WATER TEMPERATURE DATA LOGGER PROTOCOL FOR COOK INLET SALMON STREAMS

Prepared by

COOK INLETKEEPER

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This protocol is based on review of existing water temperature protocols from Oregon, Washington, Idaho and the Forest Science Project, as well as from discussions with scientists and community-based groups involved in water quality monitoring throughout Alaska.

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BACKGROUND

Water temperature is one of the most significant factors in the health of stream ecosystems. Temperature affects primary production, algae, aquatic plants, invertebrates, and fish in running waters (Hynes 1970). For salmon specifically, temperature affects survivorship of eggs and fry, rate of respiration and metabolism, timing of migration, resistance to disease and pollution, and availability of oxygen and nutrients (Richter and Kolmes 2005). 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 (ADEC) 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 (ADEC 2006). Numeric water temperature criteria are included in the water quality standards for the growth and propagation of freshwater fish, shellfish, other aquatic life and wildlife (see box).

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.

The Cook Inlet watershed is the most populated and fastest-growing region in Alaska; it is also home to renowned wild salmon runs that are at heightened risk due to the effects of climate and land-use change. Alaska is thought to be experiencing the greatest regional warming of any state in the U.S., and warming patterns are expected to continue at least into the next century. Climate records show that air temperatures in Anchorage have increased approximately 2.2°C over the last 41 years and up to 4.5°C in winter months since the 1960s (Alaska Regional Assessment Group 1999). Stream water temperatures are strongly related to air temperatures with direct sunlight providing the greatest source of heat. In addition, water temperatures are influenced by water volume, channel width, channel depth, precipitation and groundwater inputs (Poole and Berman 2001). By changing the landscape, humans can influence water temperatures by: loss of shade by removal of stream-side vegetation, lower stream flows due to water withdrawals, less water storage due to wetland loss, and greater stormwater runoff from more impervious surfaces.

Despite the association between warm water temperatures and reduced salmonid survivorship, there is little or no consistent, long-term water temperature data for salmon streams in Alaska. Without such basic information, it is impossible to gauge the health of Cook Inlet's salmon habitats and resources, and equally difficult to develop management responses to improve watershed resiliency to climate and land-use change. This protocol is intended to: promote enhanced water temperature data collection efforts in salmon streams; reduce the variability of water temperature data quality due to sampling techniques; and contribute to a standardized process for collection of water temperature data using data loggers in Cook Inlet salmon streams.

SCOPE

The purpose of this protocol is to describe guidelines for the selection, calibration, placement, maintenance, and retrieval of water temperature data loggers in Cook Inlet salmon streams. This protocol does not cover lakes, reservoirs, and large non-wadeable rivers. This information is written for a general audience to make it easier for other Cook Inlet water quality partners and other community-level groups throughout Alaska to implement stream temperature monitoring in salmon-bearing streams.

PRE-PLACEMENT PROCEDURES

> **QUALITY ASSURANCE PROJECT PLANS**
>
> For projects funded by EPA or ADEC, a monitoring plan called a Quality Assurance Project Plan (QAPP) is required. For more information, check out: http://www.dec.state.ak.us/water/wqsar/pdfs/qappelements.pdf

Developing a Monitoring Plan

Before heading to the field, you should develop a monitoring plan. In general, this plan should document: 1) your objectives for collecting data, 2) what specific types of data you are going to collect, 3) where, when and how often you will collect data, 4) who is responsible for collecting the data, 5) how will you assure the quality of the data, 6) how will you manage and analyze the data after it is collected, and 7) how and to whom will you distribute the data. Through the process of answering these questions, you should gain a clear understanding of all that is required of a well-conceived monitoring program. The time you invest in the office developing a monitoring plan will pay off when you head to the field. You will be able to make more confident decisions about site selection, logger placement and the type of information you should document on site if you have done your homework.

Selecting a Data Logger

Temperature data loggers are the preferred method for collecting continuous temperature data records. The cost of temperature data loggers continues to decline while their reliability and ease of use continues to improve. There are many manufacturers and models of data loggers from which to choose. At present, StowAway TidbiT and HOBO Water Temp Pro by Onset Computer Corporation are more commonly used models. As new options arise, you need to consider a few factors when selecting a data logger. The following characteristics are recommended:

1. submersible, waterproof logger
2. accuracy $\pm 0.2^{o}$C
3. measurement range -4^{o} to 37^{o}C (24^{o} to 99^{o}F)
4. resolution $<0.2^{o}$C (needs to be less than accuracy)
5. programmable start time/date
6. user-selectable sampling interval

Other issues to consider when selecting a data logger are memory capacity and battery life. Your storage capacity needs will depend on your sampling interval (i.e. 30 seconds, 15 minutes, 2 hours) and how long you expect to deploy the logger (i.e. 7 days, 6 months, 1 year). For battery life, some loggers have factory replaceable batteries and others have non-replaceable batteries which should last 5 years with typical use. If you select the non-replaceable type, be sure to document the logger’s use so you know when to take it out of circulation.

In addition to the data logger, you will need to purchase the appropriate software and a connector cable from your computer to the data logger (often called a Base Station). If it is an option, you also may want to buy a shuttle which allows you to download the data in the field. By downloading your data periodically, rather than at the end of the entire sampling period, you reduce the risk of losing significant amounts of data. This is particularly useful if you are concerned about vandalism or high stream flow conditions.

Calibration

It is important to check the accuracy of the data logger(s) before and after field deployment. This is a relatively simple procedure and will give you greater confidence in the quality of your data and help prevent erroneous data. A calibration logbook is highly recommended to keep data logger information organized and easily retrievable.

The accuracy of the temperature data logger should be tested in a water bath at two temperatures: 0^{o}C and 20^{o}C. A NIST (National Institute of Standards and Technology) traceable (calibrated and maintained) thermometer accurate to 0.2^{o}C is required to determine accuracy. NIST thermometers are not cheap, but with careful handling, they should last many years. These are glass, mercury-filled thermometers and should not be taken into the field.

NIST THERMOMETERS

See Appendix C for suppliers

Start the logger by connecting it to your computer, which has the appropriate data logger software installed. Program the logger to record data at a short recording interval (5 minutes works well). Be sure the clocks in the computer and logger, and the clock used during the calibration procedure are consistent. For efficiency, it is recommended to calibrate a number of loggers at the same time.

Once a batch of loggers has been launched (i.e. programmed and started), submerge them in an ice water bath in a large cooler or other covered and insulated container. The second bath should be held at room temperature (20^{o}C). Verify that each bath is uniform temperature (mixing may be required). Place the launched loggers in one of the baths long enough to equilibrate to the temperature of the bath. After the equilibration period (approximately 1 hour), measure and record water bath temperatures with the NIST thermometer as close to the time the logger is recording a measurement value as possible. Take at least 3 measurements. Once the water bath temperature measurements have been recorded, place the loggers in the second bath and repeat the process.

Once the loggers have been exposed to both temperatures and measurements recorded, remove the loggers from the water bath, connect to your computer, read out (or download) the data, and display the data. Compare the logger data to the NIST thermometer data recorded in your calibration logbook. If a reading from a data logger is greater than 0.3^{o}C from the NIST thermometer, set this logger aside. If the logger fails the calibration check a second time, do not deploy this logger in the field and contact the manufacturer about returning the logger if it is still under warranty.

PLACEMENT PROCEDURES

Launch
After you have completed the calibration procedure, restart the logger to begin recording data according to the manufacturer's recommendations. Program the logger to collect data at 15 minute intervals and to record temperature measurements in degrees Celsius. Turn 'multiple sampling' off and do not select 'wrap around when full and overwrite oldest data' if these options are available on your logger.

Site Selection
The specific stream and reach selected for logger placement is determined by the goals and objectives laid out in your monitoring plan. If monitoring is being conducted to assess non-point source temperature impacts, the logger should be placed at the downstream end of a reach with relatively uniform morphology, land use, and cover. It should be representative of the characteristics of the entire reach. For point source temperature assessments, loggers should be placed just upstream of the discharge point and just below the discharge point or the temperature mixing zone.

Logger Placement
Once at the site and in the stream channel, find a spot where the water is adequately mixed and not influenced by tides or localized warm or cool water sources such as ground water, point sources, lake outlets, or direct sunlight. Well-mixed waters can often be found in the thalweg (lowest point in the channel) of riffles. Shaded sites with moderately turbulent flows tend to make good logger placement spots. Avoid backwater pools or standing water and do not place the logger below a tributary stream unless that is part of your study design. To verify that the site is well-mixed horizontally and vertically, take at least ten measurements across the stream width with a hand-held thermometer or temperature probe, which has been calibrated in the lab/office with a NIST thermometer. Be sure to select a site where the logger is likely to be submerged throughout the monitoring period. If you are deploying the logger during high flows, you should return to the site later in the year to assure the logger is submerged and confirm the site is well-mixed at lower flows. If you are deploying the logger during low flows, consider how high the water might be when you want to retrieve it.

Additional consideration should be given to human activity in the area. If you are near a well-used fishing spot or there is notable foot traffic in the area, you should consider finding a spot that is not obvious to reduce vandalism and accidental snagging.

DATA LOGGER TYPES

No protective case

With protective case

Deployment
If the logger does not come with a protective case, it should be placed in a housing to protect the equipment from natural, wildlife or human disturbance. Housings are simple to make, inexpensive, provide total shade for the logger, protect the logger from moving debris, and provide for secure attachment with a cable. Housing design and the equipment needed to construct them are described in Appendix A. Methods for securing the data logger instream are

described in Appendix B. When selecting your method for deploying the data logger, be sure to consider how it will work at high and low flows, how much streambed movement there is at your site, and how to prevent people from tripping over rebar, sand bags or cables.

Documentation

In a write-in-the-rain field notebook, record a thorough description for each site to help ensure the logger is relocated and to account for factors that influence water temperature. The site description should, at a minimum, include water body name, latitude and longitude, a site map, photographs of the site (upstream, downstream, and across the transect), instantaneous water temperature, date and time of the actual placement, and logger serial number. Directions to the site from relatively permanent landmarks should be recorded.

Depending on the purposes of the monitoring activity, additional measurements or observations may be useful in interpreting the temperature data. Parameters that can influence temperature measurements include, but are not limited to, water depth, water velocity, stream discharge, channel width, solar input, distance from the stream bank, overhead cover, and air temperature. You should consider measuring these parameters if they are relevant to your monitoring objectives.

Maintenance

Whenever feasible, it is recommended to visit the site monthly to make a calibration check and any needed adjustment to the logger. An interim visit is especially important for spring high flow placements. When a visit is made, record the date, time, and instantaneous water temperature. Take the water temperature measurement - using a hand-held thermometer or temperature probe, which has been calibrated in the lab/office with a NIST thermometer - within a few minutes of an expected logger recording. Check the security of the housing and deployment equipment and adjust if necessary. Remove debris or sediment buildup. Record and photograph any land-use or habitat changes that are relevant.

RETRIEVAL PROCEDURES

Remove Logger

To ensure that the highest temperatures during the summer are captured in your dataset, it is recommended that loggers be instream from June 1 – October 1. However, data loggers can be left instream all year. If you plan to leave the logger in during the winter, you should give additional consideration to the deployment method and how it will respond in ice conditions. Loggers can be swapped out mid-year if there are concerns about battery life or storage capacity.

Depending on your monitoring objectives, you may want to remove the logger before freeze up to reduce the chance of losing the logger during spring high flows. When you arrive at the site to retrieve the logger, document the condition of the site and the logger. At a minimum, record such things as whether the logger is still in the water and any signs of vandalism or disturbance. Also, record the date, time, and instantaneous water temperature at the time of retrieval. If possible, remove all equipment from the site including rebar or sandbags from the stream channel.

DATA HANDLING PROCEDURES

Download Data

Depending on the type of logger used, data may be downloaded periodically in the field with a shuttle or you may need to remove the data logger from the site and connect it to the Base Station at your office computer. The temperature data logger should be gently wiped to remove any biofilm or sediment that may affect its ability to connect to the shuttle or Base Station. The logger should then be connected and downloaded using the manufacturer's procedures for the data logger type.

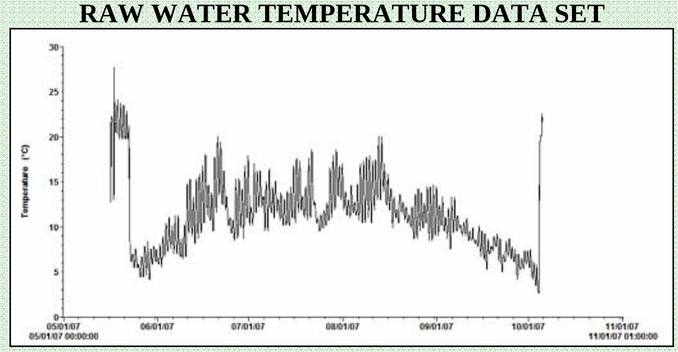
Once the data have been downloaded by the data logger software package, you should export the data into a Microsoft Excel file format. This will allow for greater data management capabilities and data sharing. You should also save the file in a universal (i.e. non-software specific) format such as a txt file as a backup if future software upgrades prevent you from being able to open older Excel file versions.

Quality Control

The accuracy of the temperature data logger needs to be verified by evaluating the results of pre- and post-deployment calibration checks. If a temperature logger fails a post-deployment calibration check (i.e. reading from a data logger is greater than 0.3^{o}C from the NIST), then another calibration check must be performed. If it fails a second time, then the raw data should be adjusted by the mean difference of the pre- and post- calibration checks results to correct for the instrument bias.

Temperature data collected before or after the deployment period must be deleted from the raw data set since it is not valid data (e.g. the data logger may be recording air temperature data). Field notes from the deployment and retrieval events will provide the dates and times necessary to identify the deployment period. Instantaneous temperature measurements collected during monthly maintenance checks should be compared to the data logger measurements to confirm accuracy goals. The data should be graphed to help identify anomalous data that might result from the data logger not being submerged or being tampered with by humans or wildlife.

RAW WATER TEMPERATURE DATA SET



Example of raw water temperature data set with air temperature data collected before and after the deployment period.

Specific data analysis and reporting recommendations are beyond the scope of this protocol. However, at a minimum, you should compare your data with Alaska's water temperature criteria to determine if you have water temperature exceedances. In the future, a centralized database for Alaska's water temperature data is expected to be available and standardized reporting formats will be developed to enhance comparison across Cook Inlet salmon streams.

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APPENDIX A

Housing Construction
PVC housings are very simple to make, inexpensive ($10-15), provide total shade for the logger, protect the logger from moving debris, and provide for secure attachment with a cable.

The data logger is suspended in a PVC pipe that allows stream water to flow through but prevents solar radiation to penetrate. Black PVC provides more camouflage than white PVC for sites where vandalism is a concern. In clear water streams, heat absorption by the dark surface may be an issue so white PVC is recommended.

Here's a supply list to make the housings:

2" Sch 40 ABS pipe (1' length)
2" DWV clean out plug (2)
2" DWV female adaptor (2)
3/8 " x 4" ZC eye bolt (1)
8" cable ties
Multi purpose cement
Assorted nuts and bolts

Glue the female adapters to each end of the PVC pipe. Drill a hole for one eyebolt to go through a clean out plug. Drill at least 20 holes in PVC to allow water flow. Secure the eye bolt through the clean out plug with appropriate-sized nuts and bolt. Use a cable tie through drilled holes to suspend the data logger in the housing. Additional cable ties can be used to secure rocks in the bottom of the housing to weigh it down. Screw the clean out plugs into the female adapters.

APPENDIX B

Rebar Method
This method is preferred for streams with moderate movement of the streambed during high flows. The protective case or PVC housing is attached by a cable to a rebar stake sunk 3 feet into the stream bed.

Secure an eyebolt to the rebar (approximately 1 foot from an end) with hose clamps. Secure one end of the cable to the eyebolt with a wire rope clip. Secure the other end to the protective case or PVC housing using a wire rope clip. Use a stake pounder to sink the rebar 3 feet into the stream bottom near a large rock or other landmark.

Materials:
1/2" rebar (4' length)
3/8 " x 4" ZC eye bolt (1)
9/16 - 1 1/16 hose clamp (3)
1/8" wire rope clip (2)
1/8" RL uncoated cable (2' length)

Stream Bank-Secured Cable Method
This method is preferred for streams with significant movement of the streambed during high flows. In this method the logger in its protective case or PVC housing is secured to the stream bank vegetation using plastic-coated wire rope.

The logger is secured to the wire rope (1/8” to 3/8” diameter and 12 feet long) using a wire rope clip. Upon deployment the cable is wrapped around a large tree, rocks, bridge supports, or other secure object within or on the stream bank. The logger is then placed within the stream channel. Large stream rocks can be placed on top of the cable near the logger to hold the logger in place within the stream. The cable should be hidden under bank vegetation to avoid vandalism or accidental disturbance. Try to avoid locations where the cable will cross active fishing or wildlife trails.

Sand Bag Method
This method is preferred only for streams with minimal movement of the streambed during high flow events.

Sturdy sand bags can be purchased at most hardware stores. Fill the bag on site with any mineral material (large rocks, cobbles or sand). Avoid organic material which is often buoyant. The logger, in its protective case or PVC housing, can be attached to the bag by weaving a cable tie through the mesh. The bag can be tied off with a rope to the stream bank for extra security. The rope should be hidden under bank vegetation to avoid vandalism or accidental disturbance. Try to avoid locations where the rope will cross active fishing or wildlife trails.

APPENDIX C

Additional Resources

1. Data loggers

    Onset Computer Corporation
    470 MacArthur Blvd.
    Bourne, MA 02532
    800.LOGGERS
    www.onsetcomp.com

2. National Institute of Standards and Technology (**NIST)** traceable thermometer
    (http://www.nist.gov/)

    ERTCO
    2555 Kerper Blvd.
    Dubuque, IA 52001
    800.553.0039
    http://www.ertco.com/nist_&_factory_calibrated.html

    Cole-Parmer
    800.323.4340
    www.coleparmer.com