

Protocol Development Summary

6 December 2007

Protocol: Lakes Ecosystems

Parks Where Protocol Will be Implemented: BELA, CAKR, GAAR, KOVA, NOAT

Justification/Issues being Addressed:

More than three hundred thousand acres of ARCN is covered by freshwater lake ecosystems. These lake ecosystems are underlain by continuous or discontinuous permafrost and represent a great range of depths, shapes and trophic states. Most lakes in ARCN are formed by the actions of ice and include shallow thaw-ponds, deep glacial lakes, large maar lakes formed by explosions of magma, and oxbows adjacent to meandering rivers. Physiographic location, connectedness and depth play a large role in determining lake food web structure, thermal budgets and water chemistry in many high latitude lakes, and will likely determine lake response to local, regional and climatic stressors.

There are several important differences between deep and shallow lakes in ARCN that will shape our monitoring plan for lake ecosystems. Large deep lakes are generally formed by major geologic events, whereas shallow lakes tend to be formed over shorter time scales with much higher rates of formation and extinction. Basins of most large deep lakes in ARCN were formed by glacial processes over the last 700,000 years. In Bering Land Bridge, the basins of four deep maar lakes were formed as rising magma met water and ice, resulting in massive explosions of steam that created large craters. These rare volcanic lakes were created from 17,000 to over 100,000 years before present and represent the largest maar lakes on the planet.

By contrast, most lakes in ARCN are shallow thaw ponds and oxbow lakes that are in a dynamic equilibrium with their environment, forming, filling in, draining and refilling over relatively short periods of time. The basins of shallow thaw ponds are generally formed as a result of thermal degradation of near surface permafrost and are supported by the existence of a deeper permafrost layer. Changes in active layer depth will have a profound effect on the formation and drainage of these lakes. Oxbow lakes are formed from meandering rivers following natural channel migration. Increased temperatures and an acceleration of the hydrologic cycle at higher latitudes may have significant impacts on the rates of formation and infilling of shallow lakes. Recently, several studies have documented unprecedented rates of change in the formation and disappearance of many shallow high latitude lakes (Smith et al 2005, Riordan 2004, White et al 2007, Yoshikawa and Hinzman 2003).

Other differences between large and shallow lakes in ARCN include patterns of use by humans and wildlife. Large and deep lakes are easily accessed via float plane and some are regularly used by sport and subsistence fishermen and recreational users.

Because large deep lakes do not freeze solid, they can support large populations of overwintering fish. The ARCN contains several lakes considered to be of particularly exceptional value, either because of their national designations, the historical datasets associated with them, or both.

Shallow lakes provide important habitat for aquatic primary producers, macroinvertebrates, and secondary consumers such as beavers, birds and fish. Due to their relatively large surface area to volume ratio and lack of thermal stratification, shallow arctic lakes are particularly susceptible to changes in climate and nutrient input. During winter when average temperatures are less than minus forty degrees Fahrenheit, shallow arctic lakes typically freeze to the bottom (Hobbie 1984). If these shallow lakes are not connected to deeper water bodies, macroinvertebrate community diversity will be limited to freeze-tolerant species and fish will be precluded. When fish are not present in these shallow lakes, several large-bodied macrozooplankton species may persist. Connection to deeper water bodies plays a large role in structuring biological communities of shallow lakes in ARCN.

During summer, water temperatures in shallow lakes increase rapidly, creating a thaw bulb surrounding the lake. As this thaw bulb increases in size, thermokarst erosion of the shoreline and ebullition of methane to the atmosphere may also increase. The lack of thermal stratification in shallow lakes can make them extremely susceptible to wind events, causing wind-mixing of sediments into the watercolumn and shoreline erosion. Over time these processes may result in significant changes in lake surface area, bathymetry and biogeochemistry, and ecology.

Over the past thirty years, average air temperature in the Alaskan arctic has increased by 2.1 degrees Celsius and global change models predict that future warming will impact the northern polar region most severely (IPCC 2007). Increasing temperature in the arctic has been associated with thawing of permafrost, melting of mountain glaciers, increasing rain and snowfall (Gleick 2000), and the disappearance of many shallow high latitude lakes (Smith et al 2005, Riordan 2006). Deposition of contaminants such as mercury, heavy metals, sulfur, nitrogen and persistent organic pollutants may also cause large changes in lake biology and process.

Specific Monitoring Questions and Monitoring Objectives to be Addressed by the Protocol:

1. What are the long-term trends in erosion along shorelines surrounding deep and shallow lakes? Estimate area of shoreline affected by thermal, wind and ice-erosion; documentation via repeat photography. **Justification:** Erosion alters nutrient availability and lake surface area which has consequences for the rest of the lake ecosystem.
2. What are the long-term trends in morphology and connectedness of deep and shallow lakes?

Ground-based estimates of changes in surface area and continuous monitoring of water levels.. **Justification:** Lake surface area can increase or decrease with shoreline erosion, thermokarsting and lake draining. Recent studies have documented high rates of change in the formation and disappearance of many shallow high latitude lakes. Ground-based measures of changes in lake surface area will provide high-resolution ground truthing for remotely sensed imagery. Seasonal estimates of variation in lake water-level will provide information regarding availability of fish habitat, and surrounding ecosystem attributes.

3. What are the long-term trends in seasonal water temperatures including the presence, timing and strength of thermal stratification in shallow and deep lakes?

Estimate seasonal variation in water temperature and midsummer stratification in intensively studied shallow and deep lakes. **Justification:** Both stratification and the timing and magnitude of peak water temperatures influence a wide variety of physical, chemical and biological lake characteristics. During studies conducted in the 1950's (Livingstone 1958) and 1970's (O'Brien et al 1974) less than 5% of lakes sampled in July were thermally stratified. More recent studies indicate that greater than 90% percent of lakes sampled in ARCN were thermally stratified during July.

4. What are the long-term trends in methane production from intensively studied shallow and deep lakes?

Estimate ebullition of methane. **Justification:** Methane production from arctic lakes is a significant portion of the global atmospheric methane budget and may be a source of significant feedback to atmospheric climate warming (Walter et al. 2006). Methane production is closely tied to temperature.

5. How are the physical and chemical constituents of lake ecosystems changing?

Measurements of traditional suite of water quality, chemical parameters, UV, and photosynthetically-active radiation (PAR). **Justification:** Parameters such as dissolved oxygen, pH, alkalinity, conductivity, turbidity, color, terrigenous carbon, and dissolved organic carbon have high relevance for fish, nutrient status, productivity, light availability and linkages with permafrost and shorelines.

6. What are the long-term trends in presence of hydrocarbons in large water bodies accessible by float plane?

Estimate levels of hydrocarbons in surface water using UV fluorescence. **Justification:** Presence of hydrocarbons can affect absorbance of photosynthetically active radiation and can have a wide range of effects on biological components. Large lakes accessible by float plane may have a higher potential for hydrocarbon spills.

9. What are the long-term trends in the community structure of algae, diatom and zooplankton assemblages in water-columns of deep and shallow lakes?

Estimate community composition of algae, diatom and zooplankton assemblages **Justification:** Algal primary productivity and community structure is a key ecosystem attribute of lakes. Diatom community composition is a good indicator of

nitrogen deposition, loss of acid neutralizing capacity in lakes, and local mining effects (Baron et al. 2000). Zooplankton community composition is both a good indicator of physical and chemical conditions and itself an important biological element of lake ecosystems. Because the silica cell walls of diatoms do not decompose, diatom communities found in lake sediment cores can serve as proxies for historical environmental change dating back to the Pleistocene, thereby providing context for the current variability of diatom community composition within lakes (Baron et al. 2000, Williamson et al. 200).

10. What are the long-term trends in composition and cover of littoral vegetation? Estimate percent cover of macrophytes in lake littoral zones. **Justification:** Macrophytes can be used as indicators of water quality, trophic status, absorbance of PAR, and rates of lake-infilling. Macrophytes provide important substrates for periphyton growth, important food sources and cover for benthic macroinvertebrates and fish.

Basic Approach:

To develop lake monitoring protocols we will rely on several collaborative, working relationships. When feasible we will adopt the Central Alaska Network protocols for monitoring lake water quality and quantity in shallow lakes and Jacqueline LaPerriere's (2004) protocols for monitoring deep lakes. We will work with Dr. Chris Luecke, a limnologist at Utah State University with extensive experience in arctic lake ecology, to further develop monitoring protocols and to incorporate protocols used by the National Ecological Monitoring and Assessment Program. Development of additional standard operating procedures for monitoring methane ebullition and surrounding active layer depth will be aided through collaborations with Katey Walter (UAF) and Guido Grosse (UAF). We will also work with technical photographer and computer scientist, Arthur Brody, to design a virtual monitoring outreach program that not only provides scientists and the general public with raw, visual and acoustic evidence of status and trends, but also provides a visual context for traditional water quality measurements.

Principal Investigators and NPS Lead:

We will collaboratively develop protocols through a cooperative agreement with Dr. Chris Luecke, Watershed Sciences, Utah State University (5210 Old Main Hill, Logan, UT, 84322). NPS Leads will be Dr. Greta Burkart, aquatic ecologist, ARCN Inventory and Monitoring Program, NPS (907-455-0669) and Dr. Amy Larsen, aquatic ecologist, Alaska Regional Inventory and Monitoring.

Development Schedule, Budget, and Expected Interim Products:

NPS leads will work with Dr. Chris Luecke to develop standard operating procedures ready for external peer review by March 2008. We plan to implement protocols for deep and shallow lakes in BELA during spring and summer 2008. We have budgeted \$60,000 for protocol implementation in FY2008.