



Water Quality

Lakes integrate water, energy, nutrients, sediments, and pollutants from the surrounding land and air. Therefore, lake water quality can be a useful indicator of broad-scale stressors, such as climate change. High-latitude lakes are projected to become not only warmer as a result of climate change, but also more turbid, more enriched in nutrients and organic matter, and more productive. These changes have the potential to impact the growth, survival, and reproduction of aquatic organisms, such as salmon, and also the terrestrial organisms that rely on them. The Southwest Alaska Network monitors several lake water quality parameters, including temperature, pH, conductivity, and dissolved oxygen. Of these parameters, temperature is particularly important because all the other parameters are directly related to it.



Lake Clark (left) and Kontrashibuna Lake (right) viewed from Tanalian Mountain, Lake Clark National Park and Preserve.

Findings

The Southwest Alaska Network (SWAN) monitors water temperature hourly and year-round in five lakes: Naknek Lake and Lake Brooks in Katmai National Park and Preserve, and Lake Clark, Kijik Lake, and Telaquana Lake in Lake Clark National Park and Preserve. Our monitoring relies on the use of programmable data loggers attached at various depths on moored vertical lines called *temperature arrays*. Preliminary results indicate that surface water temperatures are warming during the period of record at all temperature arrays except Telaquana, which was deployed in 2017 and therefore lacks sufficient data for estimating trends. Surface temperatures were particularly warm in Katmai

National Park and Preserve during the 2016 field season (Figure 1), frequently exceeding the State of Alaska's water quality threshold for fish migration and rearing areas (15°C). For example, 881 hours exceeded 15°C logged at the 5 m depth in the North Arm of Naknek Lake in 2016, compared with 73 hours in 2015. Likewise, 795 hours exceeded 15°C from the 5 m depth in Lake Brooks in 2016, compared with 11 hours in 2015. It is unlikely that juvenile sockeye salmon were adversely affected by the exceedances in 2016, since they typically migrate to deeper waters during the warmest hours of the day. Nonetheless, the warming trend—consistent across all arrays at the 5 m depth—is noteworthy.



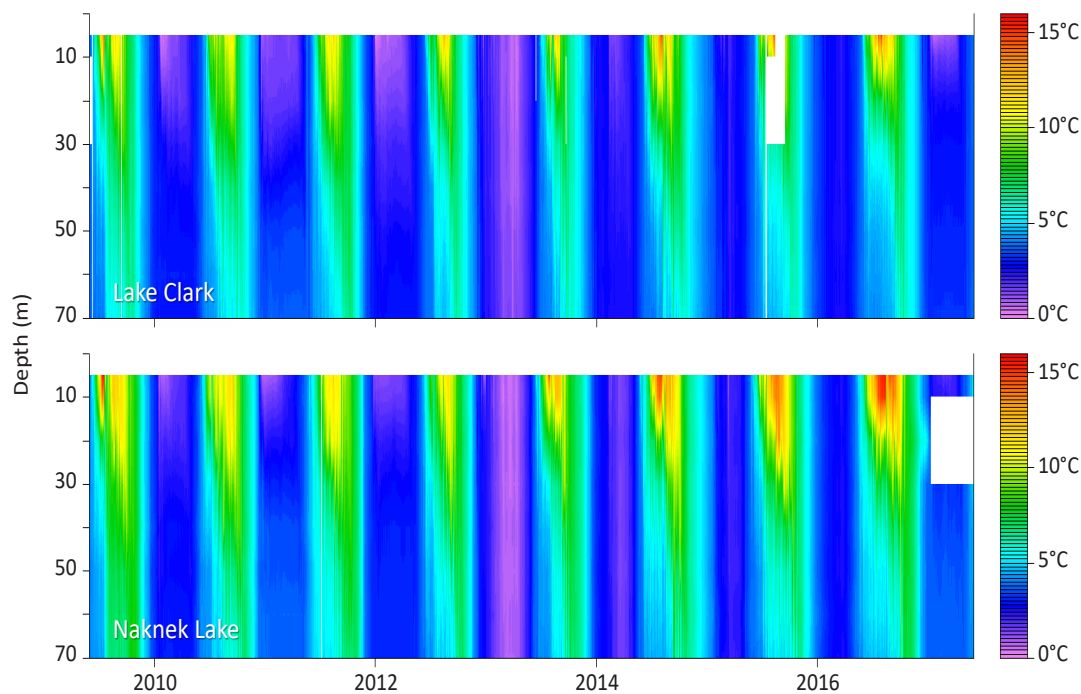


Figure 1. Average daily water temperatures (°C) from 5 to 70 m depth in Lake Clark and the North Arm of Naknek Lake, based on temperature array data from 2010 to 2017. Missing data (in white) indicate logger failures at one or more depths. According to the State of Alaska's water quality standards (<http://dec.alaska.gov/water/wqsar/wqs/>), the upper temperature limit for fish migration and rearing habitat is 15°C.

Methods

We use several approaches to monitor water temperature, ranging from year-round measurements at targeted locations to once-a-year measurements at randomly selected sites. These measurements rely on various types

of equipment. For example, temperature arrays are deployed at seven sites continuously; multi-parameter sondes are deployed at two sites seasonally, and are used at an additional 70+ sites annually (Figure 2).

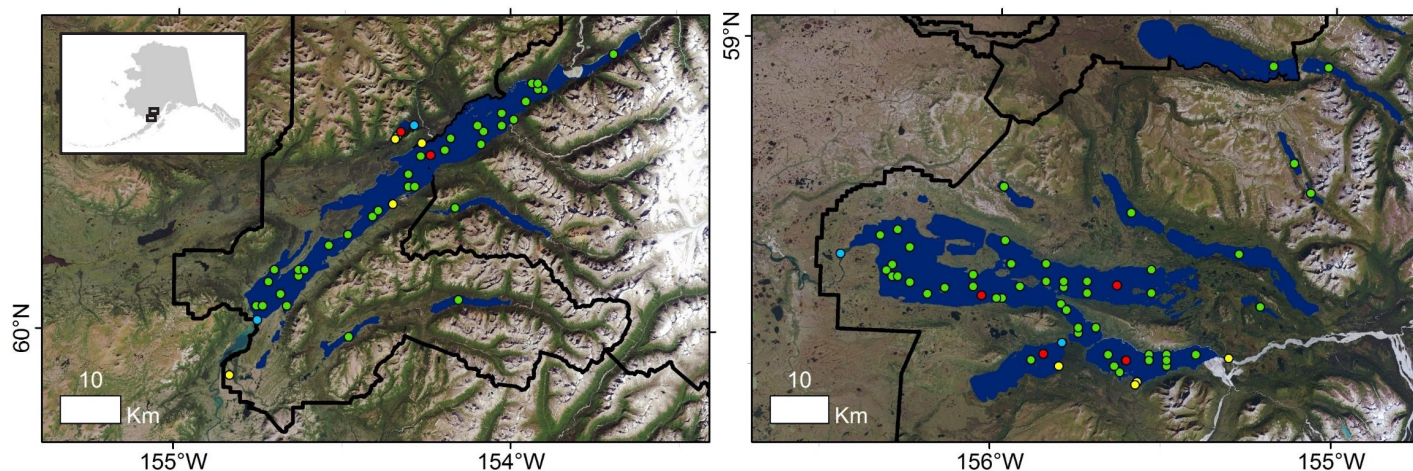


Figure 2. SWAN water temperature monitoring sites in Lake Clark (left) and Katmai (right) national parks and preserves. Red dots indicate mid-lake sites where temperature arrays are deployed continuously; green dots signify mid-lake sites where sondes are used annually; blue dots represent lake outlet sites where sondes and other types of temperature sensors are deployed seasonally or longer; and yellow dots indicate lakeshore or tributary sites where various types of temperature sensors are deployed continuously. Park boundaries are depicted in black (some outlying sites are not shown).

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