Report of a Temperature Study in the Paradise Watershed of Northeastern Pennsylvania 2008-2010

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graduate student at
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Submitted on 27 February 2012 by:
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on behalf of
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Protect coldwater fish habitat and ecosystems:

- Identify habitats and ecosystem types that support brook trout and are in danger of being lost or drastically altered. Explore ways to protect landscapes in which brook trout occur through. Through land conservation and stream buffer protection and/or restoration.
- Develop and implement a plan specific to management of brook trout, Pennsylvania's state fish and only native salmonid.
- Brook trout populations have declined in some sections of the Paradise Creek watershed. For example, brook trout (3 individuals) were found in Tank Creek in a sampling survey in 1999 but were absent 10 years later in the same stream section.
- Maintain an inventory of fish populations (and their aquatic habitats) in a GIS geodatabase so species distributions can be mapped and information readily retrieved.
- Evaluate current regulations of streams and determine if brook trout population balance can be restored under the Fish and Boat Commission's Wild Brook Trout Enhancement Program to protect brook trout status inside the watershed.

Develop a functional plan

The success of any management plan lies both in the accuracy of scientific data on which it is based and the implementation of the plan's strategies.

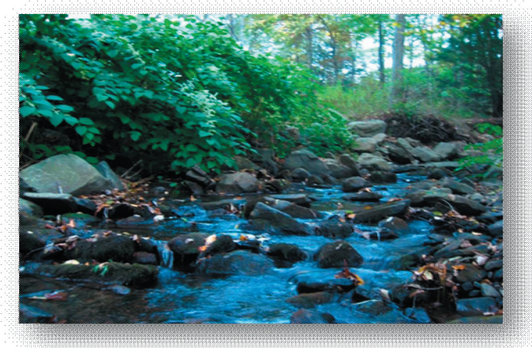
This report provides a baseline of data to assist in ongoing planning and management. A Coldwater Management Plan for the Paradise Creek Watershed provides a framework that identifies long term and short-term activities that can be implemented any time depending on available resources.

The next step to making this management plan functional is to identify stages necessary to achieve these goals and establish a reasonable time frame for completion.

Habitat Restoration:

Develop and implement a habitat improvement and restoration plan

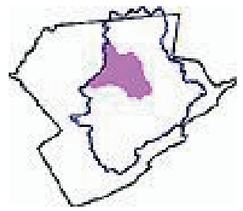
- Habitat restoration in areas that need increased riparian buffers or decreased stream width can benefit from projects such as tree plantings or bank stability projects.
- Increase riparian shading and bank stability by removing invasive plant species and planting native trees and shrubs.
- One relatively easy practice that can improve the connection between the stream and the groundwater zone is the placement of large woody debris in the streams. The debris acts as a moderating force on surface water temperatures primarily by exchanging water from the surface from exposure to solar radiation.
- Continued monitoring and improvement of techniques to control stream temperature will be necessary to combat human disturbances that increase stream temperature in the Paradise Creek Watershed.



Data Collection:

- Collection of water quality and geographical data should coincide with collection of aquatic organisms to create a better understanding of the interactions between abiotic (non-living) and biotic (living) factors.
- Monitoring of stream temperature will continue in the Paradise Creek Watershed to gain an understanding of long-term stream temperature trends.
- Extend continuous stream temperature monitoring into the entire Brodhead Watershed.

THE PARADISE WATERSHED

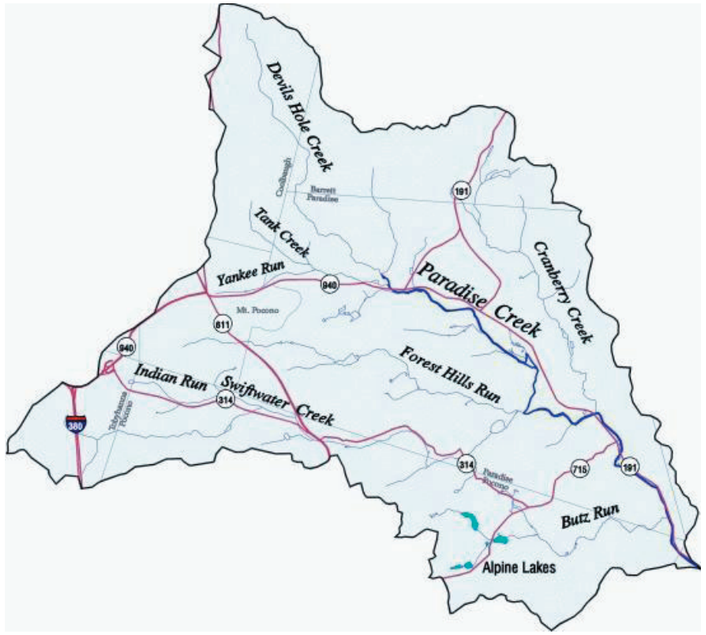


The Paradise watershed is a sub-watershed of the Brodhead Watershed, a 305 square mile watershed located primarily in Monroe County in the Pocono Mountains. The Brodhead Creek drains to the Delaware River just above the Delaware Water Gap.

Figure: Paradise Watershed within Brodhead Watershed, Monroe County (Pa)

The Paradise watershed drains from the Pocono Plateau in its headwaters in Mount Pocono Borough, and Barrett, Coolbaugh and Tobyhanna Townships, flowing for nine miles in a southeasterly direction through Paradise Township before joining the Brodhead Creek.

The Paradise Creek subwatershed drains a surface area of approximately 44.5 square miles. For much of its length, the Paradise Creek runs in close proximity to PA Route 191. This highway is largely undeveloped, with much of the stream front land owned by fishing clubs. Tributaries of the Paradise included in this study are: Devils Hole Creek, Tank Creek, Yankee Run, Cranberry Creek, Butz Run, Swiftwater Creek and Forest Hills Run (shown on map below).



Map: Paradise Watershed, a subwatershed of the Brodhead Watershed

All headwaters streams in the Brodhead watershed -- including all of the Paradise watershed streams -- are not only classified as protected for "Cold Water Fishes," they have the designated use of Exceptional Value or High Quality in PA regulations at Title 25, Chapter 93. Studies done by the Brodhead Watershed Association for the Paradise Watershed Assessment and Protection Project showed that all streams in the Paradise watershed qualify as "Class A Wild Trout" streams under the standards set by the PA Fish and Boat Commission.
Unlike many watersheds, most development in the Paradise watershed occurs in the headwaters while the lower reaches are protected by large, private landholdings. Still -- with the exception of Forest Hills Run -- which is impaired by the discharge from the Mt. Pocono sewage treatment plant and runoff from Pennsylvania Route 611 and borough streets -- the waters are clean and support a healthy, reproducing trout population.

Seven sewage treatment plants discharge into the Paradise watershed:

- Two (Paradise Stream Resort and Monsignor McHugh High School) discharge into the Paradise Creek,
- Two (Mt. Pocono Municipal Authority and Mt. Airy Resort) discharge to Forest Hills Run, and
- Three (Pocono Manor Inn, Pocono Mountain School District-Swiftwater Campus, and Sanofi-Pasteur, Inc.) discharge into the Swiftwater Creek.

PREVIOUS STUDIES

A major study of the Paradise watershed, the ***Paradise Watershed Assessment and Protection Project*** was conducted from 2002 to 2006. The project was funded by a Growing Greener grant from PA DEP. A number of technical reports were published as part of that study. One of those studies, *"Stream Morphology and Water Quality Based Restoration Plan for the Paradise Creek Watershed*," reported that:

> *Another frequent and cumulatively important problem relates to the many ponds and small dams throughout the watershed. During analysis of water quality data for the Paradise Creek watershed, it was observed that temperature violations are fairly frequent in local waterways. Hundreds of small and shallow impoundments were identified, and these may be a significant contributing factor to elevated temperatures in this important trout fishery. Dams also interrupt fish passage.*
>
> *Future monitoring of water temperature should be conducted upstream, within, and downstream of numerous ponds throughout the watershed, so that the extent of this perceived problem can be quantified*.

In response to these findings and recommendation, the BWA sought funding from the Coldwater Heritage Program for the temperature study of the Paradise watershed described in this Report.

RECOMMENDATIONS AND NEXT STEPS

Public Advocacy and Education:

Protection of our natural resources must begin with improved information about the importance of stream temperature and habitat processes.

- Share data and project results with local agencies and public by posting information on the Brodhead Watershed Association website.
- Posting information, such as the results of this study, and interactive Google Earth maps on the Internet will aid in informing the public about rising stream temperatures and its implications. This information should also be made available during public meetings.
- Continue to develop partnerships with fishing and conservation-oriented organizations to increase conservation and restoration efforts on streams and lakes.
- Along with continuing research, develop educational programs through sportsmen, conservationists, and public information programs.

Stream Temperature Monitoring:

Continue to monitor stream temperature throughout the Paradise Creek Watershed to determine trends in stream temperature over longer time periods.

- Results from Pocono Manor STP (SWIF06), Pocono Mountain School District's STP (SWIF04), and Sanofi's STP (SWIF04) were inconclusive.
- Mount Pocono Municipal Authority's STP (FOHI04) discharge caused CWF violations in stream temperature downstream.
    - Monitoring stream temperature above and below these sites will continue to determine their impact.
- Identify additional cold-water habitats that are in danger of being lost or altered. Begin long term monitoring in these locations as well.
- Extend the project to include the Brodhead Creek Watershed where impacts of urbanization are higher.

Despite reported efforts of managers to mix top and bottom water in the Mount Airy Dam impoundment, the outflow remained warmer than CWF standards for a majority of the summer when data were collected -- eliminating cold-water habitat.

Impacts of Sewage Treatment Plants (STPs)

Mount Pocono Municipal Authority Sewage Treatment Plant

The effect of the discharge on the stream temperature was inconclusive below the Pocono Manor STP discharge (SWIF06). The logger at this site was placed in such a way that it picked up the temperature impact of discharge from Lake Minausin as well.

Effects below Pocono Mountain School District's STP and Sanofi's STP were also inconclusive. In these sites some summer data had to be excluded because of inaccuracies (SWIF04). SWIF04 and SWIF06 had higher violations in the winter.

Both the Pocono Mountain School District campus and the Sanofi, Inc. campus have large amounts of impervious surface (roofs and parking lots) and runoff from these surfaces might contribute to raise the temperature of the stream in winter months.

The effect of the Mount Pocono Municipal Authority discharge on Forest Hills Run is clear. The downstream logger (FOHI04) showed very high percentage of violations for the months of October through March. The STP discharge permit includes temperature limits that are not being met.

Warm-water discharge in the winter is beneficial to the growth of coldwater species providing a year round opportunity to feed as long as food is present. This is a common occurrence and many case studies show this behavior in fish. Adverse effects have been noted as well.

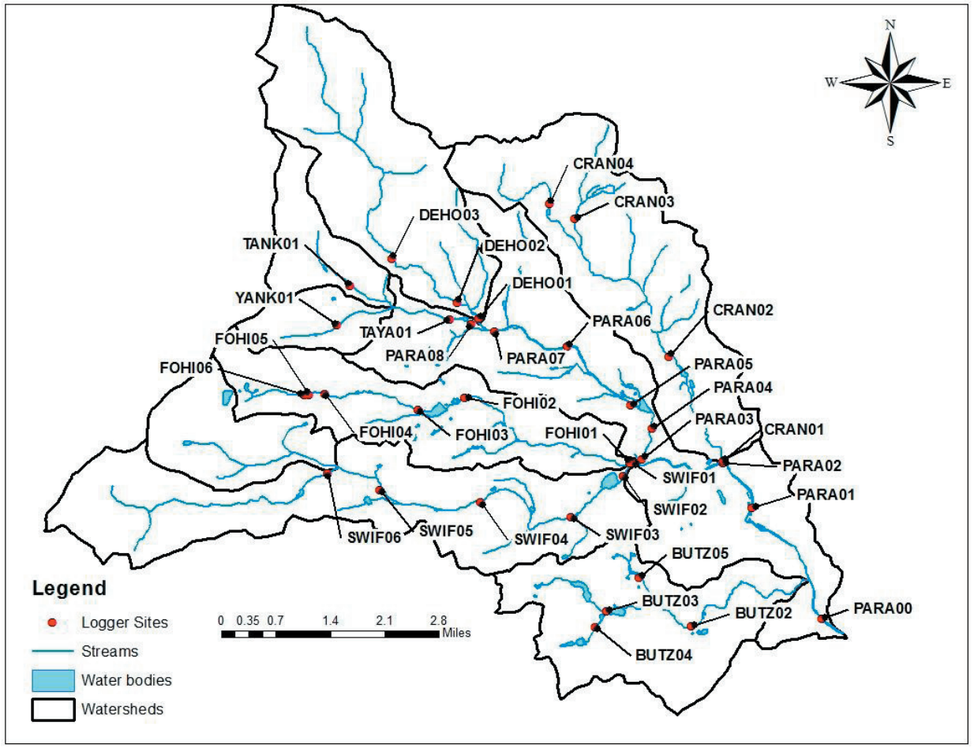
For example, a cold-shock fish kill was reported on the Susquehanna River near Harrisburg when a warm-water discharge from a plant decreased from 70° F to 34° F in less than one hour. The fish in Susquehanna were acclimated to warm-water discharge temperatures and were vulnerable to cold shock. Dead fish were observed scattered along the shore and on the bottom.

This example is not meant to over- or under-state the concerns about warm-water discharges in the winter, but rather to emphasize the caution about acclimation processes of aquatic organisms that should be exhibited by STPs when discharging.

PROJECT DESCRIPTION

SITE SELECTION

Stream temperatures for this study were collected from 35 sites inside the Paradise Creek Watershed between November 2008 and March 2010. Each site was assigned a code name (an abbreviation of the stream name) and number. The collection sites are shown on the map below.



Map: Paradise Watershed Temperature Data Site Locations

These sites were selected as those most likely to provide a comparison of stream temperatures above and below the lakes, ponds, and sewage treatment plants that discharge into the watershed -- installations that were hypothesized to increase water temperature.

Several sites were selected because they would allow comparison with temperature data collected over more than 20 years by BWA Streamwatchers.

USING LOGGERS TO COLLECT TEMPERATURE

The temperatures at each site were recorded using "HOBO pro V2" factory-calibrated temperature loggers (See image on right). These loggers were set to measure stream temperature at each site every 15 minutes with an error of less than +/- 1/3 of a degree (Farenheit).

Tables 1 and 2 (below) detail logger placement by stream section, site name, identifying whether the placement was above (upstream) or below (downstream) of the named lakes, ponds, and sewage treatment plants (STPs) that discharge into the watershed.

Table 1. Lakes, ponds, and impoundments located on the Paradise Creek Watershed and the HOBO pro temperature loggers that are installed either upstream, downstream, or not installed (x).

Stream section	Impoundments	Logger Upstream	Logger Downstream
Paradise Creek	Crawford Lake	PARA05	PARA04
Paradise Creek	Pocono Gardens Pond	X	X
Paradise Creek	Greevy Dam	X	X
Paradise Creek	Paul Dam (2)	X	X
Devils Hole Creek	Sabatino Dam	X	X
Devils Hole Creek	Harriton Dam, Paradise Stream Pond	DEHO02	DEHO01
Forest Hills Run	Mt. Airy Lake	FOHI03	FOHI02
Forest Hills Run	Fairview Lake	X	FOHI06
Swiftwater Creek	Swiftwater Lake	SWIF03	SWIF02
Swiftwater Creek	Lake Minausin	X	SWIF06
Swiftwater Creek	Whitestone Dam	X	X
Cranberry Creek	Wetbrook Dam/Weiler Pond	X	X
Cranberry Creek	Daigle Dam	X	X
Butz Run	Alpine Lake	X	BUTZ03
Butz Run	Freeland Pond	BUTZ03	BUTZ02
Butz Run	Lake Tanelo	X	X
Butz Run	Meisertown Dam	X	BUTZ05
Butz Run	Tanners Henry Lake	X	X

Paradise Watershed Temperature Study November 2008-March 2010
Submitted 27 February 2012

Table 4. Percent of Violations of CWF Temperature Standards by Month and Logger Sites

	BUTZ02	BUTZ03	BUTZ05	DEHO01	DEHO02	FOHI01	FOHI02	FOHI03	FOHI04	FOHI05	FOHI06
March	N/A	N/A	N/A	N/A	N/A	30.21	47.41	N/A	54.47		N/A
April	N/A	N/A	N/A	17.22	14.20	32.26	34.58	N/A	19.58		N/A
May	N/A	N/A	N/A	5.41	2.99	58.82	93.41	N/A	7.80	3.70	2.42
June	69.65	97.26	85.66	0.00	0.00	48.58	81.53	0.53	0.59	0.77	0.70
July	26.21	59.95	82.53	0.00	0.00	21.10	66.23	0.13	0.51	0.54	0.54
August	90.62	N/A	82.43	0.00	0.00	54.70	94.25	0.00	0.00	0.00	0.34
Sept	36.69	N/A	40.21	0.00	0.00	16.39	73.47	2.37	1.91	0.00	0.00
Oct	51.11	59.19	61.49	19.69	10.25	48.42	74.66	37.37	49.50	22.28	17.78
Nov	83.13	81.81	72.54	83.82	82.92	85.59	96.35	87.60	96.11	92.78	64.17
Dec	12.43	11.43	7.29	N/A	35.52	21.48	27.99	36.59	68.69	N/A	12.06
Jan	0.00	2.39	5.61	N/A	32.23	6.18	15.69	27.72	70.03	N/A	6.25
Feb	0.00	2.46	3.01	N/A	6.03	0.00	5.80	7.40	71.35	N/A	0.00
March	45.70	44.12	44.29	55.07	42.96	45.83	31.22	36.07	53.80	N/A	9.72

	PARA01	PARA02	PARA04	PARA05	PARA06	PARA08	CRAN01	CRAN03	CRAN04
March	33.972	36.828	N/A	N/A	36.358	N/A	23.320	N/A	N/A
April	31.285	33.681	34.306	31.667	28.576	26.597	29.097	N/A	N/A
May	53.461	56.485	52.187	31.570	24.133	25.000	37.130	47.681	6.418
June	39.826	45.382	30.833	15.313	8.160	10.729	24.479	28.021	0.000
July	28.931	41.465	14.113	6.418	2.016	2.991	6.989	9.543	0.000
August	41.235	47.760	27.823	12.466	3.091	1.882	14.748	38.105	0.000
Sept	24.236	30.451	12.708	7.326	3.021	4.028	6.424	12.951	3.997
Oct	51.210	54.066	47.749	37.332	30.208	24.899	38.878	50.437	36.692
Nov	89.375	90.069	88.021	80.069	80.590	80.174	83.125	86.285	93.438
Dec	25.773	18.716	25.504	23.891	26.318	28.831	19.456	22.312	38.474
Jan	9.644	7.594	11.346	10.380	14.718	11.391	3.293	12.265	9.812
Feb	1.116	1.079	2.009	4.092	6.213	0.037	0.372	11.682	0.000
March	49.966	55.839	49.563	49.630	38.694	N/A	N/A	N/A	N/A

	SWIF01	SWIF02	SWIF03	SWIF04	SWIF05	SWIF06	TAYA01	YANK01
March	30.712	32.930	38.575	89.651	34.241	36.794	28.696	76.109
April	28.750	32.049	23.715	14.757	12.049	11.840	17.778	26.146
May	56.519	53.125	14.718	0.000	2.083	2.352	10.887	4.536
June	42.986	41.287	1.530	0.766	0.000	0.000	1.910	0.347
July	39.751	48.353	0.336	*N/A*	0.000	0.000	0.034	0.371
August	55.074	50.538	0.000	*N/A*	0.000	0.000	0.000	0.134
Sept	22.500	61.701	2.708	0.556	0.000	0.000	8.936	0.625
Oct	54.603	77.218	44.523	27.251	15.927	10.887	15.692	16.297
Nov	85.938	95.069	87.917	83.750	83.056	77.708	72.778	88.576
Dec	23.017	33.669	35.729	35.887	42.238	37.937	28.999	70.430
Jan	6.384	36.929	29.738	33.770	42.103	43.179	11.753	68.257
Feb	0.000	2.976	12.128	16.964	22.693	31.585	0.186	93.713
March	N/A	48.522	46.136	45.766	9.109	11.166	N/A	N/A

A positive "difference" indicated a violation of the coldwater standard. This CWF standard equation was applied to data from loggers installed above and below the lakes and impoundments shown on Table 1 (page 3) and above and below the STPs as shown on Table 2 (page 4).

To make comparisons between sites, the percentages of violations by month for each were analyzed. Table 4 (on the following page) shows these results.

RESULTS AND DISCUSSION

In general

The temperature data collected during this study provided both a baseline for subsequent studies and a wealth of material for continued analysis.[1] However, a few general conclusions can be drawn about temperature impacts of dams and sewage plant discharges.

Data from sites below lakes showed increases in violations in the summer and substantially lower or no violations in the winter. This difference was a predicted consequence of lakes with warm-water (surface) outflow in the summer and cold-water outflow from the surface in the winter.

Unfortunately, as we discuss below, because of the placement of certain loggers, general conclusions cannot be drawn from data from sites below STP discharges.

Impacts of dams

Dams have been shown to cause a decline in aquatic biodiversity, change discharge regime and reduce sediment supply below dams known to cause elevated base flow; channel incision, constriction, or widening; and loss of spawning habitat. In some instances, the thermal impact of a dam has been detected for a considerable distance downstream.

Crawford Lake Dam on the Paradise Creek

As hypothesized before the study, dams in the Paradise Watershed were found to have a significant impact on downstream temperatures. When logger data were compared to CWF standards, sites below dams were found to be thermally impacted. The dams at Mount Airy Lake, Swiftwater Lake, Freeland Pond, Meisertown, and Crawford Lake (shown above) all showed a high percentage of violations at loggers downstream from their outflows. [2]

[1] Several thousand data points were collected for this study -- every 15 minutes at 35 sites, some for more than one year.

[2] Even though they were found to contribute to temperature violations downstream, some dams in the watershed, are permitted to degrade the waters because they were "grandfathered" under Pennsylvania's CODE (Chapter 93.7, Specific water quality criteria), and, thus, are not considered "in violation." Mount Airy Lake, however, is not accorded such treatment.

Table 2. Sewage treatment plants that discharge into the Paradise Creek or one of its tributaries. Temperature loggers were placed upstream and downstream on some of the sites (x if there is no logger).

Stream section	STP discharge	Logger Upstream	Logger Downstream
Paradise Creek	Paradise Stream Resort	X	X
Paradise Creek	Monsignor McHugh High School	X	X
Forest Hills Run	Mt. Pocono Municipal Authority	FOHI06	FOHI04
Forest Hills Run	Mt. Airy Resort	FOHI03	FOHI02
Swiftwater Creek	Pocono Manor Inn	X	SWIF06
Swiftwater Creek	Pocono Mountain School District	SWIF05	SWIF04
Swiftwater Creek	Sanofi-Pasteur	SWIF05	SWIF04

Landowners and municipalities were contacted for permission to access the selected stream sites. Once permission was granted, loggers were placed at appropriate sites, typically connected to bridge structures or anchored to a tree on the streambank.

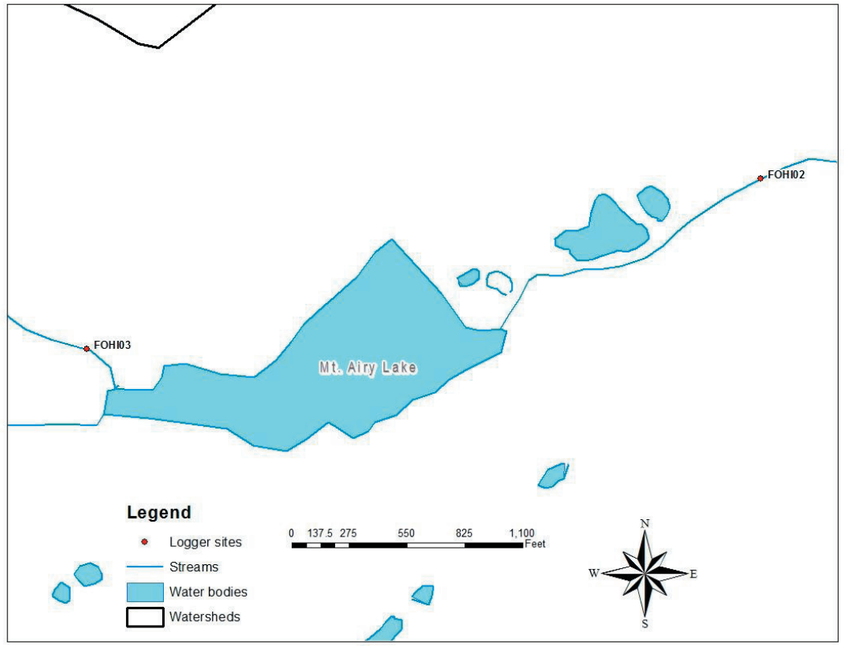
Researcher Scott Collenberg shown downloading data from a HOBO logger to his laptop.

THE STUDY

The HOBO temperature loggers were monitored regularly and temperature data downloaded to a laptop computer using Onset Computer Corporation's HOBOware software.

Data were collected from sites from November 2008 to March 2010. When the sites were visited to collect temperature data, logger conditions were also noted. High flow events washed some loggers ashore and low flow conditions caused some loggers to sit out of water. If any logger had not been continuously recording for the previous month, the data were discarded. At least a year's worth of data was collected from most loggers.

Many lakes, ponds, and sewage treatment plants discharge in the watershed. and contribute to downstream changes in stream temperature. Placement of the temperature loggers was meant to detect the extent to which, if at all, such anthropogenic effects caused an increase in stream temperature. For example, as shown on the image below, loggers in Forest Hills Run, were placed above (FOHI03) and below (FOHI02) the Mount Airy Lake to investigate possible impacts from the impoundment. Loggers were placed above and below these sources to study how much influence they have on downstream temperature (Table 1, Table 2). Sites above potential sources of heat were treated as "control" sites while sites below were treated as "test" sites.



Map: Location of loggers on Forest Hills Run, above and below Mt. Airy Lake and sewage treatment plant discharge

Cold Water Fishery Standard

The Cold Water Fishery (CWF) temperature standard was created by the Pennsylvania Department of Environmental Protection (DEP) to ensure coldwater streams maintain temperatures that are protective of coldwater fish species throughout their life cycle. In this study, the CWF standard was compared against temperature data collected from the HOBO pro temperature loggers.

Table 3. Maximum temperatures in the receiving water body resulting from heated waste sources or other sources, regulated under Chapter 92, 96 in Pennsylvania Code, where temperature limits are necessary to protect the designated use (CWF).

Critical Use Period	Temp degrees (C) CWF	Temp degrees (F) CWF
January 1 – 31	3.33	38
February 1 – 29	3.33	38
March 1 – 31	5.55	42
April 1 – 15	8.89	48
April 16 – 30	11.11	52
May 1 – 15	12.22	54
May 16 – 31	14.44	58
June 1 – 15	15.56	60
June 16 – 30	17.78	64
July 1 – 31	18.89	66
August 1 – 15	18.89	66
August 16 – 30	18.89	66
September 1 – 15	17.78	64
September 16 – 30	15.56	60
October 1 – 15	12.22	54
October 16 – 31	10.00	50
November 1 – 15	7.78	46
November 16 – 30	5.56	42
December 1 – 31	4.44	40

These regulations consider a change in temperature of more than 2°F for more than an hour a violation.

To compare amounts of thermal pollution between sites, *observed* temperature readings (T_O) were subtracted from *cold-water* standards (T_{CW}) for the date that the observed temperature was recorded:

Difference = $T_O - T_{CW}$