SOUTHEAST ALASKA WATERSHED COALITION
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Management Applications of Regional Freshwater Temperature Data for Southeast Alaska

PURPOSE

We are providing a set of justifications and recommendations for creating and maintaining a freshwater temperature monitoring network in Southeast Alaska to garner support and long-term commitments from regional partners. We have an unprecedented opportunity to collect critical baseline data that will allow us to accurately assess the rate of change of our region's watersheds in response to changing climate patterns before the problem looms larger. Managers and researchers in the lower 48 missed out on this opportunity.

To quote a *Climatic Change* paper (Isaak et al. 2011) from the western U.S.:

"One of the strongest conclusions we can make from this study is that long-term and representative monitoring of river and stream temperatures has been grossly inadequate."

In Southeast Alaska, we can strategically design a water temperature network and beat that problem if we act soon.

CONTENTS

The sensitivity of water temperature to watershed condition makes it a valuable parameter and critical tool for assessing and tracking land use and climate impacts to freshwater habitat for salmon and other aquatic life. Water temperature patterns are influenced by climate, landscape features, land use, and stream channel characteristics, such as gradient and width. As a result, water temperature reflects changing streamflow patterns, urbanization, riparian forest condition, and groundwater connections. (Photo courtesy of C. Sergeant)

Why is water temperature important?

Water temperature is one of the most significant factors in the health of freshwater ecosystems because of its influence on water chemistry and biological activity. Since temperature affects growth rates of aquatic plants, invertebrates, and fishes, warmer water can increase the overall productivity of the aquatic food web. However, as water warms, its capacity to hold dissolved oxygen decreases and reduces the amount available for respiration. Some compounds (e.g. copper, mercury) become more toxic to aquatic life at warmer temperatures.

WATER TEMPERATURE AFFECTS SALMON BY INFLUENCING:

- migration timing
- egg survival
- oxygen availability
- metabolism
- susceptibility to disease

For Pacific salmon, the influence of water temperature is pervasive. Timing of life history events, like spawning, emergence, and smolting, are adapted to prevailing environmental conditions and are driven largely by temperature. For adult salmon, high temperatures can slow or prevent migration, increase susceptibility to disease and cause stress or outright death. As such, changing temperature patterns have the potential to alter the suitability of waterbodies for salmon populations.

In the near term, shifts in temperature patterns could be good or bad for Alaska's salmon, so it is important for scientists to sort out these responses. For example, in Southeast Alaska, declines in egg and sperm viability have been observed in Pink salmon when stream temperatures exceed 15°C during the spawning migration. Partly due to warming water, Coho salmon currently return to Auke Creek to spawn 17 days earlier than they did in the 1970s. However, increased summer temperatures in Auke Lake increased the biomass of juvenile Coho and Sockeye salmon smolts the following fall, implying that moderately higher temperatures will positively affect some salmon life history stages while negatively impacting others.

Shifts in the timing of Pacific salmon populations returning to Southeast Alaska watersheds may be one adaptive response to changing thermal conditions in streams and lakes. (Photo courtesy of National Park Service)

Management applications of regional water temperature data

REGIONAL PLANNING

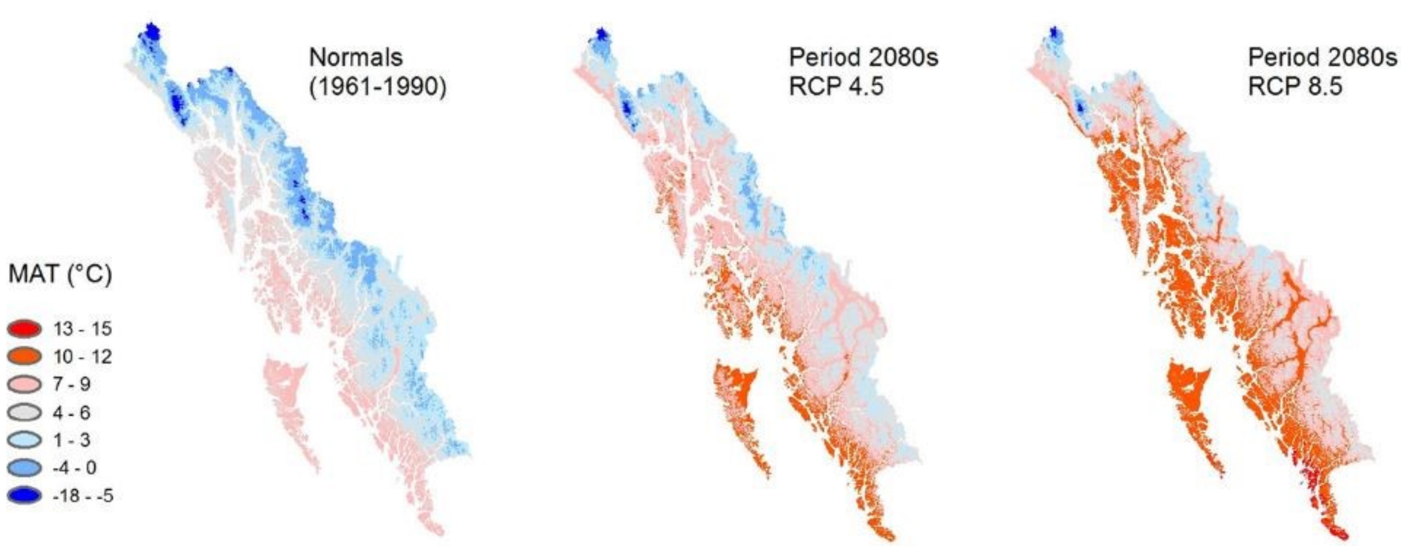
Long-term records of climate and hydrology in Southeast Alaska are sparse. The National Climate Data Center has climate datasets for nine weather stations, primarily located at airports, that are at least 70 years long. Long-term river discharge records are available at 12 locations. Based on these data, since 1920 average annual air temperatures have increased (0.05°C/decade) with winter temperatures changing fastest (0.15°C/decade). River discharge records show increased flow in winter, which suggests the impacts of air temperature warming may be resulting in a decline in snowpack storage in lieu of rainfall runoff, and possibly more rain-on-snow events.

Like much of Alaska, the Southeast region is projected to warm considerably by 2100 (3-8°C), with much of this warming occurring in winter (4.6°C). Mean annual precipitation is expected to increase 30-50%. Climate models suggest that below-freezing temperatures and snowfall will become increasingly rare. In Juneau and other locations in Southeast, mean winter temperatures are projected to rise from below freezing to well above freezing in the next few decades, potentially leading to little or no snowpack, except at the highest elevations. This will affect hydrologic cycles since winter runoff is likely to increase even more and less snowpack will be available to feed spring and summer runoff.

Managers need an understanding of changing thermal patterns and the implications for freshwater resources to set strategic goals and to answer these types of questions:

- How can we improve degraded aquatic habitats so that they will be more resilient to future climate conditions?
- Should conservation efforts prioritize currently productive areas with desirable thermal patterns or target areas that may be productive in the future?
- Will the timing window of instream work need to be shifted and how will that change the timing of hiring seasonal workers?

By developing regional-scale stream temperature datasets, we can explore how stream flows and temperature regimes interact and develop an understanding about future thermal suitability for aquatic organisms, including Pacific salmon. As snowpack contributions diminish in the future, summer base flow will likely decrease in non-glacial streams, which may result in sharper increases in summer water temperatures and increase the risk for critically low dissolved oxygen levels during salmon spawning season; however, glacial systems will respond differently. A broad network of temperature sites provides a landscape view of thermal response across diverse aquatic habitats.



From Shanley et al. 2015: A map series of potential climate change showing the current mean annual air temperature (MAT) compared to corresponding projections for the 2080s (2071–2100; 30-year normal period) from the IPCC CMIP5 scenarios RCP 4.5 and RCP 8.5. The map includes the coastal temperate rainforest of Southeast Alaska and northern coastal British Columbia, Canada.

Management applications of regional water temperature data

REGULATORY CONTEXT

Due to the critical role that water temperature plays in the function of aquatic ecosystems and because human activities may impact temperature, the Alaska Department of Environmental Conservation has adopted maximum water temperature criteria under Alaska's Water Quality Standards (18 AAC 70) to meet the federal Clean Water Act's fishable and swimmable goals. For the growth and propagation of fish, shellfish, other aquatic life, and wildlife, instantaneous uppermost thermal tolerances are defined relative to life history stages (see below).

ALASKA'S

WATER TEMPERATURE CRITERIA

The following maximum temperatures shall not be exceeded, where applicable:

egg & fry incubation = 13°C

spawning areas = 13°C

migration routes = 15°C

rearing areas = 15°C

and may not exceed 20°C at any time.

To apply these criteria, we need up-to-date life history information. The Alaska Department of Fish and Game's Anadromous Waters Catalog (AWC) specifies life history and species details for over 19,000 waterbodies in Alaska. This number is believed to represent less than 50% of all waterbodies used by anadromous species. With a commitment to annual AWC updates, we are moving towards a more effective tool for applying water temperature criteria based on catalogued life history information.

With an improving catalog of fish use, a robust regional picture of current thermal patterns, and an understanding of which stream types are most likely to exceed water temperature criteria (temperature sensitive streams) now and in the future, regulators, permit applicants, and the public will have better information to base technical decisions on during project design and the permitting process.

INVASIVE SPECIES

Particularly in Southeast Alaska where northern range extension is expected for an increasing number of species, understanding how shifting temperature regimes will facilitate invasive species movement will be important. Few freshwater aquatic invasive species are currently known to occur in Southeast Alaska, but those that do, as well as those that may show up in the future, pose a threat to freshwater habitat. Reed canary grass (*Phalaris arundinacea*) and Bohemian knotweed (*Fallopia x bohemica*) are highly invasive plants, widely distributed in the region, and thrive in both aquatic and riparian habitat. The red-legged frog (*Rana draytonii*) is the only freshwater aquatic invasive animal known in the region. Waterweed (*Elodea spp.)* has not yet been found in the lakes of Southeast Alaska.

Tracking the changing thermal landscape will help managers prioritize where rapid eradication actions are needed and where containing an infestation's distribution is more realistic. Waterbodies that are naturally vulnerable to new species invasion, because of watershed connectivity or frequent human-related vectors, may not be the best areas for costly eradication methods, but may be priority locations for preventative measures. Alternatively, eradicating new invasive species that arrive through human vectors may be worthwhile in watersheds with persistent and increasingly important cold-water habitat.

Invasive infestations like Bohemain knotweed (pictured) can form dense monocultures in riparian corridors and impact functions that support fish. By competing with native trees, which provide a taller and fuller canopy, invasive shrubs can reduce riparian shade potential

Management applications of regional water temperature data

RIPARIAN CONDITION

An effective way to keep streams as cool as possible is to minimize their exposure to direct sunlight. Numerous studies from Southeast Alaska, where timber harvest has been ongoing for decades, have shown that clear-cuts and the removal of riparian vegetation can increase maximum summer temperatures. Both federal and state policies now include the protection of riparian buffers in fish-bearing streams during timber harvest to retain shade; however, riparian restoration from urban and road development in addition to forestry activities is still an important management tool to maintain stream temperature.

Managers must now consider the additive effect of a changing climate on water temperatures when prioritizing when and where to restore, protect or modify the riparian corridor. Having an understanding of stream sensitivities to warming and baseline information to model future patterns allows us to evaluate the potential benefits of restoration actions on future stream temperature patterns and plan accordingly. Appropriate restoration activities may also change. Decisions about which riparian species to plant could factor in growth rate potential in changing climate conditions for maximum effectiveness to influencing thermal patterns in the next 20 years. In temperature sensitive systems, stricter protective measures on intact stream corridors may be needed. Riparian management can become a tool far beyond restoring degraded habitat to a past condition and develop into a proactive management technique to mitigate future temperature increases.

TIMING WINDOWS

The timing of instream restoration or construction work is scheduled to occur between smolt outmigration/fry emergence in the spring and adult returns in the late summer. If changing water temperature shifts migration timing, as it has for Coho salmon returning to spawn in Auke Creek, adjustments might be needed to the traditional timing windows for instream work. Importantly, shifts in migration timing will be very species- and stream-specific, so data from many systems will help hone the work windows that will best protect salmon populations. Managers will benefit by having this information for project planning, permit applications, and hiring of field/construction crews.

FISH PASSAGE

Road crossings and other artificial barriers can impede fish passage into more thermally suitable habitat. In addition to the number of miles a restoration project might open up, managers need to consider the current and future thermal condition of that upstream habitat. Small tributaries may become increasingly important as cold-water refugia; improving fish passage to colder upstream habitat could be a key metric for prioritizing restoration projects or designing new stream crossings.

By integrating regional temperature data with the Alaska Department of Fish and Game's Fish Passage Improvement Program and the Fish Resource Monitor interactive map, we can create a powerful tool to assess the thermal benefit of restoring fish passage into upstream habitat.

FISHERIES

Our ability to discern the environmental factors driving trends in freshwater survival of salmon is extremely limited. In many Southeast Alaska streams, biologists use weirs and fish wheels to monitor adult migration back into freshwater, but rarely are the number of juveniles leaving a system counted. As a result, when unexpectedly low returns occur, unfavorable marine conditions are often blamed. If we can account for the effects of thermal conditions on rearing and out-migrating fish we can start factoring in freshwater impacts on salmon populations.

Regional stream temperature data across a diverse array of watersheds will allow fisheries managers to consider the existing and future thermal impacts to juvenile salmon. Current efforts by the Auke Bay Laboratories (NOAA Fisheries) to forecast Pink salmon harvest in Southeast Alaska already incorporates summer ocean temperature into their models. For Chinook, Sockeye and Coho salmon, which have a longer freshwater life history phase, the annual variation of instream temperatures may be a valuable parameter to model subsequent adult return years.

Management applications of regional water temperature data

CONSERVATION

As we gain a broader picture of the thermal landscape in Southeast Alaska, we can target conservation and protection measures to help keep high-value, high-functioning freshwater habitats intact. In some cases the management tools that mitigate existing human impacts (e.g. loss of riparian habitat and wetlands, lack of connectivity, increased impervious cover) may be effective at mitigating climate change impacts as well; however, more targeted protection measures may be critical in more temperature sensitive streams. For example, groundwater plays an important role in moderating temperatures. Restoring and/or protecting groundwater connections, which support cold-water refugia and over-wintering habitat, will increase resilience to changing temperature patterns. These groundwater connections should be considered particularly during new road construction, which has the potential to disrupt near surface flow paths.

Additionally, since landscape features and watershed characteristics influence stream temperatures, tributaries within the same watershed may have distinctly different thermal profiles. Creating intensive stream and lake monitoring networks within a high priority watershed can identify small but important habitat features that benefit salmon yet might be missed in a coarser-scale monitoring program. Land managers can then work with private landowners through land trust organizations or through state/federal land management plans to protect these critical locations.

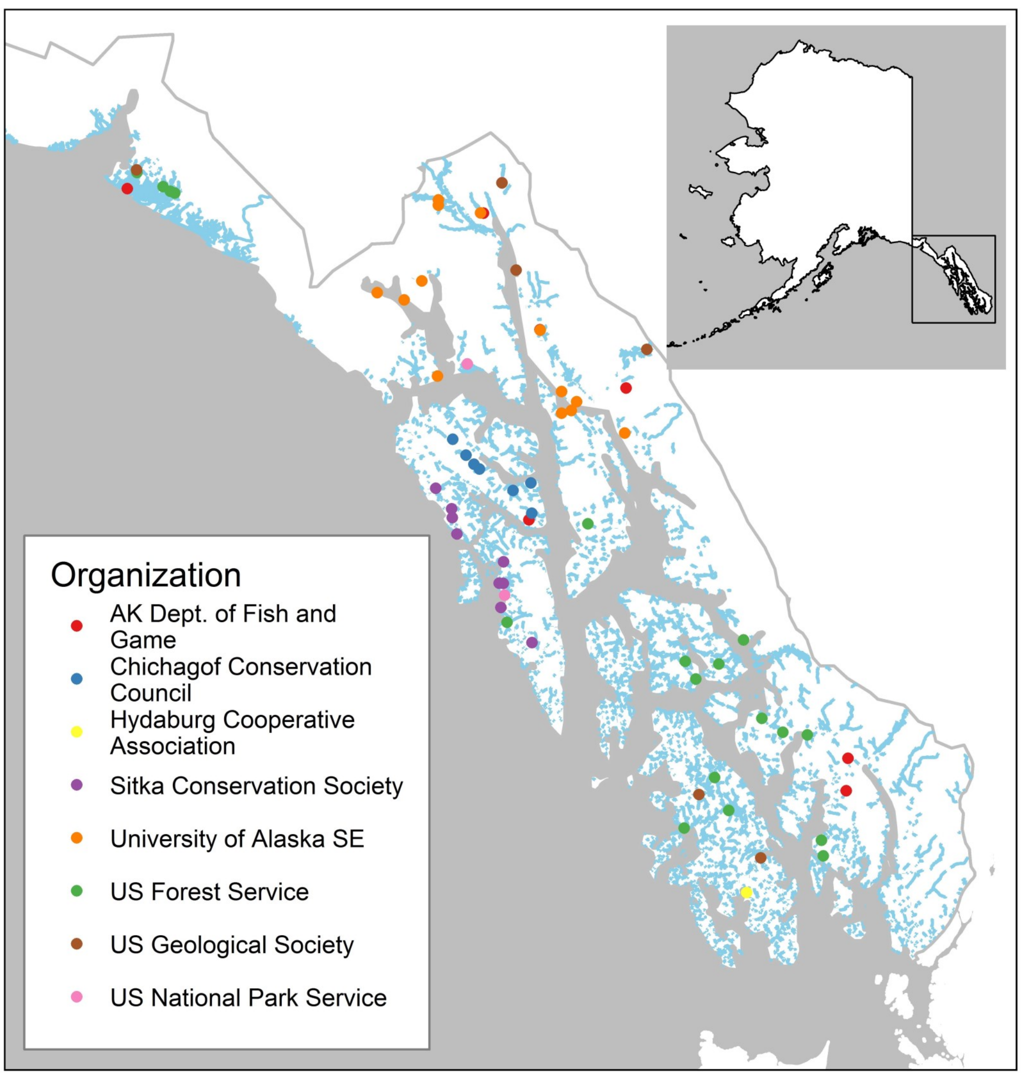
These targeted conservation strategies, when coupled with a precautionary approach of maintaining habitat connectivity and complexity and salmon's inherent life history diversity and evolutionary potential, will help the long-term viability of Southeast Alaska's salmon populations.

SUMMARY OF JUSTIFICATIONS FOR A REGIONAL WATER TEMPERATURE NETWORK	
MANAGEMENT APPLICATION	JUSTIFICATION
Regional planning	Tool for setting conservation and restoration goals and planning for changing thermal patterns and the implications for freshwater resources
Regulatory context	Provides regulators, permit applicants, and the public with better information for decision-making during project design and the permitting process
Invasive species	Understanding the thermal landscape will help managers prioritize where rapid eradication actions are needed and where containing an infestation's distribution is more realistic
Riparian condition	Tool for assessing if riparian protection and/or restoration activities can mitigate future temperature increases in sensitive streams
Timing windows	Valuable for tracking whether shifts in salmon migration timing require that adjustments be made to the traditional timing windows for instream restoration or construction work
Fish passage	Improving fish passage to colder upstream habitat could be a key metric for prioritizing restoration projects or designing new stream crossings
Fisheries	Annual variation of instream temperatures may be a valuable parameter to model trends in freshwater survival of rearing and out-migrating fish as well as subsequent adult return years
Conservation	Protecting groundwater connections, which support cold-water refugia and over-wintering habitat, can increase resilience to changing temperature patterns

Current status of regional data collection

With funding from the North Pacific Landscape Conservation Cooperative in 2016, the Southeast Alaska Watershed Coalition (SAWC) is coordinating a new effort to develop a regional freshwater temperature monitoring network with a broad array of partners. Although individual entities are currently monitoring water temperature at more than 60 locations in Southeast Alaska (see map), we have found that data-collecting methods vary and archived data are difficult to access. For example, federal and state agencies each have their own protocols for data collection and data management while Tribal and non-governmental organizations work under individual quality assurance project plans (QAPPs). Additionally, there has been no strategy to monitor important environmental variability in the region. As SAWC helps to build a strategic network and support partner efforts to collect comparable water temperature data in Southeast Alaska, we will need future funding support to ensure that the data are useful and accessible to management agencies, researchers, and local stakeholder communities.

With the recent development of minimum standards for stream temperature data collection in Alaska (see Mauger et al. 2015), Southeast Alaska partners have clearer guidance for collecting comparable datasets that can be compiled and synthesized across agencies and organizations to understand broader regional patterns. By meeting these minimum standards, partners can collect data potentially useful for both their project-specific needs as well as for other resource managers and decision makers, now and in the future, thus gaining a greater return on their monitoring investment. Freshwater temperature monitoring networks are now in place in Cook Inlet, Bristol Bay, and the Kodiak Archipelago.



Stream temperature assessments are increasingly prevalent in the scientific literature, while regional lake assessments are lagging behind perhaps due to the cost of vertical arrays and the logistics to support continuous lake monitoring. Since the justifications for stream and lake temperature monitoring are similar, we anticipate that the Southeast Alaska network will add more lake sites to the network as regional partners build their capacity.

Current locations of active water temperature monitoring sites managed by multiple agencies, community organizations and Tribal entities in Southeast Alaska (information provided by M. Winfree).

Recommendations for a successful regional network

Regional collaborative networks are growing in Alaska as resource managers seek cost-effective and strategic solutions to meet their needs for science-based decision-making. In Southeast Alaska, we can learn from the successes of other monitoring networks in the region, like the Southeast Alaska Tribal Toxins (SEATT) Network and the National Park Service's Southeast Alaska Inventory & Monitoring Network (SEAN), as well as other water temperature monitoring networks across the state. Based on a review of these networks, we recommend designating a network coordinator, leveraging existing programs and priorities, formalizing responsibilities and staffing needs, and planning for public access to the data (see the complete list of recommendations below).

The model used in the Cook Inlet, Bristol Bay, and Kodiak Archipelago regions includes having a designated network coordinator who works with existing data collectors, builds new capacity with local groups, and finds resources to fill data gaps to maintain a regional sampling design. The network coordinator could be a data collector or a contractor hired to fill the coordinator duties. This dedicated position could rotate among partners based on annual capacity.

In addition to staffing requirements, partners must identify or develop a data management system. Most federal agencies have a data structure, metadata requirements, and data evaluation process already in place (see Sergeant et al. 2013, Toohey et al. 2014). Other agencies, Tribal entities, and community organizations with various capacities can build on existing efforts to compile metadata and archive data. For example, the Alaska Online Aquatic Temperature Site (AKOATS), managed by the Alaska Center for Conservation Science at the University of Alaska Anchorage, is an online inventory of temperature monitoring locations. It provides minimum metadata standards (the "who" and the "where" of the data) as well as details about the methods used to collect the data. The Southeast Alaska GIS Library, a Southeast Alaska-specific library of spatial data maintained by the University of Alaska Southeast, has offered to archive water temperature data for the region. We recommend all Network partners take advantage of these searchable and publically discoverable metadata and data portals.

RECOMMENDATIONS FOR A SUCCESSFUL REGIONAL WATER TEMPERATURE NETWORK	
Designate a network coordinator to:	• Build data-collecting capacity among partners • Ensure the use of minimum data collection standards • Assess annual needs of each partner and provide communication across the network to meet those needs • Engage with state-wide efforts to share data, analysis techniques and management applications • Provide annual reporting to funders and partners
Leverage funding opportunities by:	• Connecting data collection and network design to existing management priorities • Collaborating on new multi-partner proposals
Formalize partner support through:	• A network memorandum of understanding • Designating roles and responsibilities among partners and within agencies/organizations • Commitments of dedicated staff time and travel to maintain sites and office time to perform data logger accuracy checks and data management
Prioritize data management by:	• Submitting metadata annually to the Alaska Online Aquatic Temperature Site (http://accs.uaa.alaska.edu/aquatic-ecology/akoats) • Archiving temperature data in the Southeast Alaska GIS Library (http://seakgis.alaska.edu)

Commitments needed from Southeast Alaska partners

The goal of the Southeast Alaska Freshwater Temperature Network is to collect water temperature data which meet the information needs of individual partners while simultaneously generating data that contributes to an understanding of regional temperature patterns and trends. Partners will benefit from shared resources, combined expertise, shared responsibilities, unified strategy, consistency of methods, and collective results.

Partners should anticipate a commitment of annual resources, particularly staff time and travel costs, to perform quality assurance protocols, maintain monitoring sites, and manage and archive data after the initial purchase of monitoring equipment. To assess regional variability and trends, we request a minimum of three years of data collection, although five years is preferred, to capture the range of annual variability for each site. After 3-5 years, a regional analysis can provide insight into which subset of sites should serve as regional index locations with a long-term goal of at least 20 years of data collection.

A network memorandum of understanding will provide confirmation of each partner's commitment and accountability to ensure a successful collaborative effort. With these commitments, we will be able to accurately assess the rate of change of Southeast Alaska's watersheds and the implications for freshwater resources, thus providing managers with better information for decision-making.

Potential partners participated in a training session in May 2017 to learn about minimum data standards and tips for site selection. (Photo courtesy of J. Kayser Forster)

Water temperature data collection is relatively easy with the availability of low cost data loggers, which offer good accuracy and reliability, and can be left instream year-round. (Photo courtesy of Sitka Conservation Society)

COMMITMENTS NEEDED FROM NETWORK PARTNERS:

- Support for staff time for field and office tasks
- Support for transportation costs to monitoring sites at least once per year
- Meet minimum data collection standards, including upgrading equipment, to ensure the quality and comparability of temperature data
- Update and submit site-specific metadata annually to the Alaska Online Aquatic Temperature Site (AKOATS)
- Submit metadata and quality-controlled temperature data to be archived with the Southeast Alaska GIS Library

Select references

We have provided a short reference list with an emphasis on Southeast Alaska-based studies, current climate change research, and stream temperature data collection methods for Alaska:

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