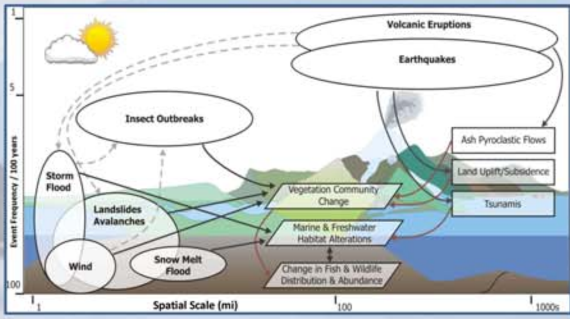
Evaluating Effects of Atmospheric and Geologic Disturbance on a Southwest Alaska Lake

Claudette Moore, Southwest Alaska Network, National Park Service, King Salmon, AK
Dan Young, Lake Clark National Park and Preserve, Port Alsworth, AK
Jeff Shearer, Southwest Alaska Network, National Park Service, Anchorage, AK

Introduction

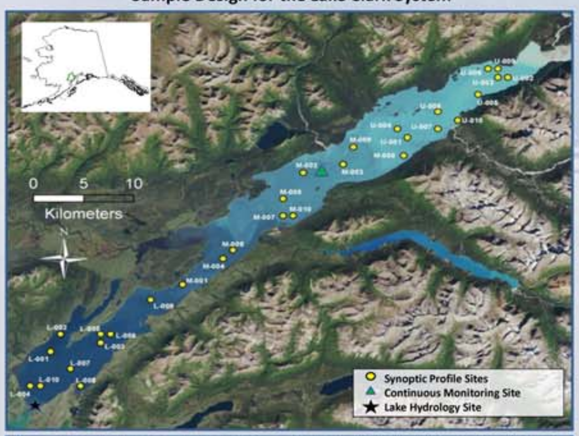
Lake systems have been identified as sentinels of environmental change because they integrate the impacts of terrestrial and atmospheric disturbances over time (Williamson et al 2009). Lake systems are well defined, provide measureable physical, chemical and biological indicators that can be monitored with a high degree of sensitivity, and extend over a wide geographic range enabling researchers to investigate the spatial and temporal effects of environmental change (e.g., changes in temperature, freeze-up/break-up and glacial extent). The Southwest Alaska Network (SWAN) aquatic systems are represented by two of the largest lakes in the National Park System, Naknek Lake (58,824 ha) in Katmai National Park and Preserve and Lake Clark (31,117 ha) in Lake Clark National Park and Preserve. The objectives of the SWAN freshwater monitoring program are to estimate inter-annual variability in water quality parameters throughout the water column and across lake basins and to determine trends in timing, duration, and magnitude of summer lake hydrology. Herein, we present examples of how Lake Clark has respond to environmental disturbance and how these signals are reflected in inter-annual variability. When integrated with emerging data from other vital sign monitoring, including landscape processes, glacial extent and climate/weather, we can begin to assess cause and effect relationships across the landscape and quantify spatial and temporal changes within these lake systems.

Spatial and Temporal Disturbance Considerations in SWAN Park Units



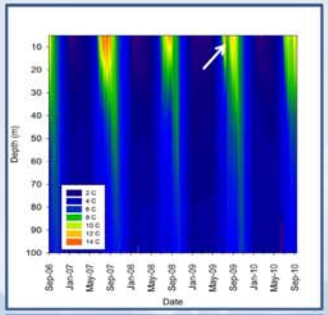
Schematic depicting the scale and frequency at which physical disturbances interact and influence habitat conditions within southwest Alaska.

Sample Design for the Lake Clark System

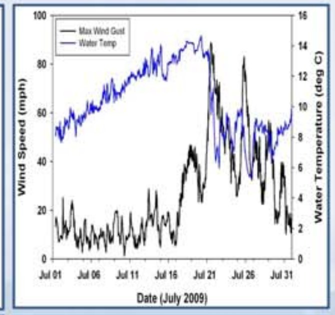


Water quality and hydrologic sample site distribution overlaid onto a IKONOS Landsat image of Lake Clark. The seasonal advance and retreat of a turbidity plume generated from glacial inputs plays a large role in dictating lake temperature dynamics, primary productivity, and fish distribution.

Effects of Regional Weather Disturbance



Lake Clark isotherm depicting seasonal temperature stratification and periods of isothermy. The 2009 large-scale wind event is clearly visible (white arrow).



High wind recorded July 2009 and subsequent Lake Clark water temperature decline as a result of wind generated vertical mixing.

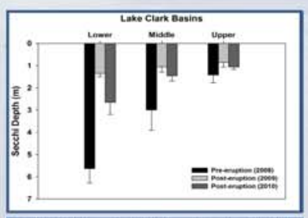
- Lake Clark, similar to other lakes within the region, is a discontinuous cold polymictic lake characterized by seasonal ice cover, periods of stratification, and frequent mixing.
- Wind-generated mixing from regional storm events play a large role in disrupting summer thermal stratification patterns.

Effects of Geologic Disturbance

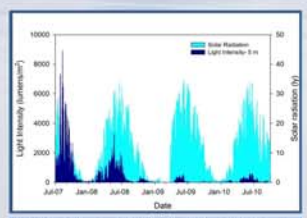
The Tlikakila River delta forms the boundary between Lake Clark (right) and Little Lake Clark (left). The Tlikakila River is the largest tributary in terms of discharge to Lake Clark.

Mt. Redoubt in Lake Clark National Park shortly after spring 2009 eruptions. Volcanic ash appears as a gray blanket covering the landscape.

- Glacial silt, primarily from the Tlikakila River, generates a turbidity gradient along the length of Lake Clark. The extent of this gradient is largely dictated by snow pack and glacial melting and subsequent runoff into Lake Clark.
- The April 2009 eruptions of Mt. Redoubt distributed an estimated 0.07 km^3 of volcanic ash on the landscape. Above average spring temperatures resulted in rapid snow melting generating a large 'flush' of volcanic ash into Lake Clark, homogenizing turbidity conditions throughout the lake.



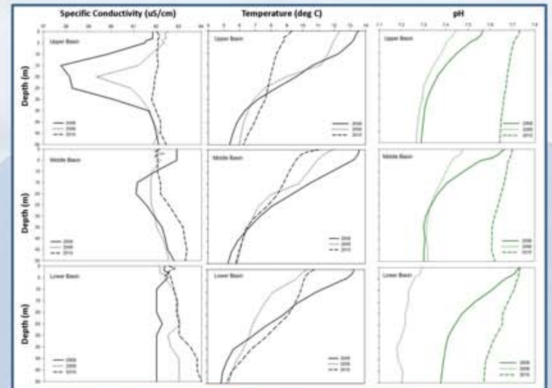
Secchi depth (i.e., water clarity) conditions for Lake Clark before and after the eruption of Mt. Redoubt.



Light intensity recorded at 5 m depth in central basin of Lake Clark and nearby solar radiation displaying inter-annual variability of water clarity conditions pre- and post-eruption.

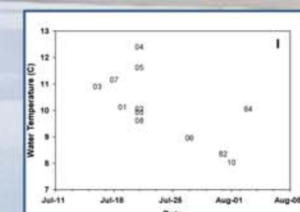
Inter-annual Variability – Physical

In-situ water quality measurements are collected during a mid-summer index period. Vertical profile date measured between 2008 and 2010 from upper, middle and lower basins display both spatial and temporal variability across vertical profiles for specific conductivity, temperature and pH. This variability is a result of complex interactions between within lake circulation patterns, thermal mixing, and tributary inputs from differing sources (e.g., glacial vs. non-glacial).

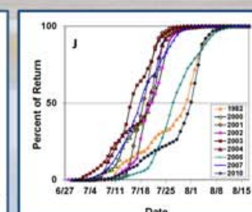


Physical Control on Salmon Escapement

Water temperature is one of the physical controls on sockeye salmon (*Oncorhynchus nerka*) returns to Lake Clark. Data collected from the Newhalen River (Lake Clark outflow) show an inverse relationship with temperature (I). In cold water years, salmon returns are delayed by one to two weeks (J).



Relationship between water temperature and the date at which 50% of sockeye salmon have returned to the Newhalen River system. Numbers on the graph correspond to a return year (e.g., '06' for 2006).



Sockeye salmon return timing in the Newhalen River system, Lake Clark.

Summary

The physical, chemical and biological conditions documented in Lake Clark to date indicate the complexity of monitoring these large lake systems and suggest that the range of limnological intra- and inter-annual variability can be substantial. Short- and long-term disturbance can result in a sudden shift in lake condition. Return to pre-disturbance conditions may be seasonal as recorded in Lake Clark water temperature or may take several years as observed water clarity. These observations reinforce the importance of proper sampling design when evaluating limnological trends.

Literature Cited

C.E. Williamson, J.E. Saros, W.F. Vincent, and J.P. Smol. 2009. Lakes and reservoirs as sentinels, integrators, and regulators of climate change. Limnology and Oceanography 54:2273–2282.