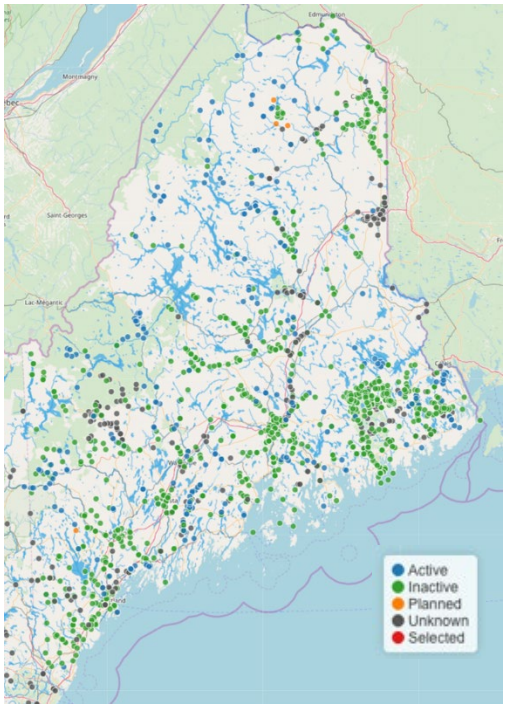
The Maine Interagency Stream Temperature Monitoring and Modeling Network

An interim report for MOHF Projects: 151-01-01 and 181-01-03



By Merry Gallagher (MDIFW) and Kirstin Underwood (USFWS)

Stream temperature is a primary control on the distribution and abundance of aquatic organisms. The Maine Stream Temperature Monitoring Network was established to provide accurate temperature information for a wide variety of users and agency management decision makers. The Network's specific goals include: 1) expanding a statewide sensor network and managing a comprehensive, interagency stream temperature database, 2) contributing data to an existing online stream temperature model that incorporates important climate drivers, riparian conditions, and geomorphic factors; 3) using the model to predict historic and future patterns in stream temperatures for fish-bearing streams; 4) translating stream temperatures to thermal habitat maps to assess species distributions and climate relationships across Maine; and 5) providing workshops to teach resource managers, landowners, and NGOs how to participate in the Network and use its products.

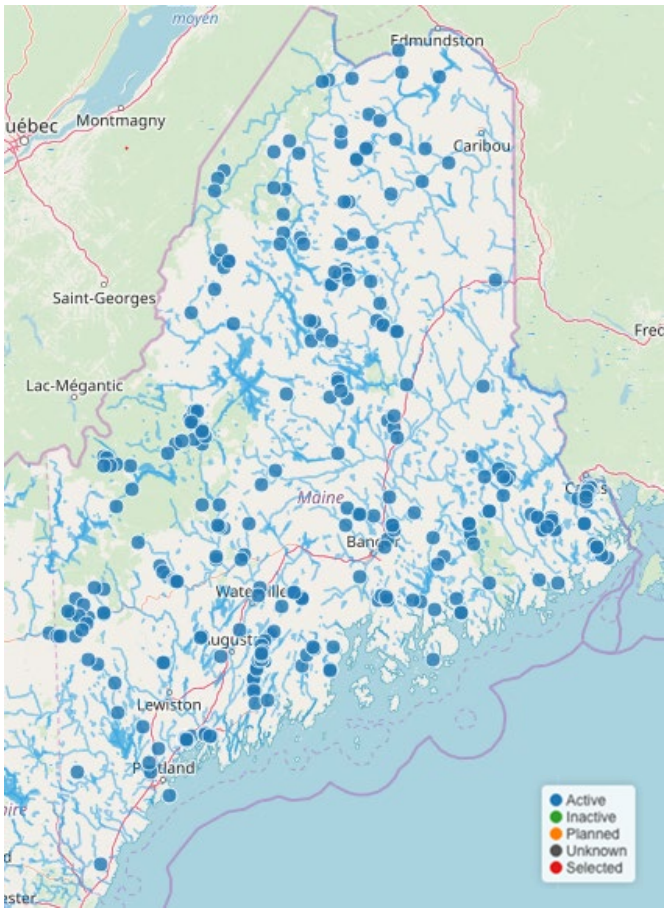


Figure 1. Current locations of stream temperature monitoring conducted by the MWTWG.

The Maine Water Temperature Working Group (MWTWG) was established in 2014 to develop a coordinated stream temperature monitoring network that could be integrated with regional and national efforts to identify watersheds with high climate resiliency. The group is composed of multiple state agencies, academics, NGOs, Tribes and federal agencies. The MWTWG has developed standardized monitoring protocols (Appendix X), conducted a comprehensive inventory of existing data for current and past water temperature monitoring efforts, and is monitoring stream temperature in >300 active stations statewide (Figure 1). Currently the MWTWG is coordinating equipment and training needs, deploying a statewide long-term temperature sensor network, and working with the U.S. Geological Survey (USGS) to utilize a web-based database to store sensor location and water temperature data and to model water temperatures across Maine.

Regional models can be useful for characterizing spatial variation, making robust predictions and estimating effects across wide environmental ranges. The project will utilize developed hierarchical, or nested, regional models for stream flow, stream temperature, and brook trout occupancy developed by USGS. This hierarchical framework across space is very powerful for estimating outcomes for locations with limited or no data because they can 'borrow' information from the hierarchy. In an effort to maximize the utility of these models by making them updatable and accessible, USGS has developed a web application that links the models together and links databases to the models. This integrated Spatial Hydro-Ecological Decision Support system (SHEDS) allows rapid updating of model results as new data become available, putting the models in the hands of the users and creating a stronger link between data collection and model results. SHEDS allows hindcasting of stream flows and temperatures by catchment as well as forecasting under alternate future scenarios. These environmental predictions are often useful on their own, but can also be linked to predict probabilities of occupancy for brook trout. For example, the user can examine regional maps and use slider bars to visualize the effects of changing forest cover or air temperature on stream temperature, flow, and brook trout occupancy. Future versions of SHEDS will incorporate components of structured decision making and will accommodate alternate models.

Currently, the MWTWG is expanding efforts and is targeting approximately 47,306 miles of fish-bearing streams and rivers across Maine for stream temperature monitoring. Significant amounts of stream temperature data have already been compiled from agency sources and these data have been uploaded to the SHEDS stream temperature database with most records being publicly accessible. The MWTWG has modified the US Forest Service's *A Simple Protocol Using Underwater Epoxy to Install Annual Temperature Monitoring Sites in Rivers and Streams* for use in Maine streams. The team will purchase and deploy Onset Tidbit v.2 sensors which are inexpensive, reusable, programmable, accurate to 0.2˚C, and can continuously read and store temperature data for up to 5 years (http://www.onsetcomp.com/products/data-loggers/utbi-001). These data are combined with hourly temperature records at over 900 historic monitoring sites already contributed to the MWTWG database by resource agencies and partners.

Project Objectives:

State agencies identified a clear need and broad support for a statewide stream temperature monitoring network, database and model. The primary objective of this project is an accurate assessment and description of historical and future stream temperatures and thermal habitat distributions for sensitive aquatic species like brook trout. The goal is to provide accurate information that is fundamental to an informed discussion about prioritizing specific management activities in different locales.

Specifically, we propose to deploy additional stream temperature sensors across the state, enter data into a USGS online regional stream temperature database, produce maps of stream temperature derived from a regional temperature model, and provide training to local, state and NGO staff and to private landowners. U.S. Fish and Wildlife Service staff will provide guidance to assist with optimizing sensor location deployments.

The Network and its Partners:

To date, twenty-seven distinct entities comprise the MWTWG (Table 1) and many actively contribute to deploying and managing the statewide sensor network (Table 2). In addition, the project works closely with multiple partners, including the Androscoggin River Watershed Council (ARWC) and Trout Unlimited chapters, to better understand how the MWTWG can most efficiently and effectively work with volunteers. These groups contribute greatly to the Network's overall success by maintaining and servicing 10-15 continuous water temperature dataloggers throughout the mainstem and tributaries of the upper Androscoggin River (Rumford upstream to the New Hampshire state line) and within the Cold Stream Forest (Bureau of Public Lands) as well as other priority locations selected by their members.

Table 1. List of organizations actively involved in the Maine Stream Temperature Working Group since 2014. Most participants have posted data on SHEDS.

Organization Abbreviation	Organization Description
ARWC	Androscoggin River Watershed Council
BSP	Baxter State Park
DLLT	Downeast Lakes Land Trust
DSF	Downeast Salmon Federation
EC	Environment Canada
FFIM	Fly Fishers of Maine
GMRI	Gulf of Maine Research Institute
HBM	Houlton Band of Maliseets

HCSWCD	Hancock County Soil and Water Conservation District
ME_MC	Midcoast Conservancy
MEDEP	ME Department of Environmental Protection
MEDMR	Maine Department of Marine Resources
MEDOT	ME Department of Transportation
MEIFW	ME Inland Fisheries and Wildlife
NOAA	National Oceanic and Atmospheric Administration
PINDNR	Penobscot Indian Nation Department of Natural Resources
PRLT	Presumpscot River Land Trust
PSQ	Passamaquoddy Tribe
PSU	Plymouth State University
SRCC	Saco River Corridor Commission
TNC	The Nature Conservancy
TU_KV	Trout Unlimited, Kennebec Valley
TU_MMB	Trout Unlimited, Merry Meeting Bay
TU_SEBAGO	Trout Unlimited, Sebago
UMAINE	University of Maine
USFWS_ME	US Fish and Wildlife Service, Maine Field Office/Coastal Program Office
USFWS_MNWR	US Fish and Wildlife Service, Moosehorn National Wildlife Refuge

Table 2. Temperature records currently on SHEDS, as of 2/1/2019. "Inactive" and "unknown" status indicates retired or short-term monitoring site. NOTE: Temperature records are ONLY from 2014-2018 monitoring period (formation of interagency network to present); SHEDS contains hundreds of additional historical records.

Organization	# Active Sites	# Inactive Sites	Additional Monitoring Sites (unknown status)	# Temperature Records
ARWC	15			471717
BSP	8			2316029
DLLT	8			258697
EC			2	226747
FFIM	3			130300
GMRI			2	10657
HBM	1		21	311976
HCSWCD		10		239006
ME_MC	11	5		323140
MEDEP	3	170	10	1841989
MEDMR	19	16	17	1092511
MEDOT			8	172141
MEIFW	68	6		1960440
NOAA	7	15		998699
PINDNR			13	241331

PSU			108	17335446
SRCC			9	9824
TU_KV	13			67271
TU_MMB	18	2		496936
UMAINE	6			112100
UNITY	4			347158
USFWS_ME	35	67		3007542
USFWS_MNWR	16			102049
Grand Total	**235**	**291**	**190**	**32073706**

SHEDS and the Stream Temperature Database:

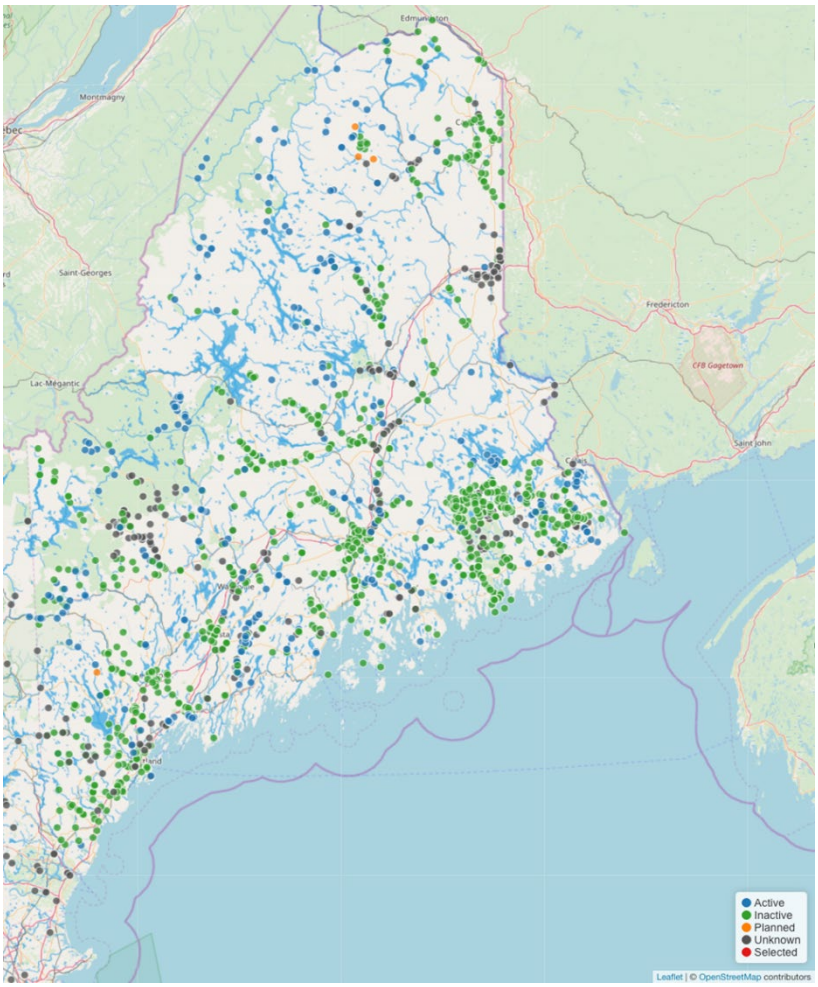


Figure 2: Stream temperature monitoring stations in the SHEDS database managed by the MWTWG.

The Spatial Hydro-Ecological Decision System (SHEDS; http://ecosheds.org) is a web-based system that seamlessly links a variety of environmental databases, models, and decision support tools for supporting resource management in the northeast and other regions of the United States. SHEDS was created in 2015 by researchers at USGS Conte Anadromous Fish Lab and UMass Amherst with funding from the US Fish and Wildlife Service Landscape Conservation Cooperative, and the USGS. SHEDS provides a number of free data services and web applications for use by government agencies, non-profit organizations, and the general public. One of the primary services SHEDS provides is a regional stream temperature database that is available for free to local, state, and federal government agencies, universities, and non-profit organizations across the northeast U.S. (Maine to Virginia). To our knowledge, SHEDS contains the largest collection of stream temperature data in the region with over 117 million temperature observations collected across 6,900 monitoring stations by 75 organizations. Registered users can upload and manage their data through a user-friendly web application (http://db.ecosheds.org), which also provides a public data viewer allowing non-registered users to access and download any dataset that is made publicly available.

Members of the Maine Water Temperature Working Group (MWTWG) have been major contributors and frequent users of the stream temperature database. The MWTWG has collectively uploaded over 50 million observations for nearly 2,000 monitoring stations among its 31 user accounts (Figure 2). Altogether, data from the

MWTWG accounts for over 40% of the total stream temperature database. The MWTWG has also contributed outside funding to SHEDS through the North Atlantic Salmon Federation for developing additional features and functionality to support the specific needs of the group. Part of these improvements included the ability to assign categories to each station (inactive, active, planned) and a custom interface for viewing and sharing data among only users who are members of the MWTWG. With these new features, the MWTWG has used SHEDS as a primary tool for planning and coordinating stream temperature monitoring efforts among its member organizations to optimize spatial coverage and capture the diversity of conditions found across the state.

Temperature Models and Climate Change:

The stream temperature database is used to calibrate regional models for predicting daily stream temperatures and the probability of brook trout occupancy at a fine spatial resolution. These models are built using a hierarchical Bayesian structure which utilizes observation data collected in monitored catchments to make historical and forecasted predictions of other catchments for which no data are available. Using this approach, the models provide spatially continuous predictions of daily mean stream temperature (Figure 3) and the probability of brook trout occupancy (Figure 4) under both current conditions and potential future climate change scenarios.

The results of the stream temperature and brook trout occupancy models as well as other geospatial information such as land cover and climate data are made publicly available through a web-based data visualization tool called the Interactive Catchment Explorer (ICE). ICE was designed to aid researchers and resource managers to improve understanding of spatial stream temperature patterns and of potential brook trout habitat through a responsive and user-friendly interface. ICE also allows users to identify and prioritize target areas in their region of interest using multivariate criteria, such as identifying which catchments exhibit high sensitivity to future climate or land use changes and therefore warrant further consideration for protection and restoration.

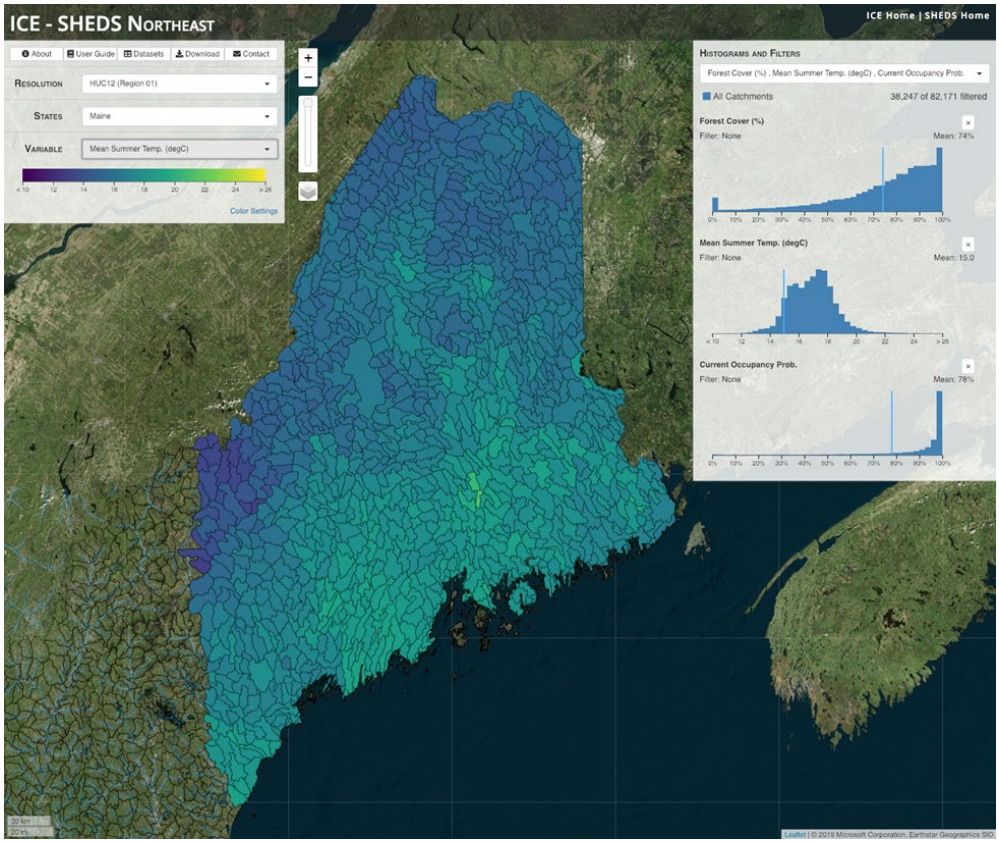


Figure 3: Mean summer temperature model predictions for all HUC12 subwatersheds in Maine shown using the SHEDS Interactive Catchment Explorer.

Project Outcomes:

Numerous deliverables are being produced from this project, including: a) expanding and continuing a comprehensive statewide temperature database; b) increased participation and investment in the project by volunteer groups, tribal organizations, and NGO's; c) spatially continuous maps and descriptive

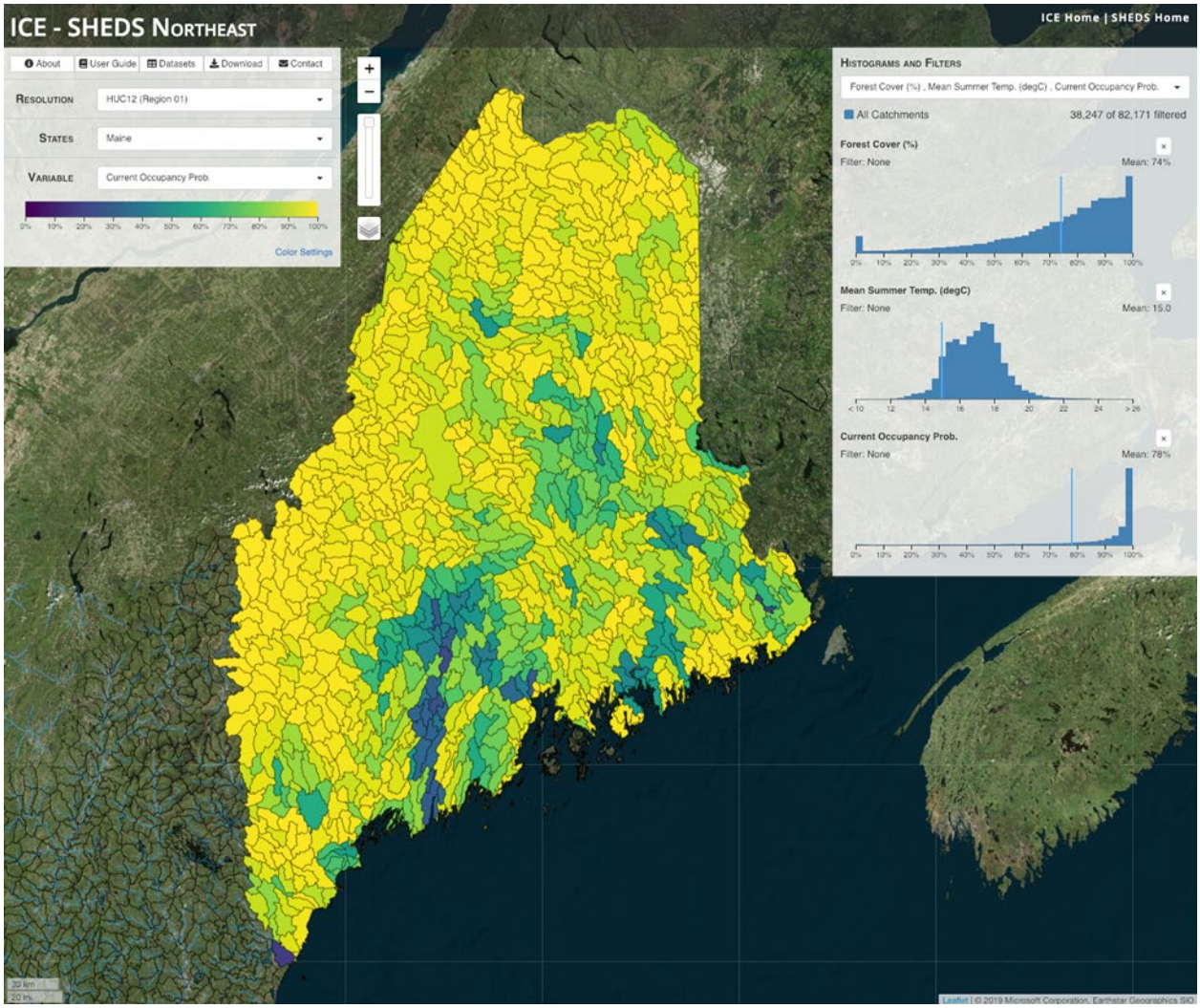


Figure 4: Brook trout occupancy predictions for all HUC12 subwatersheds in Maine shown using the SHEDS Interactive Catchment Explorer.

summaries of stream temperatures for historic and future climatic conditions, and c) spatially continuous maps showing the precision of temperature model outputs.

Project Outreach and Communication

The MWTWG has convened multiple meetings, conference calls and training workshops since this project's inception:

1/22/15: Planning meeting
4/16/15: Planning meeting (12 participants)
05/2015: Protocol workshop
12/2015: Planning meeting (12 participants)

04/2016: Planning meeting (18 participants)
05/2016: Protocol workshop
11/2016: Planning meeting (21 participants)

02/2017: Conference call (7 participants)
02/2017: MWTWG represented at SHEDS planning meeting
05/2017: Southern/central Maine protocol workshop (14 participants from 6 organizations)
05/2017: Northern/Downeast Maine protocol workshop (11 participants from 5 organizations)
11/2017: Recap/planning meeting (20 participants from 12 organizations)

05/2018: Protocol workshop @ Moosehorn National Wildlife Refuge (15 participants from 4 organizations, including 8 students from Cobscook Community Learning Center)

05/2019: ICE and Protocol Workshop held in Augusta, ME (11 participants from 9 organizations)
12/2019: Planning Webinar) (13 participants from 8 organizations)

USFWS Gulf of Maine Coastal Program office has also led small, focused protocol workshops for TU volunteers as needed throughout 2018-2020:

05/2018: TU-KV training at MDIFW headquarters in Waterville (8 participants)
07/2018: TU-Sebago training at Gulf of Maine Coastal Program office in Falmouth (4 participants)
09/2018: Focused training for 1 TU-KV volunteer in data upload using SHEDS and HOBOWare
08/2019: Focused training for 2 TU-Sebago volunteers in data retrieval and upload01/2020: Focused training in use of HOBOWare for 1 TU-MMB volunteer

In addition, MDIFW and USFWS members of the MWTWG have given project updates at 2015, 2017 and 2018 meetings of the Fisheries Improvement Network (an outreach group of the MFPC and SFI).
Merry Gallagher presented a project update at the 2018 annual meeting of the MDIFW Division of Fisheries and Hatcheries.
Jeff Stern presented project updates at annual Androscoggin River Watershed Council conferences in 2015, 2018, and 2019.

Multiple project partners have presented about this effort, posted updates on websites, or published updates. Examples include:

Date/timeframe	Agency	Activity	Link
Spring 2017 - 2019	NOAA	3 SHEDS discussions with the public during annual Alewife run on Blakman's Stream in Bradley, ME	
2017-2019	NOAA	Numerous SHEDS discussions in conjuction with use of the Stream Smart Table at various events including Common Ground Fair, Thinkers and Tinkers Expo and classroom presentations.	
Summer 2017	NOAA	Web blog highlighting SHEDS role in Atlantic salmon habitat monitoring. Northeast Fisheries Science Center's Field Fresh	Temperature Blog in Field Fresh
Fall 2019	NOAA	MWTWG actions have been incorporated into the North Atlantic Salmon Conservation Organization (NASCO) US Implementation plan for the period 2019 - 2024. Section 3.3.a with a link to SHEDS.	NASCO US Implementation Plan
Winter 2020	NOAA	Poster presentation at the Atlantic Salmon Ecosystem Forum in Orono, ME	2020 ASEF
Spring 2020	USFWS, PIN	Submitted project abstract for oral presentation at 2020 Maine Sustainability & Water Conference.	

Spring 2018	USFWS	Maine Audubon Conservation Fair: USFWS tabled at Maine Audubon's first annual outreach conservation fair and shared information about the Maine Stream Temperature Working Group/protocol/SHEDS. Approximately 500 people attended.	
Spring 2017 - 2019	USFWS	3 4th grade classroom visits/presentations in Falmouth and Portland, ME (affiliated with ASF "Salmon in the Classroom" program). Students learned how to use Interactive Catchment Explorer and view predicted stream temperatures at the catchment basin level in their hometowns. Students observed time-series temperature data at salmon release site from 2015-present. (~100 students total)	
Dec-17	USFWS	Maine Water Temperature Working Group article published in USFWS's online newsletter.	Partners Find Common Ground in Cold Water
2018 - 2019	ARWC	ARWC trained 8 students at Gould Academy in MWTWG protocol and helped students deploy Bluetooth loggers in tributaries to the Androscoggin River in Bethel, ME. Gould Academy will join the MWTWG and begin uploading their temperature time-series data to SHEDS in 2020.	
May-19	ARWC	ARWC assisted 35 students from Telstar Freshman Academy in Bethel, ME with water quality sampling. ARWC worked with students for 3 days and spent approximately 20 minutes/day discussing the Maine Water Temperature Working Group, SHEDS, and ICE.	
2016	NALCC	The North Atlantic LCC published an online article about the Maine Water Temperature Working Group. The LCC regularly posts updates about ICE on its website.	Partners in Maine search for cold water with shared regional database

TU has conducted sizable "off the books" outreach for this project. Jeffrey Reardon, Maine Brook Trout Project Director of Trout Unlimited, mentioned the project and TU's involvement at a public panel discussion in Yarmouth, ME in November 2017 ("Dams, Brook Trout and River Ecology: Implications for the Royal River Watershed"). TU-Sebago posted an update about their involvement on their Facebook page, and intended to post it in their chapter newsletter.

Project Next Steps

2 meetings were convened in 2019. In 2020, the MWTWG will convene another planning meeting and at least one training workshop. The training workshop will focus on data analysis/reporting, and on site selection for new loggers to optimize and improve the temperature model. Successive planning meetings will focus on data management, analysis and reporting in addition to next steps for project management.

All remaining loggers will be distributed at or before the spring training workshop in 2020. Partners will conduct a full summer field season of data collection, including: checking and downloading data from existing temperature loggers; replacing loggers as necessary; and uploading data to the SHEDS Temperature Database.At least 20 dataloggers will be deployed in new monitoring sites as the Network continues to expand by the end of 2020.

USFWS and PIN submitted an oral presentation abstract for the 2020 Maine Sustainability & Water Conference. If the project is not selected, USFWS and PIN will submit a poster presentation.

Appendix A

STANDARD OPERATING PROCEDURES

STREAM TEMPERATURE MONITORING

Water Temperature Working Group | 5/1/2015