Colorado River Endangered Fish Recovery Program:
Protocols for Long-term Stream Temperature Monitoring and Data Reporting

Program Director's Office

July 27, 2018

1. Introduction

Making well-informed water and fisheries management decisions in the Colorado River basin requires, among other things, access to short- and long-term water temperature data for various locations in the river system. Stream temperature data are valuable for multiple reasons, including:

- Assessing temperature regime effects on species distributions, productivity, survival and abundance within the aquatic ecosystems of the river basin;
- Monitoring temperature effects on habitat suitability, and on the biological activity, behavior, and timing of various life cycle stages of aquatic organisms;
- Determining effects on other temperature-dependent water quality parameters, such as dissolved oxygen, pH, and conductivity;
- Monitoring temperature changes over time, such as those associated with climate warming and/or altered land use, land cover, and water management within the river corridor and river basin.

This document describes how the Upper Colorado River Endangered Fish Recovery Program (Recovery Program)[1] Director's Office (PDO) collects and processes data on stream temperatures at various locations across the upper Colorado River basin.

The Recovery Program is only one of multiple entities that collect long-term stream temperature data in the upper Colorado River system. Other entities include the U.S. Geological Survey (USGS), the Utah Department of Natural Resources (Utah DNR), Colorado State University (CSU), and the Central Utah Water Conservancy District (CUWCD). In this manner, the Recovery Program and its partners and stakeholders may draw upon data collected by multiple entities when evaluating river temperatures – not solely the data collected by the PDO and posted to the Recovery Program website according to the protocols described here.

[1] The Recovery Program is a joint effort of the U.S. Fish and Wildlife Service, the U.S. Bureau of Reclamation, the states of Colorado, Utah, and Wyoming, Upper Basin water users, environmental organizations, CREDA, and the National Park Service. www.coloradoriverrecovery.org

The Recovery Program was established in 1988 with the goal of recovering four species listed as endangered under the Endangered Species Act, in the face of current and foreseeable future water depletions in the Upper Colorado River Basin.[2] According to Muth et al. (2000), the U.S. Fish and Wildlife Service (USFWS) began a program of monitoring river temperatures on the Yampa and Green Rivers in 1987 by placing thermographs at seven key locations on those rivers (see Table 3.12 in that document). Data from those thermographs, USGS gage data, and results from work done by others were the basis for that report's description of the thermal regime of the Green River. Since those initial sites were established, various temperature monitoring sites have been added, terminated, or moved to new locations. The PDO maintains an inventory of those sites that is available upon request.

Originally, USFWS collected these temperature data, at least in part, in order to calibrate and validate a general stream temperature model called SNTEMP, which is referenced, for example, in Kaeding and Osmundson, 1989. George Smith, a hydrologist with the Mountain-Prairie Region Office of USFWS at that time, was instrumental in getting a number of these sites established for that purpose. Larson et al. 1989 provide a summary of stream temperature data collected at ten locations on the Colorado River and seven locations on the Green River from 1985 through 1988.

Subsequently, various biologists associated with the Recovery Program became interested in stream temperatures associated with known or suspected spawning locations of the endangered fish, particularly where major river confluences and/or reservoir operations have the potential to influence spawning and larval emergence. Since that time, the Recovery Program has used these data for various applications in support of species recovery, such as monitoring aquatic habitat conditions, predicting the timing of fish spawning and hatching, adjusting reservoir releases, and assessing temperature effects on different lifecycle stages of both native and non-native fish (e.g., Osmundson, 2011). In addition, these data have been provided to the NorWeST stream temperature data site, whose purpose is to provide a comprehensive database of western U.S. stream and river temperature data, facilitate data sharing, decrease redundancy in monitoring efforts, and stimulate inter-agency collaboration (Isaak, D.J. et al. 2017).

Stream temperature data collected by the PBO is available on-line at **www.fws.gov/mountain-prairie/riverdata**. These data are normally updated twice a year.

[2] These species are: the Colorado pikeminnow (*Ptychocheilus lucius*), the humpback chub (*Gila cypha*), the razorback sucker (*Xyrauchen texanus*), and the bonytail (*Gila elegans*). For purposes of this document, the Upper Colorado River Basin is that area from which waters naturally drain into to the Colorado River system above Lake Powell.

2. Site Establishment

River reaches for stream temperature monitoring are selected with the assistance of Recovery Program partners based on identified data needs and gaps. The PDO establishes the stream temperature monitoring equipment at a specific site along those stream reaches by selecting a location that ideally meets a number of desirable characteristics:

- **Accessibility**: The sampling location normally can be accessed relatively easily under both low-flow and moderate-flow conditions.

- **Anchoring**: Features are present that allow for installation of anchoring cables that are not likely to be dislodged or damaged during peak river flow. This may include large boulders adjacent to or within the river channel, well-established stakes or fence posts, stable bridge features, etc.

- **Representative temperatures**: The site is likely to be representative of water temperatures across the entire cross-section of the river channel. Where tributaries enter the river upstream, sufficient distance and flow turbulence over the intervening distance is sufficient to ensure an adequate mixing of the multiple sources of inflow.

- **Streambed security**: Monitoring equipment can be placed in locations and using techniques that will minimize the possibility of sensor exposure to air, and also minimize the possibility that the sensor will get deeply buried by mobilized river sediments and debris.

- **Discreet site**: The equipment can be located where there is minimual likelihood it will be encountered and disturbed by the general public (e.g., fishermen, kayakers, picnickers).

Once an appropriate location is selected, the PDO's procedures for establishing the temperature monitoring equipment at that site are as follows:

- **Redundant instrumentation**. Whenever possible, two (or more) recording instruments are co-located at the temperature monitoring site, in order to provide redundancy in data collection. This helps to ensure the accuracy and reliability of the data collected (by comparing the data recorded by both instruments), as well as provide additional certainty that, should one instrument fail to record valid data for one reason or another

(e.g., battery failure, disturbances that relocate the sensor out of the water), the second instrument will provide valid data.

- **Placement and anchoring**. A plastic-coated cable, typically 3 to 10 meters in length, is anchored to an appropriate feature adjacent to or within the stream channel. The monitoring instrument is fastened onto a loop at the end of the cable (Figure 1), and placed within the river channel, often weighting-down the cable with a heavy object and/or lodging the cable under a large boulder to help ensure that the data logging instrument will not be swept out of the river channel and onto the river bank during a high flow event. A waterproof tag is attached to the cable that explains the purpose of the monitoring and directs anyone who might find the cable to leave the temperature logging devices undisturbed.

Figure 2. HoBo TidbiT fastened to a cable loop with warning tag.

- **Documentation**. The site location is documented by recording geographic coordinates, a description of the site, and/or annotated sketches or photographs.

3. Data Collection Procedures

Data collection equipment

Currently, the PDO utilizes the 'HoBo' TidbiT waterproof temperature data logger manufactured by MicroDAS.com, Ltd., base in Contoocook, New Hampshire (Figure 2).[3] These loggers are described as measuring temperatures between -20°C to +70°C with ±0.2°C accuracy (MicroDAQ, 2017). The lithium battery is claimed to normally last 5 years. These devices can store up to 42,000 individual temperature readings. At a frequency of one reading per hour, this allows for nearly 4.8 years of data collection between data downloading events.

Figure 2. The HoBoTidbiT version 2 temperature data logger. Approximate actual size.

This version 2 (V2) generation of the TidbiT device has been used by the PDO beginning around 2015. Prior to that, version 1 of the device was used, from approximately 2010 to 2014. Both versions are similar in form and function, but V2 has a longer battery life and offers several other convenient features. Prior to the advent of version 1 TidbiT devices in, data were recorded using TempMentor instruments (Ryan Instruments, Redmond, Washington). Over the years, temperature monitoring equipment has evolved to become more compact, more capable, and more reliable.

[3] The use of grade, firm, and product names in this document if for descriptive purposes only, and does not constitute and endorsement by the U.S. Government.

Figure 3. A collection of stream temperature logging and reading devices used by the Program over the decades. Over time, devices that were originally large and bulky (top) evolved to become increasingly more reliable and compact, culminating in the current compact tidbit technology (bottom center).

Frequency of data sampling

These data loggers record temperature at user-defined and programmed time intervals. The PDO programs them to collect stream temperature data at either one-hour or two-hour intervals, at the top of the hour, for a total of 12 or 24 stream temperature measurements each day. This frequency of sampling is considered sufficient to reflect daily variation in stream temperatures, and to calculate an accurate mean daily temperature (which is the value posted to the PDO website).

Targeted/assumed accuracy & uncertainty

As mentioned above, TidbiT version 2 devices are advertised as having ±0.2°C accuracy in their temperature measurement. They record temperature to a precision of 0.01°C. The redundancy in instrumentation at most PDO sites typically allows this assumed accuracy to be verified, by comparing measurements of the co-located instruments (see the 'Procedures' discussion below).

4. Data Processing/Reporting/Posting Procedures

The following describes the procedures currently followed and recommended when collecting and downloading field data. However, note that all these procedures were not necessarily used with the older equipment and earlier data collection activities (e.g., pre-TidBit, pre-2010 data).

Data Collection. Normally, the PDO visits each sampling site twice a year, once during the period of declining flows following the annual peak river runoff period, prior to peak summer recreational use of the river (e.g., late June), and again following the period of lowest summer flows and highest annual stream temperatures (e.g., late September).

During these visits, the PDO optically downloads data in the field from the data logging devices onto a laptop computer. A plot of the downloaded data is visually inspected at that time to verify whether obvious data irregularities exist (e.g., periods when the sensor appeared to be out of the water). The field technician saves and names the datafile based on the site location, records the beginning and end date-time of the logged temperatures that appear to be valid, and records the most recent time, temperature, and battery status recorded by the sensor.

Data Validation and Error-Checking. As mentioned above, the PDO attempts to co-locate at least two temperature loggers at each site to cross-verify the data. The starting and ending times and temperatures for each logger are compared. If there is any time error associated with the logged data, this suggests a malfunctioning sensor needing replacement, and all of that sensor's logged data may be deemed invalid. If the temperature difference between the two co-located loggers is greater than 0.5°C, the data from both loggers is more closely scrutinized to determine which logger likely recorded more accurate data and whether one of the devices needs replacement. If the sensor readings essentially match, then data from one of the sensors is published, with a preference for the readings associated with the sensor that has been used continuously for the longest period of time at that site.

Daily Mean Temperature Calculation. Following successful downloading, validation, and error-correction of logger data, the hourly data recorded for each site are converted into mean daily values using a program that averages the hourly values for each calendar day. By default, at least 17 hourly values must be recorded for a particular date to generate a valid daily mean value. However the program optionally can be set to accept fewer than 17 daily readings for averaging purposes (for example, to process data from a device that was programmed to collect readings only once every two hours). If fewer values than this threshold were recorded, no daily mean value is calculated.

Data Management and Posting. Typically, within three to six months of downloading the field data, the daily average values for each site are posted to the corresponding Recovery Program web page (https://www.fws.gov/mountain-prairie/riverdata/temperatures.html).

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