Stream Temperature Action Plan

Steps to protect
Alaska's wild salmon habitat
from the impacts of thermal change

August 2012

2024 Progress Report

Compiled by
Cook Inletkeeper

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Progress Report: December 2024

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Introduction

The purpose of the 2012 Stream Temperature Action Plan[1] was to identify the highest priority actions for the next 5-10 years that would lead to greater protection of Alaska's wild salmon habitat as thermal change continues. By implementing these priority actions in data collection, protection, and research in the Cook Inlet watershed and across Alaska and through collaboration and coordinated discussions, we hoped to achieve the following goals:

1. improve our understanding of current thermal regimes in Alaska's salmon streams;
2. refine data collection for fisheries management and modeling applications;
3. target cold water habitat protection efforts;
4. fill stream network data gaps; and
5. direct relevant fisheries and habitat research.

Much has been accomplished since 2012 with new partners across the state, more data collection, and a growing understanding of Alaska's freshwater thermal conditions. This progress report attempts to capture what has been achieved collectively to help inform the creation of a new Freshwater Temperature Action Plan to guide strategic actions for the next 10 years.

The original statement of need for the 2012 Stream Temperature Action Plan remains true today. Alaskans are witnessing the greatest warming of any region in the United States[2], and Alaska's salmon are experiencing the effects of global climate change across the full range of their habitat - from streams to sea and back[3]. Water temperature plays a critical role in all phases of the salmonid lifecycle, especially in freshwater systems where fish hatch from eggs and later return to spawn. Warm stream temperatures are frequently associated with increased stress in fish, making them increasingly vulnerable to pollution, predation and disease[4]. Because temperature plays a critical role in salmonid reproduction and survivorship - and because wild, healthy salmon support vital sport, commercial, subsistence and personal use fisheries across Alaska - there is a pressing need to assess water temperatures in Alaska's stream habitats. Without such basic information, it is impossible to gauge the health of salmon habitats and resources, and equally difficult to develop management responses to improve watershed resiliency to climate change.

[1] Mauger, S. 2012. Stream Temperature Action Plan: Steps to protect Alaska's wild salmon habitat from the impacts of thermal change. Cook Inletkeeper, Homer, Alaska. 10p.

[2] (CIFAR) Cooperative Institute for Arctic Research. 2000. Impacts of Climate Change in the United States: Alaska. Cooperative Institute for Arctic Research, University of Alaska, Fairbanks.

[3] Taylor, S.G. 2008. Climate warming causes phonological shift in Pink Salmon, *Oncorhynchus gorbuscha*, behavior at Auke Creek, Alaska. Global Change Biology 14: 229-235.

[4] Richter A. and S.A. Kolmes. 2005. Maximum temperature limits for Chinook, coho, and chum salmon, and steelhead trout in the Pacific Northwest. Reviews in Fisheries Science, 13:23-49.

Goal 1: Improve our understanding of current thermal regimes in Alaska's salmon streams.

Issue: Despite the critical role temperature plays throughout the salmonid lifecycle, we have very limited, and poorly accessible, water temperature data for salmon streams in Alaska.

Solution: We will never be able to monitor all freshwater systems in Alaska due to their vast number and remoteness but, by carefully designing regional assessments that capture gradients of watershed characteristics across larger landscapes, we can describe the range of current natural variability in stream temperature profiles. We need to establish a set of minimum standards to ensure sufficient data quality so data sharing and interpretation is possible between assessments. And finally, we need a state-wide online resource to identify where data are available.

Objective 1: Monitor temperatures across the full range of the most important environmental gradients that affect thermal regimes to understand current variation among streams.

Progress:

- Completed regional assessment of Cook Inlet stream temperatures (48 streams, 2017)[5]
- Completed regional assessment of Southeast stream temperatures (49 streams, 2018)[6]
- Completed assessment of thermal regimes in Mat-Su basin streams (68 sites, 2019)[7]
- Initiated new monitoring networks in Bristol Bay (2014)[8], Kodiak Archipelago (2014)[9], Southeast Alaska (2019)[10], Copper River (2023)[11]
- Regional assessment of Bristol Bay water temperature data funded and in progress
- Statewide meta-analysis of known monitoring sites identified significant data gaps in Yukon and Kuskokwim regions (2019)

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[5] Mauger, S., R. Shaftel, J.C. Leppi and D.J. Rinella. 2017. Summer temperature regimes in southcentral Alaska streams: watershed drivers of variation and potential implications for Pacific Salmon Canadian Journal of Fisheries and Aquatic Sciences. 74: 702–15. cjfas-2016-0076

[6] Winfree, M., E. Hood, S. Stuefer, D. Schindler, T. Cline, C. Arp, and S. Pyare. 2018. Landcover and geomorphology influence streamwater temperature sensitivity in salmon bearing watersheds in Southeast Alaska. Environmental Research Letter. 13:064034

[7] Shaftel, R., S. Mauger, J. Falke, D. Rinella, J. Davis, and L. Jones. 2020. Thermal diversity of salmon streams in the Matanuska-Susitna Basin, Alaska. Journal of the American Water Resources Association. https://doi.org/10.1111/1752-1688.12839.

[8] Mauger, S. and T. Troll. 2014. Implementation Plan: Bristol Bay Regional Water Temperature Monitoring Network. Cook Inletkeeper, Homer, AK and Bristol Bay Heritage Land Trust, Dillingham, AK. 21 pp.

[9] Pyle, B., H. Finkle, T. Dodson and T. Lance. 2014. Strategic plan for voluntary, network-based monitoring of water temperature of salmon habitat in the Kodiak Archipelago, Alaska. US Fish and Wildlife Service, Kodiak National Wildlife Refuge, Kodiak, AK.

[10] Bellmore, R. and M. Winfree. 2019. Southeast Alaska Freshwater Monitoring Network Implementation Plan. Funding provided by the North Pacific Landscape Conservation Cooperative.

[11] Copper River Watershed Temperature Monitoring Locations: https://www.arcgis.com/apps/dashboards/207fa1f794cd48699761bf8d67287226

Objective 2: Develop minimum standards to ensure sufficient data quality and facilitate more data sharing among agencies and organizations.

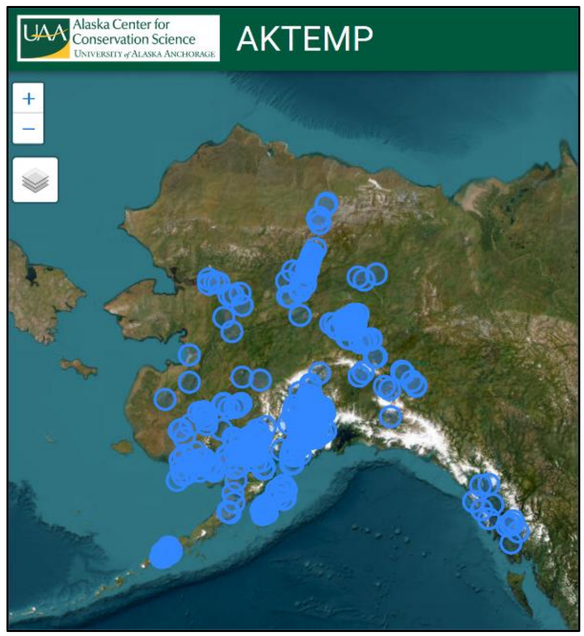
Progress:

- Published minimum standards for Alaska, including data logger accuracy and range, data collection sampling frequency and duration, site selection, logger accuracy checks, data evaluation, file formats, metadata and data sharing (2015)[12]
- Developed recommendations and minimum standards for the selection, accuracy, placement, maintenance, and retrieval of water temperature data loggers (2014)[13]
- Agency-specific protocols published by NPS (2015)[14] and USGS (2014)[15]

Objective 3: Create a state-wide online resource to identify where temperature data are available.

Progress:

- Created AKOATS (Alaska Online Aquatic Temperature Site) meta-database to identify where/when/how/who is monitoring across the state (UAA/ACCS, 2014)
- Annual updates to AKOATS managed by UAA/ACCS through 2021
- Launched AKTEMP Alaska Water Temperature Database: a publicly-facing stream temperature database with quality assurance protocols and data summaries to facilitate data sharing (UAA/ACCS, 2023)
- AKTEMP includes over 34 million water temperature measurements by 24 data providers from 472 monitoring stations (2024)



[12] Mauger. S, R. Shaftel, E.J. Trammel, M. Geist and D. Bogan. 2015. Stream temperature data collection standards for Alaska: Minimum standards to generate data useful for regional-scale analyses. Journal of Hydrology: Regional Studies 4:431-438. https://doi.org/10.1016/j.ejrh.2015.07.008

[13] Mauger. S, R. Shaftel, E.J. Trammel, M. Geist and D. Bogan. 2014. Stream temperature data collection standards and protocols for Alaska: Minimum standards to generate data useful for regional-scale analyses. Cook Inletkeeper, Homer, AK and Alaska Natural Heritage Program, UAA, Anchorage, AK. https://inletkeeper.org/wp-content/uploads/2017/03/StreamTemperatureStandardsandProtocolfor-Alaska.pdf

[14] Shearer, J., C. Moore and K.K. Bartz. 2015. Monitoring freshwater systems in the Southwest Alaska Network: Protocol narrative. Natural Resource Report NPS/SWAN/NRR-2015/925. NPS, Fort Collins, CO.

[15] Toohey, R.C., E.G Neal and G.L. Solin. 2014, Guidelines for the collection of continuous stream water-temperature data in Alaska: U.S. Geological Survey Open-File Report 2014-1182, 34 p. http://dx.doi.org/10.3133/ofr20141182.

Goal 2: Refine data collection for fisheries management and modeling applications.

Issue: Project-specific efforts to collect stream temperature data are often of short-duration (1-3 years), collected in ice-free months (May–October), and then stored on a local computer. These data are often of little use to fisheries managers looking for in-season information or to climate and hydrologic modelers needing full-year water and air temperature datasets.

Solution: Real-time monitoring stations are needed to provide in-season information for fisheries managers in key watersheds. There's an additional need for long-term (>20 years) monitoring stations using paired air and water sensors to establish the relationship between air and water temperature at more local scales, which will improve our ability to predict future water temperature conditions based on climate scenarios.

Objective 1: Provide real time data for fisheries managers.

Progress:

- Developed a paired water and air temperature, real-time station set up with beadedstream Inc. including satellite connection and solar power for remote site locations (2013)
- Real-time stations operated by Cook Inletkeeper on the Anchor River (2013-2022, pictured), Deshka River (2013-2024), Russian River (2016-2024), and Crooked Creek (2017-2024).
- Seventeen (17) real-time stations operated by U.S. Fish and Wildlife Service and served up publicly at https://www.fws.gov/project/live-stream-temperature-monitoring

Objective 2: Provide long-term datasets for climate and hydrologic modeling applications.

Progress:

- Described management applications of freshwater temperature data in Southeast Alaska to garner support and long-term commitment from regional partners (2017)[16]
- Archived existing statewide temperature data in KNB through the State of Alaska Salmon and People Project (2018)
- Created search feature for the duration of data collection at each site in AKOATS
- Dense monitoring sites established in the Deshka River, Little Susitna River, Anchor River and Kenai River allowing for watershed modeling to map thermal networks by UAA/ACCS

[16] Southeast Alaska Watershed Coalition. 2017. Management applications of regional freshwater temperature data for Southeast Alaska. Funding provided by the North Pacific Landscape Conservation Cooperative. management applications October 2017_FINAL.pdf

Goal 3: Target cold water habitat protection efforts.

Issue: Water temperature varies greatly across watersheds due to stream morphology, land cover, glacial contribution, and groundwater influence as well as to the climatic drivers of air temperature and precipitation. Certain streams types are more sensitive to the impacts of climate change and are warming more rapidly than others. In response to the inevitability of some degree of regional warming, we need to develop adaptation measures to improve watershed resilience to thermal change.

Solution: As we gain more understanding of current stream temperature profiles and can assess which streams are most vulnerable to the impacts of climate change, we need to implement conservation and protection measures to help keep cold water cold and reduce additional stressors to freshwater systems that are warm and will get warmer.

Objective 1: Protect waters that are currently cold.

Progress:

- Acquired thermal infrared imagery to identify cold water refugia on Anchor River (2010 & 2012), Ninilchik River (2012), Big Lake basin (2011), Chuit River (2016), Deshka River (2023)[17], Crooked Creek, Moose River, Beaver Creek, and Funny River (2023)[18].
- Kachemak Heritage Land Trust increased conservation status of key cold-water refugia in the Anchor River watershed
- Alaska State Parks restored connection of a cold-water inflow to the Ninilchik River
- Submitted land management plan comments to the City of Kenai, Matanuska-Susitna Borough, and State of Alaska with recommended parcel-specific actions on lands with cold-water refugia.

Objective 2: Reduce thermal stressors to "temperature sensitive streams".

Progress:

- UAA/ACCS sensitivity analysis completed to identify temperature sensitive streams in Cook Inlet, Copper River, Kodiak, Bristol Bay, and Prince William Sound (2024)[19]

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[17] Mauger, Sue, & Diabat, Mousa. 2023. Building Habitat Resiliency for Chinook Salmon in Alaska's Deshka River Watershed - thermal imagery shape files [Data set]. Zenodo. https://doi.org/10.5281/zenodo.8412376

[18] Mauger, Sue, McCarty, Marie, Rusin, Lauren, Meyer, Benjamin, & Diabat, Mousa. 2023. Kenai Mountains to Sea: Using Thermal Infrared Imagery to Implement Long-Term Salmon Conservation - thermal imagery data set [Data set]. Zenodo. https://doi.org/10.5281/zenodo.8412432

[19] Assessing Thermal Sensitivities of Salmon Habitats in the Cook Inlet, Copper River, Kodiak, Bristol Bay, and Prince William Sound Watersheds, https://accscatalog.uaa.alaska.edu/dataset/stream-thermal-sensitivities

Goal 4: Fill stream network data gap.

Issue: In Alaska, we lack an accurate hydrography or stream network GIS layer. While the rest of the country is anticipating the release of NHDPlus (version2), Alaska is not even included in the original National Hydrography Dataset (NHD). NHD is a powerful tool which links individual stream reaches within a river network and greatly increases analytical capabilities.

Solution: We need to educate resource managers and decision makers on the value of a stream network layer for Alaska and its importance in understanding climate change impacts in Alaska's salmon streams. By explaining the utility of filling this foundational data gap, we will prioritize the development of NHDPlus for Alaska.

Objective 1: Acquire NHDPlus for Alaska.

Progress:

- NHDPlus has been acquired for much of Cook Inlet and Southeast Alaska, but expansion of NHDPlus has been discontinued for the rest of the state by the U.S. Geological Survey.
- 3DHP (3D National Hydrography Program) is the next iteration and it is slowly progressing at the Hydrologic Unit Code (HUC) 8 level (subbasins) using elevation data.

Goal 5: Direct relevant fisheries and habitat research.

Issue: Our awareness that stream temperature may be a factor in current and future Alaska wild salmon productivity and survival is relatively recent. Not until monitoring projects began reporting maximum temperatures above 20ºC in the last 10 years, and the reality of climate change became more apparent on the Alaska landscape, has this critical water quality parameter received much attention. Consequently, research on thermal stress on Alaska's wild salmon is scant. In addition, our ability to discern population impacts during the freshwater phase of the salmon life cycle is extremely limited. In many Alaska streams we use weirs and sonar technology to monitor adult migration back into the watershed, but rarely do we count how many juveniles actually leave a stream. As a result, when unexpectedly low returns occur, unfavorable marine conditions are often blamed. Until we can better account for out-migrating fish we will likely underestimate thermal impacts to salmon populations occurring in the freshwater environment.

Solution: We need to determine if Alaska's wild salmon populations are more or less tolerant to thermal variation than the fish - typically from southern parts of the range – used in previous laboratory studies. And we need to understand how thermal stress during freshwater rearing periods can impact salmon productivity.

Objective 1: Assess relevance of threshold temperatures to Alaska salmon.

Progress:

- Modeling of hatch and emergence timing of sockeye salmon in western Alaska[20].
- Observations and field experiment of heat stress in Yukon River Chinook across a wide range of water temperatures (2020)[21,22]
- Development of differential heat shock protein markers and their relevance for Chinook and coho (2023).[23]

Objective 2: Encourage more watershed-based research on salmon productivity to better understand freshwater survival versus marine survival.

Progress:

- Retrospective assessment of freshwater drivers of Chinook salmon productivity in Cook Inlet[24]
- Deshka thermal mapping project design informing new juvenile salmon project with additional watershed-based research initiated in the Little Su and Gulkana rivers

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[20] Sparks, M., Falke, J., Quinn, T., Adkison, M., Schindler, D., Bartz, K., Young, D., and Westley, P.. 2019. Influences of spawning timing, water temperature, and climatic warming on early life history phenology in western Alaska sockeye salmon. *Canadian Journal of Fisheries and Aquatic Sciences*. 76:123-135. https://doi.org/10.1139/cjfas-2017-0468

[21] von Biela, V., L. Bowen, S. McCormick, M. Carey, D. Donnelly, S. Waters, A. Regish, S. Laske, R. Brown, S. Larson, S. Zuray, C. Zimmerman. 2020. Evidence of prevalent heat stress in Yukon River Chinook salmon. Canadian Journal of Fisheries and Aquatic Sciences 77:1878-1892.

[22] Bowen, L., V. von Biela, S. McCormick, A. Regish, S. Waters, B. Durbin-Johnson, M. Britton, M. Settles, D. Donnelly, S. Laske, M. Carey, R. Brown, C. Zimmerman. 2020. Transcriptomic response to elevated water temperatures in adult migrating Yukon River Chinook salmon (Oncorhynchus tshawytscha). Conservation Physiology 8:coaa084.

[23] von Biela, A. Regish, L. Bowen, A. Stanek, S. Waters, M. Carey, C. Zimmerman, J. Gerken, D. Rinella, S. McCormick. 2023. Differential heat shock protein responses in two species of Pacific salmon and their utility in identifying heat stress. Conservation Physiology 11:coad092.

[24] Jones, L, E. Schoen, R. Shaftel, C. Cunningham, S. Mauger, D. Rinella, and A. St. Saviour. 2020. Watershed-scale climate influences productivity of Chinook salmon populations across southcentral Alaska. Global Change Biology. DOI: 10.1111/gcb.15155.

- Significant amount of newly published literature linking temperature and salmon in Alaska[25] including ocean conditions affecting egg retention in sockeye salmon in the Pilgrim River during the 2014-2016 marine heatwave[26]; effects of 2019 heatwave on mortality in all five salmon species[27], and expansion of salmon into the Arctic[28]

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[25] For example:

Lisi, P.J., D.E. Schindler, K.T. Bentley and G.R. Pess. 2013. Association between geomorphic attributes of watersheds, water temperature, and salmon spawn timing in Alaskan streams. Geomorphology 185:78–86.

Armstrong, J.B., D.E. Schindler. 2013. Going with the flow: spatial distributions of juvenile coho salmon track an annually shifting mosaic of water temperature. Ecosystems 16: 1429-1441.

Armstrong, J.B., D.E. Schindler, C.P. Ruff, G.T. Brooks, K.E. Bentley, and C.E. Torgersen. 2013. Diel horizontal migration in streams: juvenile fish exploit spatial heterogeneity in thermal and trophic resources. Ecology 94: 2066-2075.

Leppi, J.C., D.J. Rinella, R.R. Wilson, and W.M. Loya. 2014. Linking climate change projections for an Alaskan watershed to future coho salmon production. Global Change Biology, 20(6): 1808-1820. https://doi.org/10.1111/gcb.12492

Schoen, E.R., M.S. Wipfli, E.J. Trammell, D.J. Rinella, A.L. Floyd, J. Grunblatt, . . . F.D.W. Witmer. 2017. Future of Pacific Salmon in the Face of Environmental Change: Lessons from One of the World's Remaining Productive Salmon Regions. Fisheries, 42(10), 538-553. https://doi.org/10.1080/03632415.2017.1374251

Sergeant, C.J., J.R. Bellmore, C. McConnell, and J.W. Moore. 2017. High salmon density and low discharge create periodic hypoxia in coastal rivers. Ecosphere, 8(6), e01846. https://doi.org/10.1002/ecs2.1846

Adelfio L.A., S.M. Wondzell, N.J. Mantua, and G.H Reeves. 2018. Warm winters reduce landscape-scale variability in the duration of egg incubation for coho salmon (Oncorhynchuss kisutch) on the Copper River Delta, Alaska. Canadian Journal of Fisheries and Aquatic Sciences. https://doi.org/10.1139/cjfas-2018-0152

[26] Carey, M., V. von Biela, A. Dunker, K. Keith, M. Schelske, C. Lean, and C. Zimmerman. 2021. Egg retention of high-latitude sockeye salmon (Oncorhynchus nerka) in the Pilgrim River, Alaska, during the Pacific marine heatwave of 2014–2016. *Polar Biology* 44:1643–1654.

[27] von Biela, V. C. Sergeant, M. Carey, Z. Liller, C. Russell, S. Quinn-Davidson, P. Rand, P. Westley, and C. Zimmerman. 2022. Premature Mortality Observations among Alaska's Pacific Salmon During Record Heat and Drought in 2019. *Fisheries* 47:157-168.

[28] Dunmall, K. D. McNicholl, C. Zimmerman, S. Gillk-Baumer, S. Burril, and V. von Biela. 2022. First juvenile chum salmon confirms successful reproduction for Pacific salmon in the North American Arctic. *Canadian Journal of Fisheries and Aquatic Sciences* 79:703-707.