm. For more information, refer to **Section 5.6, Metadata Procedures**.

After the quality review is completed, the Project Lead should package the certification materials for delivery as follows:

1. Create a compression file (using WinZip® or similar software, or by right-clicking in Windows Explorer). This file should be named in accordance with general file naming standards, and the name should include the project code ("WCa02") and the year or span of years for the data being certified. For example: WCa02_2010_certification_pkg.zip.

2. Add the completed metadata interview and data certification forms to the compressed file. Both files should be named in a manner consistent with the file naming standards described in **SOP 11: Project Workspace and Records Management**.
3. Add any geospatial data files that are not already in the possession of the GIS Specialist. Geospatial data files should be developed and named according to NCCN GIS Naming Conventions (NCCN 2007c).
4. Deliver the compressed file containing all certification materials to the Data Manager by placing it in the Data folder of the project workspace and notifying the Data Manager by email. If the Project Lead does not have network access, then certification materials should be delivered as follows:
   a. If the compressed file is under 9.5 mb in size, it may be delivered directly to the Data Manager by email.
   b. If the compressed file is larger than 9.5 mb, it should be copied to a CD or DVD and delivered in this manner. Under no circumstances should products containing sensitive information be posted to an FTP site or other unsecured web portal.

Upon receiving the certification materials, the Data Manager will:

1. Review them for completeness and work with the Project Lead if there are any questions.
2. Check in the delivered products using the NCCN project tracking application.
3. Notify the GIS Specialist if any geospatial data are delivered. The GIS Specialist will then review the data, and update any project GIS data sets and metadata accordingly, and post those products to the NCCN Digital Library.
4. Submit the certified data to WASO on a semi-annual basis so that it can be merged with WRD STORET and EPA STORET. The Data Manager will then download an updated master copy of NPSTORET containing the newly-certified data and make this available to the project staff. At this point the Project Lead may proceed with data summarization, analysis and reporting using the updated master copy of NPSTORET
5. Develop, parse and post the XML metadata record to the NPS Data Store.
6. After a holding period of two years, the GIS Specialist will upload the certified data to the NPS Data Store. This holding period is to protect professional authorship priority and to provide sufficient time to catch any undetected data quality problems.

No sensitive information (e.g., information about the specific nature or location of protected resources) may be posted to the NPS Data Store or any other publicly-accessible website, or otherwise shared or distributed outside NPS without a confidentiality agreement between NPS and the agency, organization, or person(s) with whom the sensitive information is to be shared. Only products that are intended for public/general-use may be posted to public websites and clearinghouses – these may not contain sensitive information.

Instructions for Reports and Publications

Annual reports and trend analysis reports will use the NPS Natural Resource Publications template, a pre-formatted Microsoft Word template document based on current NPS formatting standards. Annual reports will use the Natural Resource Technical Report (NRTR) template, and trend analysis and other peer-reviewed technical reports will use the Natural Resource Report (NRR) template. These templates and documentation of the NPS publication standards are available at: http://www.nature.nps.gov/publications/NRPM/index.cfm.

The procedures for annual reports, technical reports, and publications are as follows. (Note: This is optional for field season reports, which are intended to be internal communications only.)

1. The Project Lead or Data Analyst formats the document according to the NPS Natural Resource Publications standards.
    a. Formatting according to NPS standards is easiest when using the report template from the very beginning, as opposed to reformatting an existing document.
    b. When creating the file, use appropriate naming standards (described in this document).
    c. Open the document and add "DRAFT" to the header or document watermark as appropriate.
2. The document should be peer reviewed at the appropriate level. For example, I&M annual reports should be reviewed by other members of the project work group. The Network Program Manager will also review all annual reports for completeness and compliance with I&M standards and expectations. Before sending the document for review, rename the document by adding a date stamp to the end of the file name using the YYYYMMDD format.
3. Upon completing the peer review, the Project Lead should acquire a publication series number from the appropriate regional or national key official. Instructions for acquiring a series number are available at: http://www.nature.nps.gov/publications/NRPM/index.cfm.
4. The Project Lead should finalize the document:
    a. Ensure that the publication/version date (last saved date field code in the document header, if used) and file name (field code in the document footer, if used) are updated properly throughout the document.
    b. Remove the word "DRAFT" from watermarks, document headers, and file name.
    c. Remove any previous date stamp from the file name.
    d. If the document has been developed and maintained in SharePoint (e.g., the Digital Library), update the document attribute to “Final”.
    e. To avoid unplanned edits to the document, reset the document to read-only by right-clicking on the document in Windows Explorer and checking the appropriate box in the Properties popup.
    f. Create a PDF version of the document and upload the PDF copy to the Digital Library for long-term storage.
    g. Store both the Word document and PDF copy in the appropriate section of the project workspace (see **SOP 11: Project Workspace and Records Management**).
5. Notify the Park Curator and Data Manager that the report is available, and send a printout to the Park Curator to add to the host park collections.
6. The Data Manager (or a designee) will create a bibliographic record and upload the PDF copy to the NPS Data Store according to document sensitivity.

File Naming Standards

Prior to delivering or uploading digital products, files should be named according to the naming conventions appropriate to each product type.

Reports and Publications

- No spaces or special characters in the file name.
- Use the underbar ("_") character to separate file name components.
- Try to limit file names to 30 characters or fewer, up to a maximum of 50 characters.
- Dates should be formatted as YYYYMMDD.
- As appropriate, include the project code (e.g., "WCa02"), network code ("NCCN") or park code, and year in the file name.

Examples:

- NCCN_WCa02_2012_Annual_report.pdf
- NCCN_ WCa02_2012_Field_season_report.doc
- NCCN_ WCa02_2012_Certification_report.doc

Other Files

General naming standards as described in **SOP 11: Project Workspace and Records Management** apply to all deliverables. When delivering files to the Digital Library, file names should be modified as needed to include the project code (e.g., "WCa02"), network code ("NCCN") or park code, and year as appropriate (e.g., NCCN_WCa02_2012_cert_package.zip). Specific standards for images are described in **SOP 10: Managing Photographic Images** and in **SOP 13: Revising the Protocol** for protocol documents.

Product Posting

Once digital products have been delivered and processed, the Data Manager or a designee will post them to or otherwise update the following applications to make them generally available:

1. The NPS Data Store is an internet clearinghouse for documents, data and metadata on natural and cultural resources in parks. It is a primary component of the NPS Integrated Resource Management Applications (IRMA) portal (http://irma.nps.gov). Refer to the section on sensitive information in **Section 5.10, Identifying and Handling Sensitive Information** for information on options for flagging products containing sensitive information within the system, or for modifying products prior to posting so that they no longer contain sensitive information and can therefore be shared broadly. Full metadata records will be posted to the NPS Data Store as they are created; data sets will be posted after a two-year hold to protect professional authorship priority and to provide sufficient time to catch any undetected quality assurance problems. For reports and other publications, an online record is created after first verifying that one does not already exist. The digital report file in PDF format is then uploaded.
2. NPSpecies is the NPS database and application for maintaining park-specific species lists and observation data, and is also a component of the IRMA portal (http://irma.nps.gov). Species observations will be extracted from project data sets and uploaded into NPSpecies.
3. NCCN Web Site is maintained by NCCN staff as part of the NPS Inventory and Monitoring web site (http://science.nature.nps.gov/im/units/nccn) to describe our program, the vital signs selected for monitoring, and to highlight certain products and

information derived from inventory and monitoring work at NCCN. The site has both internet and intranet components. Select products such as annual reports and technical reports will be posted to the web site.

These applications serve as the primary mechanisms for sharing reports, data, and other project deliverables with other agencies, organizations, and the general public.

Holding Period for Project Data

To protect professional authorship priority and to provide sufficient time to complete quality assurance measures, there is a two-year holding period before posting or otherwise distributing certified project data. This means that certified data sets are first posted to publicly-accessible websites (i.e., the NPS Data Store) approximately 24 months after they are certified (e.g., data collected in June 2010 and certified in February 2011 becomes generally available through the NPS Data Store in February 2013). In certain circumstances, and at the discretion of the Project Lead, data may be shared before a full two years have elapsed.

Note: This hold only applies to raw data, and not to metadata, reports or other products which are posted to NPS clearinghouses immediately after being received and processed.

Responding to Data Requests

Occasionally, a park or project staff member may be contacted directly regarding a specific data request from another agency, organization, scientist, or from a member of the general public. The following points should be considered when responding to data requests:

- For all Inventory and Monitoring projects in NCCN, NPS is the originator and steward of the data, and the NPS Inventory and Monitoring Program should be acknowledged in any professional publication using the data.
- NPS retains distribution rights; copies of the data should not be redistributed by anyone but NPS.
- The data that project staff members and cooperators collect using public funds are public records and as such cannot be considered personal or professional intellectual property.
- No sensitive information (e.g., information about the specific nature or location of protected resources) may be posted to the NPS Data Store or any other publicly-accessible website, or otherwise shared or distributed outside NPS without a confidentiality agreement between NPS and the agency, organization, or person(s) with whom the sensitive information is to be shared. Refer to **Section 5.10, Identifying and Handling Sensitive Information**.
- For quality assurance, only certified, finalized versions of data sets should be shared with others. In exceptional cases where a provisional data set needs to be shared with others prior to certification:
    - Any accompanying communications should clearly indicate that the data set is provisional and subject to change according to our quality review process.
    - File names and the media it is sent on should be clearly labeled as containing provisional data not for distribution.

The Project Lead will handle all data requests as follows:

1. Discuss the request with other Park Biologists as necessary to make those with a need to know aware of the request and, if necessary, to work together on a response.
2. Notify the Data Manager if s/he is needed to facilitate fulfilling the request in some manner.
3. Respond to the request in an official email or memo.
4. In the response, refer the requestor to the NPS Data Store and the IRMA portal (http://irma.nps.gov), so they may download the necessary data and/or metadata. If the request cannot be fulfilled in that manner – either because the data products have not been posted yet, or because the requested data include sensitive information – work with the Data Manager to discuss options for fulfilling the request directly (e.g., writing data to CD or DVD). Ordinarily, only certified data sets should be shared outside NPS.
5. It is recommended that documents and presentation files be converted to PDF format prior to distribution. This is to maximize portability and to reduce the ability for others to alter and redistribute files.
6. If the request is for data that may reveal the location of protected resources, refer to the next section in this document about sensitive information.
7. After responding, provide the following information to the Data Manager, who will maintain a log of all requests in the NCCN project tracking database:
    a. Name and affiliation of requestor
    b. Request date
    c. Nature of request
    d. Responder
    e. Response date
    f. Nature of response
    g. List of specific data sets and products sent (if any)

Freedom of Information (FOIA) Requests

All official FOIA requests will be handled according to NPS policy. The Project Lead will work with the Data Manager and the park FOIA representative(s) of the park(s) for which the request applies.

Special Procedures for Sensitive Information

Products that have been identified upon delivery by the Project Lead as containing sensitive information will normally be revised into a form that does not disclose the locations of protected resources – most often by removing specific coordinates and only providing coordinates that include a random offset to indicate the general locality of the occurrence. If this kind of measure is not a sufficient safeguard given the nature of the product or the protected resource in question, the product(s) will be withheld from posting and distribution.

If requests for distribution of products containing sensitive information are initiated by the NPS, by another federal agency, or by another partner organization (e.g., a research scientist at a university), the unedited product (i.e., the full data set that includes sensitive information) may be shared only after a confidentiality agreement has been established between NPS and the agency, organization, or person(s) with whom the sensitive information is to be shared. Refer to **Section 5.10, Identifying and Handling Sensitive Information** for more information.

Literature Cited

NCCN – National Park Service. 2007a. GIS Development Guidelines. USDI National Park Service. Internet document: http://science.nature.nps.gov/im/units/nccn/datamgmt_guide.cfm.

NCCN – National Park Service. 2007b. GIS Product Specifications. USDI National Park Service. Internet document: http://science.nature.nps.gov/im/units/nccn/datamgmt_guide.cfm.

NCCN – National Park Service. 2007c. GIS Naming Conventions. USDI National Park Service. Internet document: http://science.nature.nps.gov/im/units/nccn/datamgmt_guide.cfm.

Standard Operating Procedure (SOP) 13. Revising the Protocol

Revision History Log

Revision Date	Author	Changes Made	Reason for Change
9/21/2006	S.C. Fradkin	Minor editorial clarifications	Response to peer review

This SOP describes how to make and track changes to the NCCN Large Lakes Monitoring Protocol, including its accompanying SOPs. Project staff should refer to this SOP whenever edits are necessary, and should be familiar with the protocol versioning conventions in order to identify and use the most current versions of the protocol documents. Required revisions should be made in a timely manner to minimize disruptions to project operations.

Peer Review

This protocol attempts to incorporate the best and most cost-effective methods for monitoring and information management. As new technologies, methods, and equipment become available, this protocol will be updated as appropriate, by balancing current best practices against the continuity of protocol information.

All edits require review for clarity and technical soundness. Small changes to existing documents – e.g., formatting, simple clarification of existing content, minor changes to the task schedule or project budget, or general updates to information management SOPs – may be reviewed in-house by project and NCCN staff. However, changes to data collection or analysis techniques, sampling design, or response design are usually more significant in scope and impact and will typically trigger an outside review to be coordinated by the Pacific West Regional Office of the National Park Service.

Document Life Cycle

Protocol documents may be maintained as separate files for each component (e.g., narrative, SOPs, appendices in separate document files) or unified into a single document file. During its life cycle, each document file can be classified in one of six life cycle stages:

1. Draft documents – Documents that have been drafted or revised but have not been reviewed and approved yet.
2. Review documents – Draft documents that have been sent out for peer review or administrative review.
3. Active documents – The current, reviewed and accepted version of each protocol component in Microsoft Word format. These documents have been reviewed and approved at the appropriate level, and are currently implemented for active monitoring projects.
4. Inactive documents – Older versions of approved protocol components that are no longer in active implementation.

5. Archived documents – Comprehensive set of active protocol components plus older, inactive versions of approved protocol components in Microsoft Word format. These are stored as read-only and have a date stamp to identify their approval date. The history of the protocol versions through time should be entirely traceable from within the document archive.
6. Distribution copies – PDF versions of approved, date-stamped protocol components, used to post to websites or otherwise share outside NPS.

Protocol documents are stored in the project workspace in separate subfolders named for each life cycle stage, except for inactive documents which are filed together with date-stamped copies of active documents in the archive folder. See **SOP 11: Project Workspace and Records Management** for additional details about the project workspace.

Document Versioning Conventions

Rather than using a sequential numeric versioning convention, we use date stamps to distinguish document versions because they are more intuitive and informative than version numbers. Date stamps are embedded within the document header, and also included in the document name.

Document Header

Within each document, the upper right section of the document header should show the date that the document was last saved. By using save date instead of current date, printouts and document previews will show the correct version number. The following is the field code to be used within the header to indicate the version number:

SAVEDATE } \@ "MMMM d, yyyy"

File Naming Conventions

All documents *except for active documents and draft documents* should include the last edit date as a suffix, using the YYYYMMDD format so that documents will sort by date rather than month or day (e.g., NCCN_Large_Lakes_Protocol_DRAFT_20110401.doc for the review draft on 4/1/2011).

Active documents and draft documents that have not been shared with others (as review documents) should not include the date because – unlike documents in other life cycle stages – they are not "point in time" document snapshots. By omitting the date stamp from these documents, they can more easily be distinguished from review drafts and archive or distribution copies. Draft documents should clearly contain the word "DRAFT" in the file name.

Note: General file and folder naming conventions are described in **SOP 11: Project Workspace and Records Management**; these should be followed when naming protocol document files.

Revision Procedures

Proposed changes to protocol components should be discussed among project staff prior to making modifications. It is especially important to consult with the Data Manager prior to making changes because certain types of changes may jeopardize data set integrity unless they are planned and executed with the continuity of the data set in mind. Because certain changes may require altering the database structure or functionality, advance notice of changes is

important to minimize disruptions to project operations. Consensus should be reached on who will be making the agreed-upon changes and in what timeframe.

Note: A change in one document also may necessitate other changes elsewhere in the protocol. For example, a change in the narrative may require changes to several SOPs; similarly renumbering an SOP may mean changing document references in several other sections of the protocol. The project task list and other appendices also may need to be updated to reflect changes in timing or responsibilities for the various project tasks.

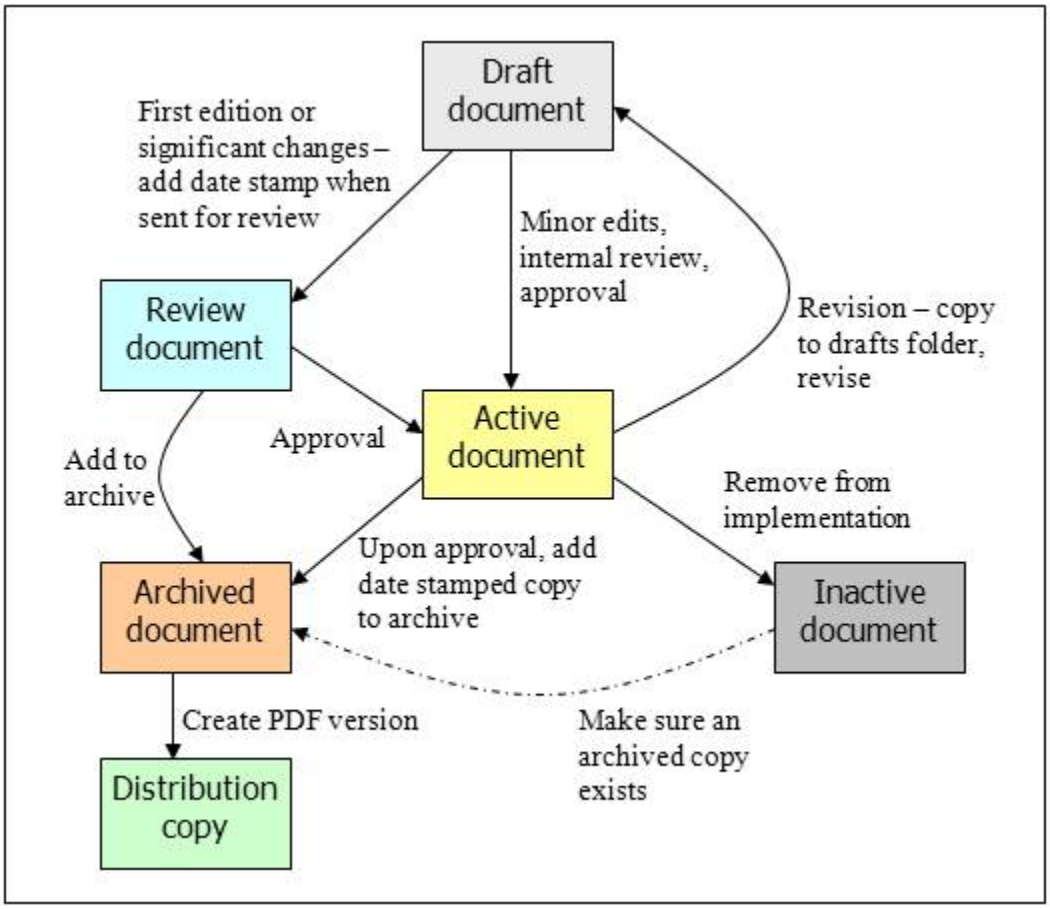


Figure SOP 13.1. Process for creating and revising protocol documents. Boxes represent document life cycle stages, and connecting arrows indicate procedures.

The Project Lead is the person primarily responsible for making edits and ensuring document review at the appropriate level. The process for creating and revising protocol documents is shown in Figure SOP 13.1, and outlined below:

1. *Create the draft document in Microsoft Word format*. If modifying an existing document (usually an active document), copy the document to the draft document folder, remove any date stamp from the name. Add "DRAFT" to the file name. Open the document and add "DRAFT" to the header or document watermark as appropriate.

2. *Track revision history*. If modifying an existing document, document all edits in the Revision History Log embedded in the protocol narrative and each SOP. Log changes only for the section of the document being edited (i.e., if there is a change to an SOP, log those changes only in the revision history log for that SOP). Record the date of the changes (i.e., the date on which all changes were finalized), author of the revision, describe the change and cite the paragraph(s) and page(s) where changes are made, and briefly indicate the reason for making the changes.
3. *Document review*. Circulate the changed document for internal review among project staff and cooperators. If the changes are significant enough to trigger peer review (as defined above), create a review document by adding a date stamp to the end of the file name using the YYYYMMDD format, copy the file to the archive folder, and submit the document for peer review according to current instructions.
4. *Finalize and archive*. Upon approval and final changes:
    a. Ensure that the version date (last saved date field code in the document header) and file name (field code in the document footer, if used) are updated properly throughout the document.
    b. Move the approved document to the active folder. Remove the word "DRAFT" from watermarks, document headers, and file name. Remove any previous date stamp. This is now an active, implemented document.
    c. To avoid unplanned edits to the document, reset the document to read-only by right-clicking on the document in Windows Explorer and checking the appropriate box in the Properties popup.
    d. Create a copy of the file and add the revision date to the end of the file name using the YYYYMMDD format. Move this copy to the archive folder.
    e. Inform the Data Manager so the new version number can be incorporated into the project metadata.
5. *Create distribution copies*. As needed, create a PDF version of the archived document to post to the internet and share with others. These PDF versions should have the same date-stamped name as the archived Microsoft Word file. Post the distribution copy to the NCCN Digital Library and forward copies to all individuals who had been using a previous version of the affected document.
6. *Remove from implementation*. If it is decided that a document needs to be removed from implementation – either because it is no longer necessary (e.g., an unneeded SOP), or because it has been superseded by a more recent version – this can be easily done by removing the document from the active document folder, after first checking that a copy of that version already exists in the archive folder.

Standard Operating Procedure (SOP) 14. Field and Laboratory Safety

Revision History Log

Revision Date	Author	Changes Made	Reason for Change

Overview

Assembling a field crew of safe and responsible individuals is a top priority of the Project Lead and Lead Technician. The Lead Technician should have substantial field and supervisory experience. Crew members should be capable of living and working cooperatively with others under often stressful and challenging conditions in rugged and isolated areas for extended periods. Under these conditions, risk of personal injury increases and crews are often hours removed from emergency medical help. Although the field crew's primary objective is to gather data at lakes, individuals are responsible for personal safety and the safety of other crew members while maintaining positive work relationships. In addition to field safety, laboratory procedures have been developed to ensure sample analyses are conducted in a safe manner.

Field and laboratory procedures will be conducted in accordance with park and NPS safety requirements including the Project Operation and Risk Management Template (provided by Project Lead) and associated Job Hazard Analysis found in Appendix 4. In addition, Hazard Communication and Chemical Hygiene Plans for OLYM are maintained at Park Headquarters. Comprehensive project pre-season safety training will be conducted and documented and routine safety sessions will be held during the field season.

Access to Sampling Sites

Prior to leaving on all field trips the field crew along with the Project Lead will complete a Project Operations and Risk Management Plan following guidelines established as part of the NPS Operational Leadership program.

Access to lake sampling sites is via motorized boats. The boat operator will have completed a DOI MOCC boating course and have demonstrated experience in piloting motorized craft on large lakes. When a boat is not already moored in the target lake, it will be launched by NCCN staff trained and experienced in trailering and launching a boat.Safety related information pertaining to travel to work site and motorboat use is found in Appendix 4.

Safety tailgate sessions are presented at the beginning of and during the field season, covering topics such as prevention of overuse type injuries, safe stream crossing, thermoregulation, physical response to cold, hypothermia, frostbite, insulation qualities of clothing types, and bear and mountain lion safety, etc.

Sampling Crew Safety

A two-person crew is generally adequate for safe and efficient sampling of most NCCN aquatic habitat sites. Additional crew members may be needed periodically if the sampling regime requires additional staff. Before each sampling trip, the boat pilot and all passengers will conduct a safety briefing covering all standard boating procedures to be performed, and an assessment of operations taking into consideration the boating conditions of the current day. All boating operations will be conducted during daylight hours. Samplers will exercise extreme caution in selecting foot placements and in movement when conducting field sampling onboard a moving or shifting boat. Personal floatation devices will be worn by all staff while onboard a boat.

Safety training increases the safety awareness of crew members and prepares them for responding to potential medical emergencies. Each crew member should be trained, skilled, and/or certified in:

- Basic first aid and cardiopulmonary resuscitation (CPR)
- Swimming
- Use of a PFD
- Use of handheld communication devices
- DOI MOCC certification (pilot at a minimum)
- Completing risk management plans according to Operational Leadership Guidelines.

Crew members also will be oriented to and trained in the safe and proper use of sampling equipment and chemicals used for water-quality analysis or organism preservation.

Crew Safety Training

Crew training will include development and completion of a Job Hazard Analysis (JHA), a Project Operations Plan and Risk Assessment for each field trip. This should include all planned activities: packing equipment, transporting equipment to a field site, work at a field site, return trip, and processing samples in the park laboratory (see Appendix 4). Each field crew member is responsible for completing a Risk Assessment for each field trip during the field season. The Field Crew Lead is responsible for completing a Project Operations Plan for every field trip and ensuring that the Project Lead is given a copy. Crews will be required to have a park safety orientation, training in use of radios, pfds, vehicles, boats, accident and injury prevention, accident reporting, map, compass, GPS use, and laboratory safety including safe handling of chemicals and use of Material Safety Data Sheet (MSDS) information.

Laboratory Safety

Analysis of all samples will be conducted in accordance with park safety plans and guidelines (Chemical Hygiene Plan, Hazard Communication). Material Safety Data Sheets (MSDS) are detailed informational documents which describe the physical and chemical properties of hazardous chemicals. These documents are prepared by the manufacturer of the chemicals. The Hazard Communication Standard (Federal Standard 29 CFR 1910.1200 or for Washington State WAC 296-62-054) also known as the "Right -to-Know" law enacted in 1985 sets forth the following requirements:

1. It is the responsibility of the manufacturer of a material to determine what hazards are associated with the material, to prepare an MSDS for the material, and to provide the MSDS to any recipients of the material.

2. It is the responsibility of an employer to provide MSDS and training in their interpretation to the employees. MSDS for hazardous materials must be readily available in the workplace.

3. It is the responsibility of the employees to read and understand the MSDS of any chemical used on the job.

Chemical Hygiene Plans with MSDS for every chemical used as a part of this monitoring project will be kept on file in the park laboratories for all crew members to review at the beginning of and during the sampling season.

Appendices

A winter storm ripping across the eastern basin of Lake Crescent, OLYM.

Appendix 1: Yearly Project Task List.

This table identifies tasks by project stage, indicates who is responsible for the task, and establishes the timing for its execution.

Project Stage	Task Description	Responsibility	Timing
Preparation	Plan schedule and logistics, identify needed equipment and supplies	Project Lead	By Feb 15
	Inform GIS Specialist and Data Manager of specific needs for upcoming field season	Project Lead	By Mar 1
	Hire seasonal field crew positions	Project Lead	By Mar 15
	Purchase equipment and supplies	Project Lead	By Jun 1
	Ensure that project workspace is ready for use (SOP 11)	Project Lead	By Apr 15
	Deploy working database copy for data entry	Data Manager	By May 1
	Update and load data dictionary, background maps, and target coordinates into GPS units. Make sure that GPS download software is available to field crews as needed.	GIS Specialist	By May 1
	Initiate computer access and key requests (may need park-specific dates)	Project Lead	Apr 15
	Provide field crew email addresses and user logins to Data Manager. Grant modify access to project workspace once crew user logins are known.	Project Lead	May
	Provide database/GPS training as needed	Data Manager and GIS Specialist	May
	Train field crew in use of equipment, field sampling protocols, and safety	Project Lead	May
	Calibrate and redeploy lake level pressure gage	Technicians	July
	Calibrate sonde instrument prior to each field trip	Technicians	Monthly
Data Acquisition	Collect field observation data, zooplankton samples, and sonde data during field trips. Review data forms for completeness and accuracy after each field day.	Technicians	Monthly
	Collect water samples for local nitrate and ammonium analysis during field trips	Technicians	Monthly
	Collect water samples for off-site analytical laboratory analysis during field trips, refrigerate until shipment	Technicians	Quarterly (Jan, Apr, Jul, Oct)
	Review field forms for completeness and accuracy	Field Lead	After each field trip
	Preliminary identification of live zooplankton specimens, store remaining samples until processing	Field Lead	After each field trip
	Download data from sonde instrument, rename using naming convention, and store in text format	Technicians	After each field trip
	Ship water samples to analytical lab within 48 hours of collection	Technicians	After each field trip

Project Stage	Task Description	Responsibility	Timing
	Zooplankton processing and identification, complete data forms	Field Lead	Within 8 weeks of collection
	Review zooplankton identification forms for completeness and accuracy	Field Lead	After each sample processed
	Download lake level data from instrument, rename using naming convention, archive in text format	Technicians	Quarterly (Jan, Apr, Jul, Oct)
	De-brief crew on operations, field methods, gear needs	Project Lead	Monthly
Data Entry & Processing	Download GPS data and provide files to GIS Specialist for correction	Technicians	After each field trip
	Download and process digital images (SOP 10)	Technicians	After each field trip
	Import sonde data into MS Excel for processing and preliminary quality checks; extract vertical profile data from the full data record and generate preliminary graphs of data for quality checks; document observed quality issues in the field trip report	Technicians	After each trip
	Verify correct processing of sonde data	Field Lead	After each trip
	Upload sonde data into working copy of the database	Technicians	After each trip
	Enter other data into the working copy of the database	Technicians	After each field trip
	Manually enter zooplankton identification data into working copy of the database	Technicians	After each sample processed
	Review analytical lab report of water sample analysis, document observed QA/QC issues in the field trip report; enter results into working copy of the database	Field Lead	Upon receipt of results from lab
	Verify accurate transcription from field forms to database as data are entered and/or uploaded	Technicians	After each field trip
	Correct GPS data and relate any problems to Field Crew Lead and Project Lead	GIS Specialist	After each field trip
	Import lake level data into MS Excel for processing and preliminary quality checks; generate preliminary graphs of data for quality checks; document observed quality issues in the field trip report	Technicians	Quarterly (Jan, Apr, Jul, Oct)
	Upload lake level data into working copy of the database	Technicians	Quarterly (Jan, Apr, Jul, Oct)
	Review GPS location data and database entries for completeness and accuracy	Field Lead and/or Project Lead	Quarterly
	Scan all field forms and file in the project workspace	Field Lead	By Sep 15
	Confirm that data entry and data verification is complete, and notify the Project Lead and Data Manager	Field Lead	By Sep 15
Quality Review	Complete field trip report documenting any data irregularities, deviation from protocol, or logistics issues. Store in project workspace when finalized.	Field Lead	After each trip

Project Stage	Task Description	Responsibility	Timing
	Complete quarterly season reports documenting any data irregularities, deviation from protocol, or logistics issues. Send to Project Lead, Data Manager, and GIS Specialist; submit to the NCCN Digital Library [1] when finalized (SOP 12)	Field Lead and Project Lead	Jan, Apr, Jul, Oct
	Complete data quality review and data validation using database tools	Project Lead	Nov-Dec
	Determine best coordinates for subsequent mapping and field navigation	Project Lead and GIS Specialist	Nov-Dec
Metadata	Identify any sensitive information contained in the data set	Project Lead	By Dec 15
	Update project metadata interview form	Project Lead	By Dec 15
Data Certification & Delivery	Certify the annual cycle data and complete the certification report	Project Lead	By Dec 15
	Deliver certification report, certified data, and updated metadata to Data Manager (SOP 12)	Project Lead	By Dec 15
	Submit certified data in working copy of NPSTORET [2] to WRD for merging with WRD STORET [2] and EPA STORET [2]; store certified data files in the project workspace	Data Manager	Dec-Jan
	Update project GIS data sets, layers and associated metadata records	GIS Specialist	Dec-Jan
	Finalize and parse metadata records, store in the project workspace	Data Manager and GIS Specialist	By Mar 15
Data Analysis	Download an updated master copy of NPSTORET [2] containing the newly certified data; notify Project Lead that the new copy is ready for analysis and reporting	Data Manager	Jan-Feb
	Explore data in summary queries using database tools	Data Analyst	Feb-Mar
	Analyze data for annual report and/or 5-year trend analysis	Data Analyst	Feb-Mar
Reporting & Product Development	Export automated summary results and reports from database	Data Analyst	Feb-Mar
	Generate report-quality map output for reports	GIS Specialist	Feb-Mar
	Acquire the proper report template from the NPS website (http://www.nature.nps.gov/publications/NRPM/index.cfm), draft annual report	Data Analyst and Project Lead	Feb-Apr
	Screen all reports and data products for sensitive information	Project Lead, Data Analyst	Feb-Apr
	Prepare draft report	Project Lead, Data Analyst	By Apr 15
Product Delivery	Submit draft I&M report to Network Program Manager for review	Project Lead/Data Analyst	By Apr 1
	Review report for formatting and completeness, notify Project Lead of approval or need for changes	Network Program Manager	May
	Upload completed report to NCCN Digital Library [1], notify Data Manager (SOP 12)	Project Lead	Upon approval
	Deliver other products according to the delivery schedule and instructions (SOP 12)	Project Lead	Upon completion

Project Stage	Task Description	Responsibility	Timing
	Product check-in	Data Manager	Upon receipt
Posting & Distribution	Submit metadata to the NPS Data Store [3]	Data Manager	By Mar 15
	Create an online reference record and post reports to the NPS Data Store [3]	Data Manager	Upon receipt
	Update NPSpecies [4] records according to data observations	Data Manager	Dec-Mar
	Submit certified data and GIS data to the NPS Data Store [3]	Data Manager	Jun (after 2-year hold)
Archiving & Records Management	Store finished products slated for permanent retention in NCCN Digital Library [1]	Data Manager	Upon receipt
	Review, clean up and store and/or dispose of project files according to NPS Director's Order 19 [5] (SOP 11)	Project Lead	Jan
	Move hard-copy data forms and voucher specimens to park collections collections after making sure that all forms have been scanned and all species records are entered into NPSpecies [4]	Project Lead	Jan
Season Close-out	Inventory equipment and supplies	Field Lead	By Oct 15
	De-brief field crew concerning safety, logistics, and data concerns	Project Lead, Technicians	By Oct 15
	Meet to discuss the recent field season, and document any needed changes to field sampling protocols or the database. Discuss and document needed changes to analysis and reporting procedures and plan for the coming field season	Project Lead, Data Analyst, Data Manager, and GIS Specialist	Jan-Feb

[1] The NCCN Digital Library is a document management system implemented in Microsoft SharePoint for maintaining important digital files (reports, protocol documents, and select project images) within a content management system, and to make them available to NCCN and NPS users.

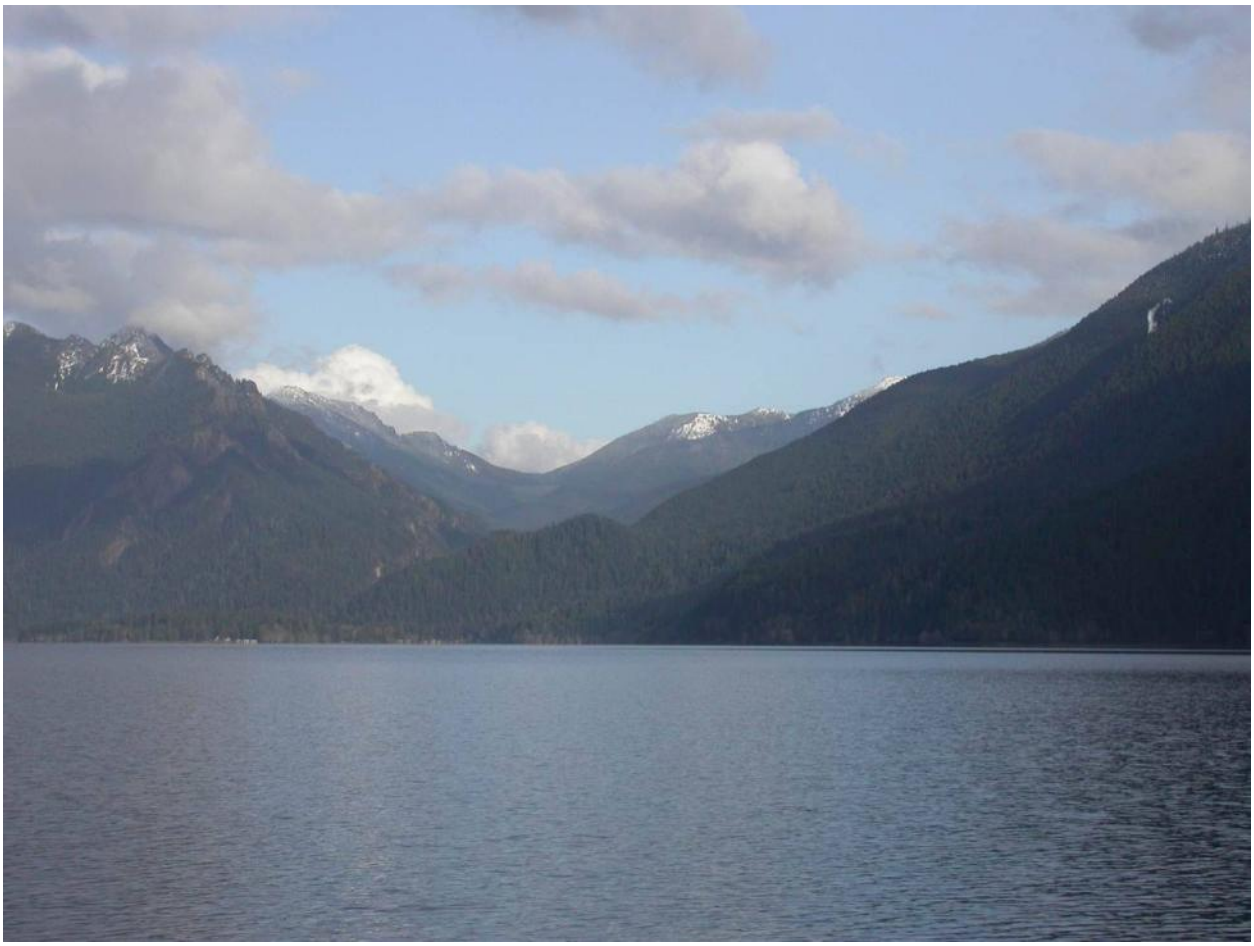
[2] NPSTORET and EPA STORET (http://www.epa.gov/storet) are, respectively, the NPS and national enterprise data warehouses for water quality data. NPSTORET is maintained by NPS-Water Resources Division (WRD) and is synchronized with EPA STORET on a regular basis. NPSTORET is also available as a desktop database for local use. We refer to this local version as either the 'working database' or the 'master project database' depending on whether or not it includes certified data from previous seasons.

[3] The NPS Data Store is an internet clearinghouse for documents, data and metadata on natural and cultural resources in parks. It is a primary component of the NPS Integrated Resource Management Applications (IRMA) portal (http://irma.nps.gov).

[4] NPSpecies is the NPS database and application for maintaining park-specific species lists and observation data, and is also a component of the IRMA portal (http://irma.nps.gov).

[5] NPS Director's Order 19 provides a schedule indicating the amount of time that the various kinds of records should be retained. Available at: http://home.nps.gov/applications/npspolicy/DOrders.cfm.

Appendix 2: Data Forms.



Barnes Point and the Barnes Creek watershed, Lake Crescent, OLYM.

Olympic National Park
Lake Crescent Lab

Large Lake Monitoring Protocol
Field Form

Lake:_____ **Date:**_____

Observers:_____

Comments:

Sonde Depth Profiles

Station	Time	Sonde Depth (m)	Secchi Depth (m)	QA ☑

Nutrients

Station	Time	Depths

Zooplankton

Station	Device	Replicates/Depths

QA/QC

Reviewed: _____ date: _____
Entered: _____ date: _____
Verified: _____ date: _____

Olympic National Park
Lake Crescent Lab

Plankton Enumeration

Lake:_____ **Sample ID:**_____
Sample_____ **Count observer:**_____
[d]Volume filtered:_____ **[[c]Sample Volume]:**_____

Taxa	Aliquot Counts (aliquot volume = ____ ml)										[a]Total # Inds.	[b]Total aliquot volume	Number per liter of original H_2O =a/(bd/c)
	1	2	3	4	5	6	7	8	9	10			

QA/QC
Reviewed: _____ date: _____
Entered: _____ date: _____
Verified: _____ date: _____

Remarks:

Olympic National Park: Lake Crescent Laboratory

Calibration Log

QA/QC

Reviewed: ____ date: _____

Entered: ____ date: _____

Verified: ____ date: _____

Date	Pre/ post	Temp c	Depth ft	DO mg/L	SpCond mS/cm	pH		ORP mv	Turbid ntu		Chl ug/L	
						7	10		0	10	0	
	pre											
	Calib											
	pre											
	Calib											
	pre											
	Calib											
	pre											
	Calib											
	pre											
	Calib											
	pre											
	Calib											
	pre											
	Calib											
	pre											
	Calib											
	pre											
	Calib											
	pre											
	Calib											

Olympic National Park: Lake Crescent Lab

Lake:

Probe Log

Parameter	Probe code	Serial #	Manufacture date	Purchase Date	Expiration date (expected)

QA/QC

Reviewed: _____ **date:** _____

Entered: _____ **date:** _____

Verified: _____ **date:** _____

Appendix 3: Lake Crescent Zooplankton Guide.

National Park Service
U.S. Department of the Interior

Olympic National Park
Port Angeles, Washington

Lake Crescent Zooplankton Guide

(Version 2.0 August, 21, 2008)

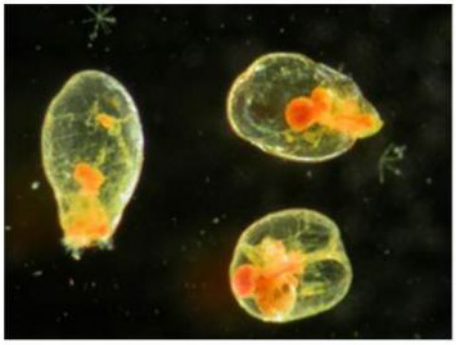
by
Steven C. Fradkin

This document is a pictorial guide to the known zooplankton found in Lake Crescent. Its intended use is as a training guide for zooplankton identification by technicians. In addition to text describing the salient features of animals, two photos accompany each entry — a photo of the live organism, and a photo of an acid Lugol's preserved organism. Most photos are from organisms taken directly from Lake Crescent. Where appropriate Lake Crescent photos are not available, images of the same species from other systems are used. This guide benefited greatly from the help of Jessica Duvall.

Cover Photo: The North basin of Lake Crescent and the OLYM sampling vessel *Marley* viewed from the NPS Lake Crescent Laboratory.

Asplanchna girodi

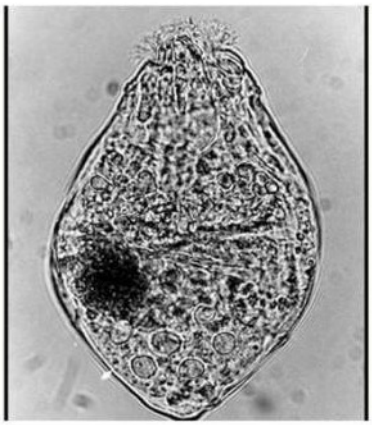
Live Specimen



Preserved Specimen

Phylum: Rotifera
Size: 146-182 µm
Description: Large sacs-like rotifers when preserved (and alive)
Preserved specimens are much larger than *Synchaeta*

Ascomorpha saltans

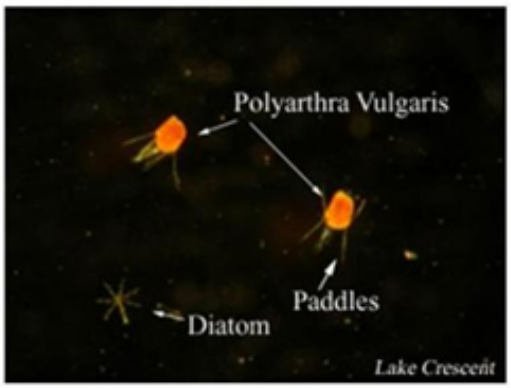


Live Specimen

Preserved Specimen

Phylum: Rotifera
Size: 95-150 µm
Description: Body of live individual is pear-shaped with a thin lorica that has two lengthwise grooves. These folds become visible when contracted upon preservation.

Polyarthra vulgaris



Live Specimen **Preserved Specimen**

Phylum: Rotifera
Size: Fin Length: 78.4-135.0 µm; Body Length: 90.7-151.9 µm
Description: Very fine paddles askew when preserved

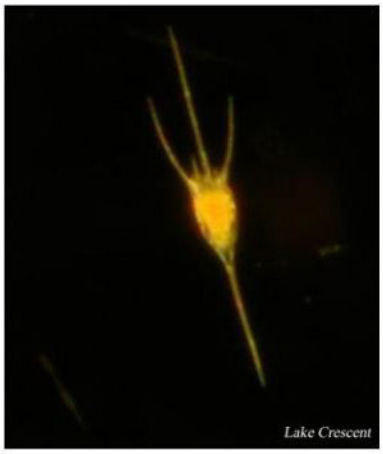
Collotheca pelagica

Live Specimen **Preserved Specimen**

Phylum: Rotifera
Size: TL (when extended): 275-400 µm
Description: Foot and corona usually retracted upon preservation
Retracts and extends foot during locomotion
Usually smaller and more delicate than other rotifers

Kellicottia longispina

Live Specimen

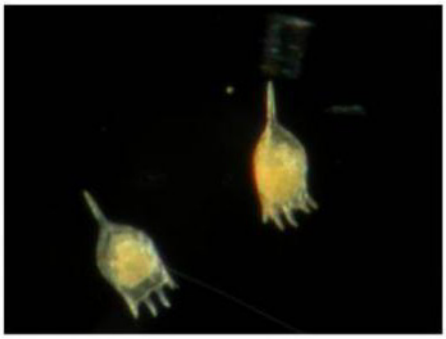


Preserved Specimen

Phylum: Rotifera
Size: LL: 400-860 µm; Posterior Spine >200 µm
Description: Footless; Smooth lorica
Preserved specimen looks very similar to live specimen because of hardened lorica

Keratella cochlearis

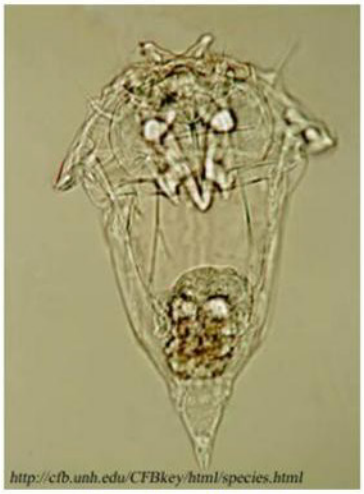
Live Specimen



Preserved Specimen

Phylum: Rotifera
Size: LL: 89-320 µm
Description: Some specimens may lack posterior spine
Potential for confusion with Dinoflagellate *Ceratium*

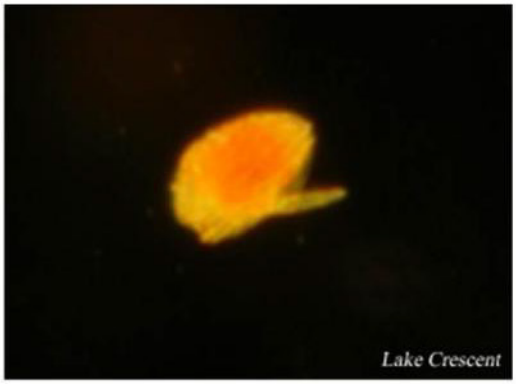
Synchaeta pectinata



Live Specimen **Preserved Specimen**

Phylum: Rotifera
Size: 340-511 µm
Description: Illoricate rotifer
4 distinct hairs on anterior end; 2 knobs/tufts side of anterior end
Can appear sac-like when preserved, but are much smaller than *Asplanchna*,

Ploesoma lenticulare



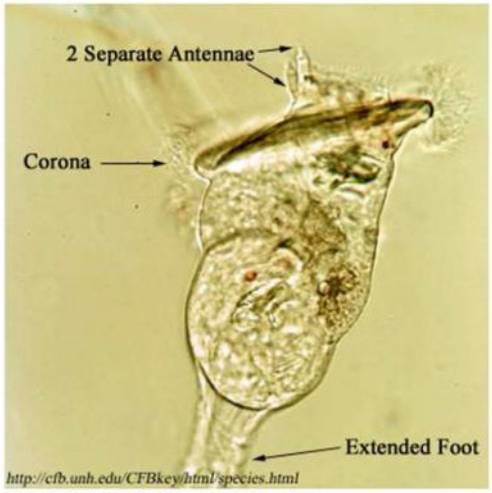
Live Specimen **Preserved Specimen**

Phylum: Rotifera
Size: 150-300 µm
Description: Loricate rotifer
Ovoid shape with foot in middle
Rapid movement punctuated by momentary pauses during which foot is extended
Foot usually extended upon preservation

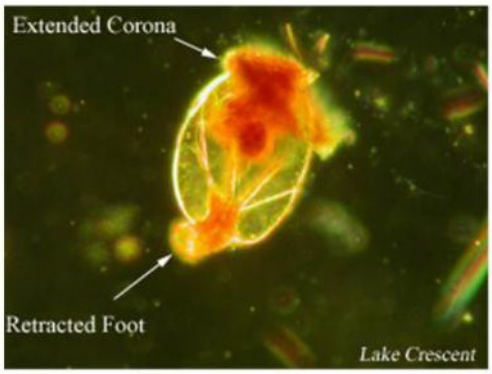
Conochilus hippocrepis

Live Colony

Preserved Colony



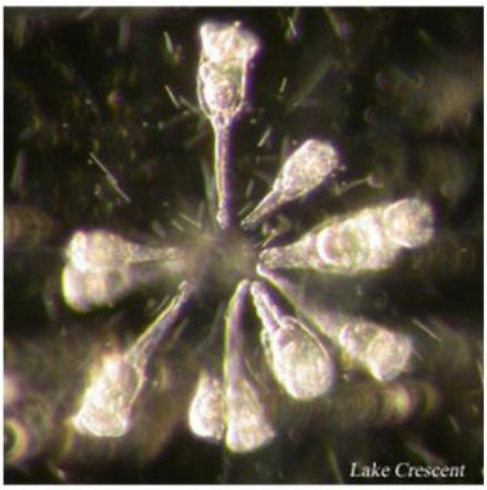
Live Individual



Preserved Individual

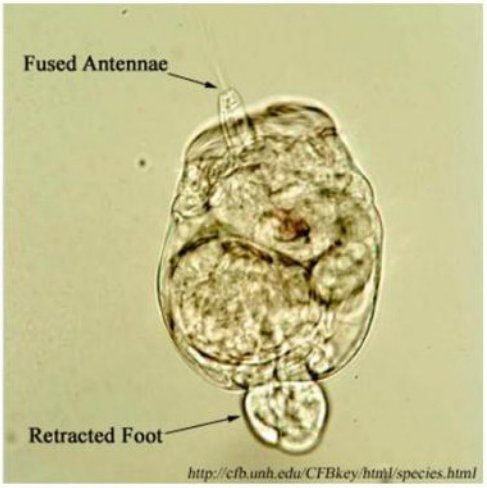
Phylum: Rotifera
Size: TL: 400-800 µm (extended specimen)
Description: Larger individual body size than *C. unicornis*
2 separate lateral antennae on apical field
2 distinct, separate eye spots on base of corona
Usually in colonies of 30 - 60 individuals until disturbed or preserved
Colonies usually surrounded by gelatinous sheath
Foot often retracted, especially in individuals not in colony
Individuals usually swim backwards in a spiral motion
Foot retracts when preserved, corona usually remains slightly extended
"Horns" often difficult to see, use size to differentiate between species

Conochilus unicornis

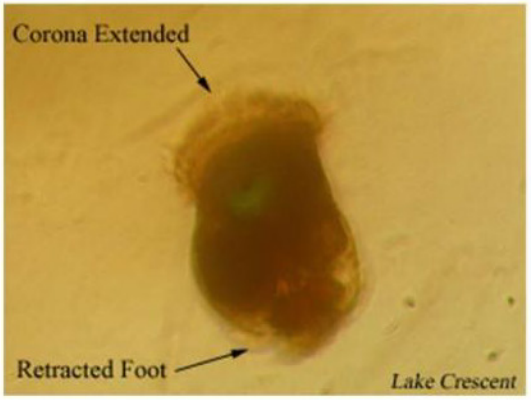


Live Colony

Preserved Colony



Live Individual

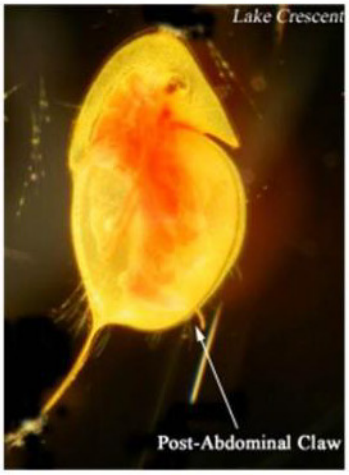


Preserved Individual

Phylum: Rotifera
Size: TL: 200-450 µm (extended specimen)
Description: Smaller individual body-size than *C. hippocrepis*
2 short lateral antennae partially fused on apical field
Usually in colonies of 5 - 12 individuals until disturbed or preserved
Colonies usually surrounded by gelatinous sheath
Foot often retracted, especially in individuals not in colony
Individuals usually swim backwards in a spiral motion
Foot retracts when preserved, corona usually remains slightly extended
"Horn" often difficult to see, use size to differentiate between species

Daphnia longiremis

Live Specimen



Preserved Specimen

Subclass: Cladocera
Size: Adult Female - 0.6-2.4 mm (600-2,400 µm)
Description: "Long Spine" - length of posterior spine ≈ length of body
Parabolic head with triangular rostrum; Eye is roughly in middle of head

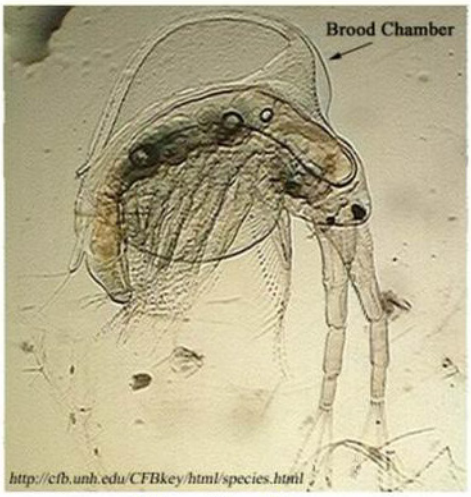
Daphnia rosea

Live Specimen

Preserved Specimen

Subclass: Cladocera
Size: Adult Female - 1.2-2 mm (1,200-2,000 µm)
Description: Spine short relative to body
Rounded head with beak-like rostrum (ski-slope nose)
Eye is closer to edge of body

Holopedium gibberum



Live Specimen

Preserved Specimen

Subclass: Cladocera
Size: Males: 0.5-0.6 mm (500-600 µm); Females: 1.5-2.2 mm (1,500-2,200 µm)
Description: Posterior antennae are long and curved
Body housed in mucous ball
Brood chamber (hump on back) obvious with preservation

Leptodora kindtii

Live Specimen

Preserved Specimen

Subclass: Cladocera
Size: Up to 15 mm (15,000 µm)
Description: "Winged Angel of Death"
Very transparent, so difficult to see unless preserved (stained)
Large predator not well sampled with current protocol, while info obtained is largely qualitative, specimens to do occur in samples.

Bosmina longirostris

Live Specimen

Preserved Specimen

Subclass: Cladocera
Size: 0.4-0.6 mm (400-600 µm)
Description: "Long rostrum", like swimming elephants
Almost circular

Scapholeberis mucronata

Live Specimen

Photo Unavailable

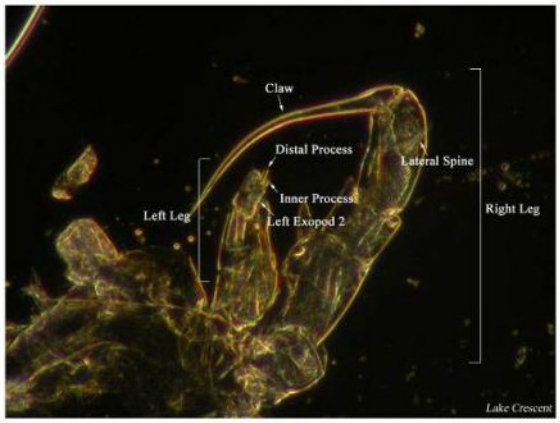
Preserved Specimen

Phylum: Cladocera
Size: ~1000 µm
Description: Very short tail-spine
Shape almost rectangular

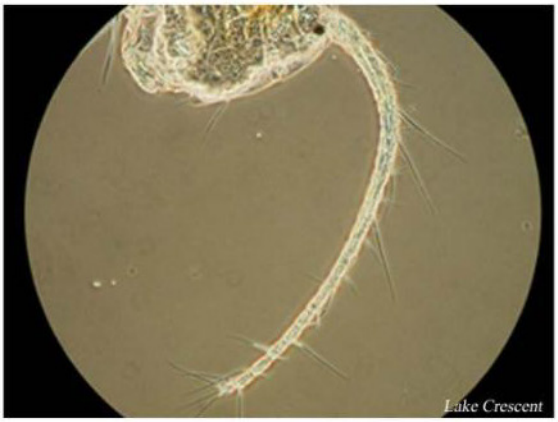
Diaptomus tyrelli

Live Male

Preserved Male



Male 5th Leg



Male L 1st Antenna

Order : Copepoda **Suborder**: Calanoida
Size: 1.1-1.6 mm
Description: Caudal Ramus w/ 5 short terminal Setee
Male R antenna geniculate more noticeable preserved, no process on last segment
L 1st antenna with only 1 seta on segments 11 and 13-19
Significantly smaller than *Epischura nevadensis*
See key for 5th leg description

Epischura nevadensis

Live Female

Preserved Female

Live Male

Preserved Male

Male 5th Leg

Order : Copepoda **Suborder**: Calanoida

Size: Female: 1.3-2.5 mm; Male: 1.27-2.1 mm

Description: Caudal ramus w/ 3 long setee
Male urosome segment asymmetrical with process on right side
Female urosome usually straight, apical caudal setae uniform in size
Significantly larger than *Diaptomus tyrelli*
Often has green tint

References on Zooplankton ID and Methods

Methods

Bogorov, V. G. 1927. On the methods of plankton processing. Russian Gidrobiological Zhurnal 6:193-198.

Downing, J. A. Sampling the benthos of standing waters. 1984. Pages 87-130 *in*: J. Downing and and F. H. Rigler (eds.). A manual on methods for the assessment of secondary productivity in fresh waters. 2nd ed. Blackwell Scientific Publications, Oxford, England.

Forbes, A., and D. Stewart. 202. Center for limnology guide to the preservation of research specimens. Center for Limnology, University of Wisconsin, Madison, Wisconsin.

Wetzel, R. G., and G. E. Likens. 2000. Limnological analyses. 3rd ed. Springer-Verlag, New York, New York.

Taxonomy

Brandlova, J., Z. Brandl, and C. H. Fernando. 1972. The cladocera of Ontario with remarks on some species and distribution. Canadian Journal of Zoology 50:1373-1403.

Brooks, J. L. 1957. The systematics of North American Daphnia. Memoirs of the Connecticut Academy of Arts and Sciences 13:1-180.

Edmondson, W. T. (ed.). 1959. Freshwater biology. 2nd ed. John Wiley and Sons, New York, New York.

Koste, W. 1978. Rotatoria. Die rädertiere mitteleuropas. Vol. 1. Borntraeger, Berlin, Stuttgart, Germany.

Sandercock, G. A., and G. G. E. Scudder. 1994. An introduction and key to the freshwater calanoid copepods (Crustacea) of British Columbia. Department of Zoology, University of British Columbia, Vancouver, B.C.

Stemberger, R. S. 1979. A guide to rotifers of the Laurentian Great Lakes. EPA 600/4-79-021. U. S. Environmental Protection Agency, Cincinnati, Ohio. Available from http://nepis.epa.gov (accessed 3 April 2013).

Thorp, J. H., and A. P. Covich. 1991. Ecology and classification of North American fresh-water invertebrates. Academic Press, San Diego, California.

Appendix 4: Job Hazard Analysis and Safety Considerations.

OLYMPIC NATIONAL PARK JOB SAFETY ANALYSIS			
JOB TITLE Large Lowland Lakes Monitoring		DATE: 1/16/2013	NEW
TITLE OF PERSON WHO DOES JOB: Ecologist Biological Technician	SUPERVISORS: Steve Fradkin	ANALYSIS BY: Adapted in part from NCCN Mountain Lakes and Water Quality Monitoring protocols.	
LOCATION: OLYM	DIVISION: Resource Management	REVIEWED BY:	
REQUIRED AND/OR RECOMMENDED PPE: See **Recommended Action or Procedure**		APPROVED BY:	

SEQUENCE OF JOB STEPS	POTENTIAL HAZARDS	RECOMMENDED ACTION OR PROCEDURE
Office Work - Computer use for email and data entry, report writing	Muscle and eye strain, repetitive stress injury	Maintain proper posture and use of ergonomic furniture. Take breaks every hour.
Field Work Preparation - Packing and loading gear/equipment	Unpreparedness, straining muscles/back	Use check lists, check radio batteries, pack carefully, prepare itinerary and pack appropriate food, clothing and shelter.
Vehicle Travel - Driving to/from site	Break-downs/Vehicle failure	Be licensed to operate vehicle and be familiar with controls before driving. Pre-operational checks of lights, tires, windows, mirrors, body damage, fluids on ground, vehicle fluid levels, vehicle belts and general vehicle condition. Make sure you have clear vision from windows and mirrors are clean and adjusted. Make sure safety equipment is available and in good condition (first aid kit, fire extinguisher, flares, wheel chocks, tire changing equipment). Make sure seat belts are working and adjusted properly.

Vehicle Travel - Driving to/from site (continued)	Break downs/Vehicle failure (continued)	Make sure engine is operating properly. Do not use a vehicle that is unsafe to operate.
	Driving on highway and unpaved roads to job site	Use Defensive Driving Techniques. Do not drive aggressively. Avoid driving fatigue. Switch drivers when possible or pull off road and rest for a while. Do not drive if not feeling well or on medication or in any condition which could affect judgment. Always drive with headlights on. Stay alert to the type and pattern of traffic around you. Follow all traffic regulations-do not exceed speed limit or tailgate. Watch ahead to anticipate traffic or object hazards and adjust speed accordingly. Make sure you are seen by large trucks and allow them plenty of room for their turning radius. Drive at a safe speed for road, traffic and terrain type. Drive at a safe speed for the type of roadway and its surface conditions. Be alert to changing road conditions and adjust speed and driving techniques accordingly.

Vehicle Travel - Driving to/from site (continued)	Driving on highway and unpaved roads to job site (continued)	Be aware of the capabilities, power and clearance of the vehicle you are operating. If the road ahead is too narrow, rough, muddy, brushy or snow is too deep, do not push vehicle capabilities. Park and walk to destination or use another means of transportation or another route. Watch out for animals, anticipate their actions and slow down or stop. Drive at a speed that is safe for weather and visibility conditions. Carry tire chains for snow and ice conditions and use them. Use visor and sun glasses to shield glare. Keep windshield clean and ensure wipers work properly. Take proper clothing with you in case your vehicle breaks down and you are stranded for a while. Keep window cracked if idling engine for any length of time. Move away from and avoid large trees during windstorms.
	Backing and parking vehicles	Get out of vehicle and walk behind it to look for objects and hazards. Have a passenger be a spotter and guide you. Always face danger with front of vehicle when turning around. Ensure adequate sight distance while turning around i.e., don't turn around on blind corners. Avoid backing down steep grades-especially on loose gravel, snow and ice. Park vehicle in a safe location. Back vehicle in to park.

Vehicle Travel - Driving to/from site (continued)	Backing and parking vehicles (continued)	Ensure there is adequate clearance for passing traffic. Put vehicle in park or lowest gear in direction of roll, set parking brake turn front wheels into curb or cutbank, place chock blocks in front of, or behind tires. Do not park in a truck turn-around.
General Field Hazards	No emergency contact	Carry and use radios. Do radio checks at new jobsites. Check radio contact on daily basis. Carry extra batteries. Know dead zones.
	Getting lost	Have map and compass and other navigational aids and know how to use them. Travel together when off-trail. Make sure members of the team are aware of location, and can find route out if they are separated. When trail hiking, plan stops at trail junctions to regroup. Arrange meeting places and times -all crew members must wear a watch. Have a travel plan for each day and make sure it is understood by all crew members. Stay in communication via radio, voice or stay in sight. If lost, follow prearranged procedures (most likely to stay put). Have emergency equipment (food, shelter, heat, clothing) to survive spending

General Field Hazards (continued)	Getting lost (continued)	time on your own. If lost for a long period, consider moving to an area where you can be seen by helicopter (gravel bar or ridge top). Do not leave your gear if you travel. Do not panic. Have a mental plan for what to do if lost.
	Dehydration/Heat exhaustion	Always carry plenty of water (minimum 1 liter). Replace bodily fluids and salts regularly (every 15 minutes). Rest in cool, shady places during periods of high temperatures.
	Hypothermia	Wear proper equipment- and have extra layers for cold conditions in waterproof bags. Do not rely on cotton clothing for warmth. Remove wet clothing immediately after hiking, carry spare layers in accessible part of pack. Recognize the signs of hypothermia in yourself and others. Have shelter such as tent, sleeping bag or emergency shelter. Have the means to create heat such as matches or a stove. Carry and eat high-calorie foods, stay well-hydrated.
	Wind	Never work in a forested area during high winds when blow down is likely. Never work near burned trees or snags during high winds; watch for falling trees, bark branches. Be aware that standing dead trees become more hazardous through time. Anchor tents and inflatable boats using large rocks and stakes to avoid loss.
	Lightning	Do not stand under trees or next to rock outcrops. Get off ridges and other high points.

General Field Hazards (continued)	Lightning (continued)	Get/stay out of water and away from other conductors. If you are in a vehicle, stay completely inside, don't touch metal parts of vehicles. Turn off electronic devices. Get rid of any metal on your person. If caught in the open or in a tent squat on sleeping pad.
	Illness from Giardia, *E. coli* or other bacteria	Do not drink any water unless it has been filtered, boiled or treated in some fashion. Do not create more contaminated areas- urinate away from streams and water, dig a cat hole for solid waste and bury toilet paper. Wash hands when possible and carry hand cleaner.
	Hazardous animals and plants	Keep updated on specific hazards in your area. Be able to identify hazardous plants. Advise supervisor/co-workers of allergies. Apply proper first aid methods and wash thoroughly following exposure. Be aware of the presence of potentially hazardous animals in your working environment. Be familiar with signs implicating their presence. Keep your distance from animals especially if they act unusual (rabies). Don't touch wild animals. Make noise (radio squelch etc.) if you cannot stay out of the way of bears or other large animals.

General Field Hazards (continued)	Hazardous animals and plants (continued)	Store food in bear safe containers or hang from trees 15 ft. high and 4 ft. from tree and branches.
	Public contact where personal safety is uncertain due to: hostile people, domestic disputes, apparent intoxication or impaired judgment or presence of weapons	Do not make contact. Seek law enforcement assistance. Contact communications center. Position vehicle for easy departure. Leave personal escape routes. Do not get boxed in. Establish personal space
Communications		Establish check-in and check-out procedure prior to field work. Set up procedure with a contact person at communications center Establish overdue procedures. Contact person calls head ranger if overdue. Tailgate safety session before beginning work to reemphasize the hazards and control factors particular to the day's work.
Working from motorboats boats: • Prior to leaving check engine oil, fuel supply, and test engine • Make sure all boat occupants are wearing a pfd. • Proceed to sampling sites • Conduct sampling, stow samples • Proceed back to dock or boat launch. • Dock or trail boat.	• Drowning and hypothermia • Running out of fuel • Engine failure • Falling into water • Contact with moving prop • Boating accident/running into objects.	Be aware of hypothermia, make sure you have access to dry clothing and a heat source. Prior to departure, check engine oil, fuel supply and test engine Warn all boat occupants whenever boat is getting under way or whenever boat speed changes. Warn all occupants not to lean over side of boat. If man-overboard does occur, immediately cut power, navigate to person in water, throw attached pfd device and retrieve person Never place hand/arm/leg in water while engine is on.

Working in Laboratory	Exposure to hazardous chemicals	Review and follow the Lab Hygiene Plan and MSDS sheets before working in the laboratory. Work with another person or notify co-workers if you will be working in the lab alone. Use appropriate personal protective equipment at all times. Keep counter-tops clean and uncluttered.
	Muscle and eye strain, repetitive stress injury	Proper posture and use of ergonomic furniture Take breaks every hour

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS 963/120404.April 2013

National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science
1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

www.nature.nps.gov