



Data Quality Standards for Lake Communities and Ecosystems in Alaska's Arctic Network

Natural Resource Report NPS/ARC/NRR— NPS/ARC/NRR—2018/1723





ON THIS PAGE

Kuzitrin Lake in Bering Land Bridge National Preserve, Alaska.
Photograph by Jon O'Donnell (NPS).

ON THE COVER

Desperation Lake in Noatak National Preserve
Photograph by Jon O'Donnell (NPS)

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Natural Resource Report NPS/ARCN/NRR—2018/1723

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Abstract

The Lake Communities and Ecosystems vital sign is one of 19 vital signs monitored by the National Park Service's (NPS) Arctic Inventory and Monitoring Network (ARCN). In accordance with guidelines set forth by the NPS Inventory and Monitoring Division, this report summarizes data quality standards associated with the monitoring of lake water quality in ARCN parks. This report documents the standards, policies, and procedures for activities related to the collection, processing, storage, analysis, and publication of monitoring data. Components of the report include monitoring activities, sampling design, data quality objectives, and change detection over space and time. The policies described here are consistent with and compliment data quality standards for water quality monitoring across the NPS Inventory and Monitoring Division.

Introduction

The purpose of this report is to document the standards, used by the Arctic Inventory and Monitoring Network (ARCN) for activities related to the collection, processing, storage, analysis, and publication of monitoring data as described in the ARCN Lake Communities and Ecosystems Monitoring Protocol (O'Donnell and Miller 2017 in review). The policies and procedures documented in this quality-assurance plan for activities complement the quality-assurance plans for other monitoring activities conducted by the ARCN and supplement National Inventory & Monitoring Division Quality Management Plan. The plan also serves as a guide for all ARCN personnel who are involved in protocol/program activities and as a resource for identifying memoranda, publications, and other literature that describe associated techniques and requirements in more detail.

Protocol Overview

The ARCN Lake Communities and Ecosystems Monitoring Protocol describes the background, rationale, and sampling design for monitoring large, deep lakes in three of the five ARCN parks: Bering Land Bridge National Preserve (BELA), Gates of the Arctic National Park and Preserve (GAAR), and Noatak National Preserve (NOAT). There are very few large, deep lakes in Cape Krusenstern National Monument (CAKR) and Kobuk Valley National Park (KOVA), thus we focused on lakes in these three NPS units. The main goals of the protocol are to: (1) detect long-term trends in lake thermal regime, (2) detect long-term changes in the chemical composition of lakes, and (3) monitor and evaluate the effects of and implications of physical and chemical changes for lake biota.

The structure of this protocol follows the recommended framework and suggestions of Oakley et al. (2003). The Lake Communities and Ecosystems Monitoring Protocol also describes the sensitivity and vulnerability of aquatic resources within ARCN parks to climate change and disturbance (e.g. permafrost thaw) that are unique to Arctic parklands. Using existing datasets (O'Donnell et al. 2015) and peer-reviewed articles, the protocol establishes that while most lakes are pristine with respect to water quality, climate change and disturbance may alter the physical, chemical, and biological properties of surface waters.

The objective of this monitoring program is to determine annual status and long-term trends for a suite of chemical parameters at a range of intensive monitoring sites throughout the ARCN parks. Discrete water samples will be collected annually at 18 large lakes, and will be analyzed for a broad range of chemical constituents, including carbon, nutrients, and major ions. All samples will be collected during the ice-free season. Lake temperature profiles will be continuously monitored using an array of sensors mounted to a customized lake buoy system. These temperature arrays will allow for the project manager to examine seasonal and annual trends in the lake thermal regime.

Continuous time-series data collected using this protocol will be stored in the National Park Service's (NPS) Integrated Resource Management Applications (IRMA) and analyzed using Aquatic

Infomatics Aquarius software. The primary emphases of the NPS Inventory and Monitoring Program are to secure data for long-term storage, to ensure that results and knowledge obtained from monitoring are communicated in a timely manner, and to maximize understanding in order to best meet park needs. Where appropriate, monitoring results will be shared as broadly as possible with park partners, NPS staff, and the public. Water quality status will be summarized in annual reports and resource briefs at the end of each calendar year. Longer-term trends and/or synthesis reports will be written every three to seven years, depending on the needs of the parks. The synthesis reports will include information from a regional perspective in order to look at landscape-scale changes. Water quality data collected using this protocol will provide a scientific foundation for evaluating ARCN parks.

Protocol Activities and Modules

Under this protocol, discrete water samples for chemical characterization of lake water are collected at 18 large, deep lakes (O'Donnell and Miller 2017 in review). Samples will be collected from both surface waters of the epilimnion and deeper waters of the hypolimnion. Recent evidence indicates that lake chemistry in ARCN parklands is sensitive to permafrost and geology (Larsen et al. 2017), and our monitoring lakes reflect a gradient of these basin characteristics. Continuous temperature arrays will be deployed at two large lakes: Devil Mountain and Kuzitrin Lakes (BELA). Temperature profiles will be analyzed to examine seasonal and annual trends.

Discrete water samples are analyzed for a broad suite of chemical constituents at Oregon State University's Cooperative Chemical Analytical Laboratory (CCAL). Lab managers at CCAL provide NPS personnel with data reports and results of internal quality control/quality assurance (QA/QC) measures. Data collection and data handling procedures are carried out by ARCN personnel.

Data are collected as part of five separate activities or modules. These data collection activities are summarized in Table 1 below for the following activities:

1. Field Measurements and Site Reconnaissance: Data generated from *in situ* measurements conducted during site visits.
2. Collecting Discrete Water Samples: Describes different types of water samples collected for laboratory analyses.
3. Laboratory Analyses: Describes different types of laboratory analyses conducted on water samples collected from monitoring locations.
4. Continuous Monitoring of Core Water Quality Parameters: Includes any data collected by the sensor, information associated with sensor deployment and retrieval, or post-processing.
5. External data: Data collected and managed by cooperators (e.g., USGS).
6. QA/QC data. Data collected and managed as a part of the protocol when it is to be used as a part of a QC process.

Table 1. Protocol activity matrix for Lake Communities and Ecosystems monitoring in the Arctic Inventory & Monitoring Network (O'Donnell and Miller 2016).

Category	Activity #	Activity	Description
Field Measurements and Site Reconnaissance	1	Core water quality parameters	Discrete measurement of four core water quality parameters across lake depth profiles are conducted at all monitoring sites.
	2	Secchi depth	Secchi depth measurements will be conducted at all sites, as described in SOP: Field Measurements.
Collecting Discrete Water Samples	3	Filtered sample	This sample is collected using a Geotech Peristaltic Pump and 0.45-micron high-capacity capsule filter and is stored in a 500-mL HDPE Nalgene bottle. The sample can be frozen until shipped to CCAL, where it will be analyzed for dissolved nitrogen and phosphorus species, base cations, and anions.
	4	Dissolved organic carbon (DOC)	This sample is collected using a Geotech Peristaltic Pump and 0.45-micron high-capacity capsule filter and stored in a 125-mL amber glass bottle. The sample is refrigerated and shipped as soon as possible to the USGS for analysis of DOC concentration.
	5	Unfiltered sample	This unfiltered sample is collected using a Geotech Peristaltic Pump (without filter attached) and is stored in a 250-mL HDPE Nalgene bottle. The sample can be frozen until shipped to CCAL, where it will be analyzed for total nitrogen, phosphorus, and alkalinity.
	6	Dissolved inorganic carbon (DIC)	This sample is collected (unfiltered) in a 60-mL syringe with luer-lock tip fitted to a three-way stopcock. The sample is kept refrigerated and shipped immediately to CCAL for analysis of DIC concentration.
	7	Chlorophyll a	This sample is collected by filtering 500 mL of lake water through a GF/F filter in the field. The filter is then shipped to CCAL for analysis of chlorophyll a concentration.
Laboratory Analyses	8	Organic carbon	DOC concentration is determined by oxidative combustion and infrared analysis on a Shimadzu TOC-VCSH at CCAL.
	9	Dissolved inorganic carbon	DIC concentration is determined by acidification, sparging, and infrared analysis on a Shimadzu TOC-VCSH at CCAL.

Table 1 (continued). Protocol activity matrix for Lake Communities and Ecosystems monitoring in the Arctic Inventory & Monitoring Network (O'Donnell and Miller 2016).

Category	Activity #	Activity	Description
Laboratory Analyses (continued)	10	Nitrogen species	All N species are measured at CCAL. Total nitrogen (TN) and total dissolved nitrogen (TDN) are determined by persulfate digestion followed by colorimetric analysis on a Technicon Auto-Analyzer II. Nitrate + nitrite are determined by the cadmium reduction method. Unionized ammonia is determined following the phenate method.
	11	Phosphorus species	All P species are measured at CCAL. Total P (TP) and total dissolved P (TDP) are determined using the persulfate digestion method followed by colorimetric analysis on a Technicon Auto-Analyzer II. Soluble reactive phosphorus (SRP) concentration is determined using the ascorbic acid method.
	12	Base cations	All cations are measured at CCAL. Calcium, magnesium, potassium, sodium and total iron concentrations are all measured using flame atomic absorbance spectroscopy.
	13	Anions	All anions are measured at CCAL. Chloride and sulfate are analyzed using ion chromatography on a Dionex 1500.
	14	Alkalinity	Alkalinity is determined at CCAL by titrating to a pH of .5 on a ManTech PC-Titrate Auto Titrator System.
	15	Chlorophyll a (seston)	Chlorophyll a is determined using spectrophotometric methods.
Continuous Monitoring of Lake Temperature Profiles	16	Temperature	Annual checks using a NIST-calibrated thermistor.
QA/QC Data	17	Quantifying bias and variability of water samples	Field blanks are collected across a range of condition to assess bias due to possible contamination of water samples. Replicate samples are collected from a subset of monitoring sites to quantify variability in sample collection and analysis.
	25	Analytical sensitivity of laboratory methods	For each chemical analysis, CCAL has provided data for method detection limits (MDL), minimum level of quantification (ML), and precision (http://ccal.oregonstate.edu/detection). MDL is three times the standard deviation of a low level standard. ML is 3.18 times the MDL.
	26	Data sonde calibration	Multi-parameter sonde sensors calibrated prior to conducting measurements.

Table 1 (continued). Protocol activity matrix for Lake Communities and Ecosystems monitoring in the Arctic Inventory & Monitoring Network (O'Donnell and Miller 2016).

Category	Activity #	Activity	Description
QA/QC Data (continued)	27	Data editing	Continuous temperature data outliers and uncorrectable fouling conditions manually removed from record using USGS ADAPS system or Aquarius system. Data shifts made in accordance with procedures described in Wagner et al. (2006).
	28	Data quality assessment	Data verification is conducted to ensure that data are free of transcription or coding errors, and that all documentation is correct. Data review is conducted to ensure that lab results are reasonable. Data validation is conducted by CCAL to determine the specific quality of a data set.
	29	Site representativeness	All samples will be collected from the deepest section of the lake, and will be representative of pelagic zone conditions.

Sampling Design

Information regarding the sampling design is provided in **Error! Reference source not found..**

Table 2. Activity-level sample design matrix for Lake Communities and Ecosystems monitoring in the Arctic Inventory & Monitoring Network (O'Donnell and Miller 2016). Numbers (left column) match those in the Protocol Activity Matrix (Table 1).

Category	Activity #	Activity	Sampling Design	Revisit Design
Field Observations	1	Core water quality parameters	Targeted following initial pilot study results reported in O'Donnell et al. (2015).	Revisit annually; Take every fourth year off for data analyses and writing.
	2	Secchi depth	Targeted following initial pilot study results reported in O'Donnell et al. (2015).	Revisit annually; Take every fourth year off for data analyses and writing.
Collecting Discrete Water Samples and Laboratory Analysis	5	Filtered sample	Targeted following initial pilot study results reported in O'Donnell et al. (2015).	Revisit annually; Take every fourth year off for data analyses and writing.
	6	Dissolved organic carbon (DOC)	Targeted following initial pilot study results reported in O'Donnell et al. (2015).	Revisit annually; Take every fourth year off for data analyses and writing.
	7	Unfiltered sample	Targeted following initial pilot study results reported in O'Donnell et al. (2015).	Revisit annually; Take every fourth year off for data analyses and writing.
	8	Dissolved inorganic carbon (DIC)	Targeted following initial pilot study results reported in O'Donnell et al. (2015).	Revisit annually; Take every fourth year off for data analyses and writing.
	9	Chlorophyll a	Targeted following initial pilot study results reported in O'Donnell et al. (2015).	Revisit annually; Take every fourth year off for data analyses and writing.

Table 2 (continued). Activity-level sample design matrix for Lake Communities and Ecosystems monitoring in the Arctic Inventory & Monitoring Network (O'Donnell and Miller 2016). Numbers (left column) match those in the Protocol Activity Matrix (Table 1).

Category	Activity #	Activity	Sampling Design	Revisit Design
Continuous Monitoring of Core Water Quality Parameters	7	Temperature	Targeted; two lakes selected to due unique features (Devil Mountain Lake is a maar lake) and access (Kuzitrin Lake can readily accessed from Nome or Kotzebue.	Revisit only as needed

Data Quality Objectives

Data quality values and standards for implementation are provided in Table 3 through Table 5.

Table 3. Data Quality Values (DQVs) for continuous water quality monitoring in the Arctic Inventory & Monitoring Network (O'Donnell and Miller 2017).

Category	Data Quality Value	Definition	Protocol Considerations
Intrinsic Data Quality	Accuracy	Measurements reflect the true value of the parameter being observed. This applies to measures (length, width, position) or classes (species, types, or categories). Includes components of precision and bias.	All chemical analyses are determined using standards prepared using high-quality reagents. Labs use methods following EPA standards. Sondes sensors are calibrated in a laboratory environment in accordance with methods described in <i>SOP: Instrument Calibration</i>). Continuous monitoring is of lake temperature is conducted following methods of Wagner et al. (2006).
	Representativeness	Measurements represent conditions at the time of sampling. Combined with accuracy, leads to repeatable data collection.	Water samples are collected at representative locations of large lakes reflecting pelagic zone conditions.
Contextual Data Quality	Comparability	At all monitoring sites, data are collected using identical water sampling and field monitoring equipment. All sites are monitored on a consistent schedule using standardized procedures.	Instrumentation, standard operating procedures, calibration procedures, and routine maintenance schedule is identical for all continuous monitoring stations. Data management and editing is conducted in accordance with standard operating procedures that are consistent between stations.

Table 3 (continued). Data Quality Values (DQVs) for continuous water quality monitoring in the Arctic Inventory & Monitoring Network (O'Donnell and Miller 2017).

Category	Data Quality Value	Definition	Protocol Considerations
Contextual Data Quality (continued)	Timeliness / Currency	Discrete field measurements and water samples for chemical analyses are collected annually during the ice-free open-water season. While field measurements are available right away, lab results are typically not available for up to six months following sample submission. Continuous temperature monitoring data are collected year-round, and are available in real-time.	Data verification, review, and validation of field measurements and water chemistry are conducted in the fall/winter. Chemistry data reports from USGS or CCAL typically take six months to receive from the time of sample submission. Data certification will be completed annually. Continuous data are available in real time, following transmission from remote stations via Iridium satellite technology.. All continuous data importing, management, and editing is conducted in the fall following retrieval. Data certification will be conducted on an annual basis for all three monitoring stations. Where certified data cannot be provided for resource management decisions in a timely manner, requirements for provisional use of data are defined and documented prior to data dissemination and use.
	Completeness	All data/ measures required to evaluate accuracy representativeness are present; incomplete data sets (either at a location, across sampling locations, or over time) lose utility or relevance. Data records contain values as planned across the period of record.	Methods, sampling plans, and analyses are designed and implemented such that they result in a complete dataset across space and the planned period of record. Note that this value is for a collection of data records; how many measures are deemed valid and suitable for use at the completion of all QA/QC procedures.
Representational Data Quality	Consistent Representation	Use of standard definitions when describing data quality or resource quality based on data	Standard definitions of data quality are provided. Provisional data indicate data that have been reviewed but not certified. Certified data are defined as those data that have been reviewed, QA/QC checked, and edited in accordance with procedures described in SOPs. Data are reported and flagged in comparison to established management, ecological, or regulatory thresholds in accordance with procedures described in O'Donnell and Miller (2017 (in review)).

Table 3 (continued). Data Quality Values (DQVs) for continuous water quality monitoring in the Arctic Inventory & Monitoring Network (O'Donnell and Miller 2017).

Category	Data Quality Value	Definition	Protocol Considerations
Data Accessibility	Secure	Access to data, products, and systems limited to appropriate audiences.	Field observations, discrete water chemistry, and continuous water quality data are all stored and managed in the NPS IRMA (https://irma.nps.gov/Portal) No protected data will be generated as part of the ARCN Lake Communities and Ecosystems Monitoring Protocol.

Table 4. Measurement Quality Objectives for Lake Communities and Ecosystems monitoring protocol in the Arctic Inventory & Monitoring Network (O'Donnell and Miller 2016). Activities (shaded cells) match those in the Protocol Activity Matrix Table (Table 1). Accuracy, range, and resolution standards from YSI, Inc. (2009).

Category	Measure / Quality Indicator	Quality Objective
Site Establishment	Location Accuracy	Monitoring sites have been established following pilot studies (O'Donnell et al. 2015). GPS coordinates and ARCN park unit maps are available for all monitoring sites.
	Location Description Detail	Maps, narrative directions, and site access descriptions are included in field folders for each continuous sampling location.
pH (cross-sectional and continuous measurements)	Units	standard pH units
	Accuracy	+/- 0.2 units
	Resolution	0.01 units
	Range	0 to 14 units
	Reporting	Report to one decimal place.
	Calibration/Data Correction Criteria	+ 0.2

Table 4 (continued). Measurement Quality Objectives for Lake Communities and Ecosystems monitoring protocol in the Arctic Inventory & Monitoring Network (O'Donnell and Miller 2016). Activities (shaded cells) match those in the Protocol Activity Matrix Table (Table 1). Accuracy, range, and resolution standards from YSI, Inc. (2009).

Category	Measure / Quality Indicator	Quality Objective
pH (cross-sectional and continuous measurements) (continued)	Maximum allowable discrepancy from field meter	± 2
Temperature (cross-sectional and continuous measurements)	Units	degrees Celsius (°C)
	Accuracy	+/- 0.15°C
	Resolution	0.01°C
	Range	- 5 to 50 °C
	Reporting	Report to one decimal place
	Calibration/Data Correction Criteria	+ 0.2
	Maximum allowable discrepancy from field meter	± 2.0
Dissolved Oxygen (cross-sectional and continuous measurements)	Units	milligrams per liter (mg/l)
	Accuracy	+/- 1%
	Resolution	+/- 1%
	Range	0 to 50 mg/l
	Reporting	Report to one decimal place
	Calibration/Data Correction Criteria	+ 0.3
	Maximum allowable discrepancy from field meter	± 2.0 or 20%, whichever is greater

Table 4 (continued). Measurement Quality Objectives for Lake Communities and Ecosystems monitoring protocol in the Arctic Inventory & Monitoring Network (O'Donnell and Miller 2016). Activities (shaded cells) match those in the Protocol Activity Matrix Table (Table 1). Accuracy, range, and resolution standards from YSI, Inc. (2009).

Category	Measure / Quality Indicator	Quality Objective
Specific Conductivity (cross-sectional and continuous measurements)	Units	microsiemens per centimeter [$\mu\text{S}/\text{cm}$])
	Accuracy	0.5% within calibrated range
	Resolution	1 $\mu\text{S}/\text{cm}$
	Range	0 to 100,000 $\mu\text{S}/\text{cm}$
	Reporting	Report to whole number
	Calibration/Data Correction Criteria	+ 5 or + 3% of the measured value, which-ever is greater
	Maximum allowable discrepancy from field meter	$\pm 30\%$

Table 5. Data Protection standards for Lake Communities and Ecosystems monitoring in the Arctic Inventory & Monitoring Network (O'Donnell and Miller 2017 (in review)). With the exceptions noted, all data collected are to be made publicly available in a timely fashion.

Type of Data	Level of Protection	Rules for Dissemination
Water Quality Data and Information		
Water Quality Data	Unprotected	Data available on-line as public information.
Water Quality Data	Operationally protected	Data provided without reference to sensitive species proximity.
Location Data and Information		
Permanent Sampling Locations	Operationally protected	Provided upon request only. Shown in reports
Personally Identifiable Information		

Change Detection

The primary goal of the Lake Communities and Ecosystems vital sign is to detect changes in lake properties over time. As part of the vital sign protocol, we will monitor 23 different water quality parameters, and most of these parameters will be measured at a minimum of two different depths. Preliminary data indicate that variability in chemical parameters is considerably higher across lakes than within a given lake (O'Donnell et al. 2015). For instance, lake DOC concentration is highly variable across lakes (mean $\pm$ standard deviation = 4.5 ± 3.0 mgC L⁻¹), but less variable within a given lake (e.g., Devil Mountain Lake: 2.8 ± 0.4 mgC L⁻¹). Mean DOC concentration across lakes is highest in White Fish Lake in BELA (11.2 mgC L⁻¹) and lowest in Walker Lake in GAAR (1.3 mgC L⁻¹). Similarly, calcium concentration is highly variable across lakes (17.2 ± 17.7 mg L⁻¹), but less variable within a given lake (e.g., Devil Mountain Lake: 7.0 ± 1.1 mgC L⁻¹). The spatial patterns in lake chemistry are likely due to variability in landscape characteristics (e.g., permafrost, hydrology; Larsen et al. 2017). Thus, detecting patterns in lake chemistry over space should be relatively straightforward. To detect change within a given lake over time, we would expect a deviation greater than or less than one standard deviation of the historical mean.

Whereas the ARCN Shallow Lake monitoring program was designed to detect change at the regional level by sampling large numbers of small lakes (of which there are 1000s in the region; Larsen et al. 2011), the Lake Communities and Ecosystems vital sign is designed more for detecting change within a limited number of large, deep lakes within the ARCN parks. These lakes were selected not only for their size but for the unique character (e.g., maar lakes in BELA), link to prior research (e.g., Feniak Lake in NOAT), subsistence and recreational use (e.g., Walker Lake in GAAR), and proximity to areas of anthropogenic disturbance (e.g., Nutavukti Lake, Lake Selby in GAAR).

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