Workshop on the development & implementation of a water temperature monitoring network for Atlantic Salmon (Salmo salar) rivers in eastern Canada held in Quebec City, Quebec, 22-23 January 2014: Abstracts and proceeedings

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ABSTRACT

Benyahya, L., A. St-Hilaire, D. Caissie, N. Bergeron, R.A. Curry, K. Clarke, N. El-Jabi and S. Dugdale. 2014. Workshop on the development & implementation of a water temperature monitoring network for Atlantic Salmon (*Salmo salar*) rivers in eastern Canada held in Quebec City, Quebec, 22-23 January 2014: Abstracts and proceedings. Can. Manuscr. Rep. Fish. Aquat. Sci. 3045: vi + 14p.

Water temperature is an important characteristic of aquatic ecosystems, both because of what it influences and what it is influenced by. Water temperature is also relatively inexpensive to measure. Therefore, establishing a monitoring program for water temperature is vital to Atlantic Salmon rivers. As such, a workshop was organised to provide an opportunity for a coordinated approach to design and implement an effective and efficient water temperature monitoring network. The *Institut national de la recherche scientifique* (INRS), with the assistance of the *Centre interuniversitaire de recherche du Saumon Atlantique* (CIRSA), the Canadian Rivers Institute (CRI) and Fisheries and Oceans Canada organised a two-day workshop entitled: "Development & Implementation of a Water Temperature Monitoring Network for Atlantic Salmon (*Salmo salar*) Rivers in Eastern Canada" during the period 22-23 January, 2014.

This workshop brought together 40 hydrologists, biologists, industry representatives as well as government representative to achieve the following objectives:

- To stimulate discussion on the merits of the establishment of the network between academics, industries, government and non-government agencies.
- To provide the basis of a research protocol that will lead to the establishment of a thermographic network for Atlantic Salmon rivers.
- To develop an implementation strategy with key stakeholders.

A series of presentations highlighted the challenges in establishing the appropriate design criteria for a monitoring network; spatio-temporal scales of the thermal habitat for salmonids; relevant thermal indices for salmon behaviour and physiology; case studies on water temperature network adequacy; water temperature in rivers and heat budgets; data gathering and analysis by the Water Survey Canada and the rapid emergence of temperature monitoring networks in rivers and streams across North America. Following these presentations, a number of questions were discussed, and these resulted in the following recommendations:

Priority recommendations for advancing toward regional network for monitoring water temperature monitoring included:

- Identify pilot studies in selected drainage basins for this project.
- Conduct a more comprehensive inventory of metadata for current and past rivers and stream temperature monitoring efforts (e.g., who, what, where, when).
- Implement data collection (sensors and protocols) and analysis methods in order to optimize the network.
- Identify the expected outcomes of the "pilot studies".

- The "pilot projects" need an overriding question that will give it focus and guide the next steps. Two case studies were identified: The Restigouche and Miramichi drainage basins. Both systems sustain important salmon populations, they already have some water temperature monitoring sites and have some thermal imagery data. These case studies should ideally begin in the summer of 2014, with the deployment of sensors.
- Develop funds to support the water temperature network for Atlantic salmon streams (e.g., crowdsourcing).

As a result of these discussions, it was agreed to establish a steering committee that would guide and further develop this project. The mandate of the steering committee is to identify a principle coordinator; guiding principles for the project and clarify research themes that will guide the project.

This brief report highlights key results from the workshop and documents the priority recommendations developed by the participants.

RÉSUMÉ

Benyahya, L., A. St-Hilaire, D. Caissie, N. Bergeron, R.A. Curry, K. Clarke, N. El-Jabi and S. Dugdale. 2014. Workshop on the development & implementation of a water temperature monitoring network for Atlantic Salmon (*Salmo salar*) rivers in eastern Canada held in Quebec City, Quebec, 22-23 January 2014: Abstracts and proceedings. Can. Manuscr. Rep. Fish. Aquat. Sci. 3045: vi + 14p.

La température de l'eau en rivière est l'une des variables les plus déterminantes à la fois en raison de son influence sur l'écosystème aquatique et en raison des phénomènes et des variables physiques qui l'influencent. Elle est relativement peu coûteuse à mesurer. De ce fait, l'établissement d'un réseau de suivi de la température de l'eau est vital pour l'avenir des rivières à saumon. Dans ce contexte, l'Institut national de la recherche scientifique (INRS) de Québec, avec le recours du Centre interuniversitaire de recherche sur le saumon Atlantique (CIRSA), le Canadian Rivers Institute (CRI) et Pêches et Océans Canada a organisé un atelier de travail sur l'évaluation et la reconfiguration des réseaux de suivi de la température de l'eau des rivières à saumon (*Salmo salar*) de l'est du Canada, les 22 et 23 janvier 2014.

Une quarantaine de chercheurs universitaires, de professionnels (à la fois du domaine public et privé) ont participé à l'atelier, qui a couvert une série de présentations sur l'évaluation et la reconfiguration des réseaux de suivi de la température de l'eau des rivières des provinces Atlantiques. Les objectifs de l'atelier étaient de:

- Compiler toutes les informations dans le domaine et de créer ainsi une base de connaissances commune permettant des discussions plus objectives;
- Créer un protocole de recherche approprié pour la création d'un réseau de thermographes sur les rivières à saumons de l'Atlantique;
- Mettre en œuvre une stratégie en collaboration avec les différents intervenants;

Les participants ont eu la possibilité de poser des questions et d'exprimer leurs commentaires aux conférenciers, et ils ont pu travailler en petits groupes pour déterminer les éléments clés d'un éventuel projet "pilote". Les faits saillants des discussions en petits groupes ont ensuite été présentés en plénière.

Le présent rapport résume les présentations et les discussions qui ont eu lieu durant les deux jours de l'atelier.

INTRODUCTION

Atlantic salmon is an important aquatic resource in eastern Canada. Salmonids are stenotherm fish, which means that they can tolerate a relatively narrow range of temperatures. One management strategy that has been adopted for individual rivers is focused on fishery closures when water temperature exceeds a certain threshold. Although water temperature is monitored in some rivers, Canada does not have a comprehensive, well-structured river temperature network.

Nationally, there has been very little dialogue between scientists who design most hydrological tools and the industry and government agencies that are the end users of such tools. There is no concerted effort to provide consistent thermal information that is relevant for fishery management. Yet, water temperature loggers (thermographs) are relatively cheap and reliable. Workshop organizers believe that there is an opportunity to develop a much needed water temperature network for Atlantic Salmon rivers.

On January 22nd and 23th, 2014, a workshop was convened in Quebec City, Qc, bringing together 40 biologists, hydrologists, industry representatives and government agencies to begin a dialogue to develop a standardized thermographic network for Atlantic Salmon rivers. The specific objectives of the workshop were:

- To stimulate discussion on the merits of the establishment of a network between academics, industries, government and non-government agencies.
- To provide the basis of a research protocol that will lead to the establishment of a thermographic network on Atlantic Salmon rivers.
- To develop an implementation strategy with key stakeholders.

This workshop was a platform to discuss and examine new technologies and new approaches to standardize water temperature monitoring and analysis. Participants were unanimous in their desire to improve water temperature tools and approaches, and to develop such a network. These proceedings summarize the workshop and discussions.

WELCOME & OPENING REMARKS

The workshop started with welcome remarks and an opening presentation by A. St-Hilaire. He asked the group to consider three key questions throughout their participation in the 2-days workshop:

- What are the water temperature metrics of interest?
- Where to sample?
- At what frequency should sampling occur?

The workshop proceeded with presentations addressing the following general themes: statistical approaches for a monitoring network; Water Survey Canada’s current monitoring efforts and; water temperature in rivers and heat budgets; spatio-temporal scales of the thermal habitat for salmonids; relevant thermal indices for salmon behaviour and physiology; rapid emergence of temperature monitoring networks in rivers and streams across North America and case studies on water temperature network adequacy. Presentations provided an opportunity for scientists and end users to share knowledge, ask questions, discuss needs and identify potential collaborations.

SUMMARY OF PRESENTATIONS

Statistical approaches for monitoring network: Analysis and Redesign
André St-Hilaire, INRS-ETE

A. St-Hilaire, briefly described the statistical approaches for monitoring network analysis and design. The choice of indices could be completed using a combination of policy requirements and statistical methods such as multivariate approaches, which allow for the inclusion of information other than thermal. A. St-Hilaire raised a number of questions that need to be addressed in order to monitor water quality, more specifically:

- Where to measure?: selection of sampling sites.
- When to measure?: sampling frequency and duration
- What to measure?: water quality variables or indices to be monitored (basin and climatic characteristics; local hydraulics and biological information)
- How do we expand the network?
- How do we assess the final network?

A. St-Hilaire noted that there is a unique opportunity to start with a sparse network and asked the question: how do we expand it? How do we assess the final network? Some statistical tools (see Benyahya et. al, 2014) were proposed to measure the information content of the network.

Water survey of Canada: water temperature network
Dave Hutchinson, Environment Canada

D. Hutchinson gave a historical overview of the Water Survey of Canada (WSC). In Canada, regular water temperature observations began over 60 years ago and continuous recordings began in the mid-1970s on a project-by-project basis. Unfortunately, much of these data are lost but some hardcopy reports exist in Environment Canada library holdings and data could be recovered. In the late 1990s, continuous water temperature started to be recorded in order to support client-specific monitoring requirements.

Currently, there are approximately 350 water temperature stream gauges located across Canada. The stream gauge network consists of sites with equipment operated by Environment Canada staff. Water temperature is generally recorded during routine hydrometric surveys using a handheld thermometer (digital or alcohol in-glass). Continuous water temperature data are collected at some specific stream gauge stations and temperatures are generally recorded hourly. The following characteristics should be noted for water temperature recording:

- Probe accuracy typically +/- 0.1 to 0.2 °C.

- No standards for probe siting (depth, distance).
- No quality assurance and quality control (QA/QC) of collected data (raw).
- No permanent archive.

D. Hutchinson completed his presentation with potential future steps to improve water temperature data. They include:

- Digitally capture spot water temperature readings as part of regular hydrometric surveys.
- Extract other paper records from existing Environment Canada archives.
- Develop Standard Operating Procedures (SOP) and QA/QC procedures for water temperature.
- Develop business case for WSC to be a data provider of water temperature.

River temperature: overview of heat exchange processes
Daniel Caissie, DFO Gulf Region

D. Caissie provided a summary of key physical processes related to river water temperature. He presented his findings from research conducted in a medium-sized river (Little Southwest Miramichi River) showing how, on sunny days, surface heat exchange (via short and longwave radiations and evaporation) and streambed fluxes could be used to better understand river temperature dynamics. His research showed that evaporation was a parameter that is not very well studied in rivers even though it is important during high temperature events (evaporative cooling) and a key parameter in climate change studies. D. Caissie's research has shown that the direct measurement of evaporation flux using floating minipans could be an inexpensive and an effective tool (Maheu et al., 2013).

As watercourses become smaller and as groundwater contribution becomes more significant, the streambed contribution is also important. D. Caissie raised the following question that needed to be addressed in order to move forward in the understanding of the river thermal regime: 'What is the spatio-temporal variability of hyporheic exchange (downwelling and upwelling behavior)?'

Spatio-temporel scales: thermal habitat for salmonids
Normand Bergeron, INRS-ETE

The aim of the presentation was to provide some background information on the spatial and temporal variation of river water temperature in order to better inform the decision process leading to the optimal distribution of thermographs necessary to adequately model the thermal habitat for Atlantic salmon in river systems.

N. Bergeron discussed the temporal variability of various types of thermal refuges from repeated thermal and optical airborne imagery of the Ouelle River, a thermally stressed Atlantic salmon river in Québec, Canada. The results demonstrated important inter-annual differences in the abundance of thermal refuges during summer low flows and revealed the role of long-term hydrometeorological trends in explaining this variability. Specifically, inter-annual abundance of groundwater seep refuges correlated strongly with seasonal mean discharge (R^2 = 0.94).

In the second part of the presentation, the spatial distribution of thermal refuges in the Restigouche River (Québec/New Brunswick, Canada) was analysed from a ~700 km-long record airborne thermal and optical images. GIS-based analyses revealed that the streamwise density of groundwater driven thermal refuges was strongly linked to channel entrenchment ratio (R^2 = 0.76), highlighting the role of channel geomorphology in driving refuge density. Jacobs selectivity index (Jacobs, 1974) applied to thermal refuge presence/absence data suggested that refuge presence was also positively associated with high values of channel curvature as well as with proximity of flowing and relict tributaries ($X^2 < 0.05$, df = 9). Given that thermal refuges will likely be of critical importance towards sustaining salmonid populations under future climate change scenarios, the results of this study will help identify and protect vital thermally sensitive habitats and ensure the future survival of thermally-stressed salmon populations.

How warming water temperatures affect wild juvenile Atlantic salmon (*Salmo salar*): relevant thermal indices?

Richard A. Cunjak. Emily Corey, Allen Curry & Tommi Linnansaari, Canadian Rivers Institute (CRI), University of New Brunswick

The objective of this presentation was to review the research on the response of wild juvenile Atlantic Salmon to high temperature events in the Miramichi River (NB) based on data collected over the past two decades. A previous study has shown evidence of a physiological stress at 23^{o}C – 24^{o}C (change to anaerobic metabolism) coincident with behavioural thermoregulation based on field studies (abandonment of territories, reduction in feeding, movement and aggregation in coolwater refugia) (Breau et al. 2011). These aggregations were most common once maximum water temperatures exceeded ~27^{o}C but it is still not clear whether absolute daily maxima initiate such thermoregulation behaviour, or if it was the result of a combination of successive daily maxima and/or nighttime minima. Current laboratory studies (carried out by Emily Corey) should help resolve this question. During extreme heat events, such as occurred in July 2010 when maximum water temperatures exceeded 30^{o}C, mortalities of juvenile and adult salmon were observed. Based on movement data, we now know that salmon parr are capable of moving long distances (5-10 km) in search of thermal refugia during these heat stress events. Collaboration with researchers will help better understand the exact mechanism of movement and how aggregation behavior is initiated across a range of salmon rivers and temperature regimes.

Case studies on water temperature network adequacy

Anik Daigle, INRS-ETE, CEGEP Garneau

A. Daigle presented a methodology for evaluating the adequacy of a water temperature network over three spatial scales:

- Large scale: United States (using USGS data).
- Regional scale: Haute-Savoie (France).
- Drainage basin and reach scale: Ouelle & Ste-Marguerite rivers (Québec).

The methodology consists of the following:

- Identify physiographic variables that best represent the study area;

- Choose optimal spatial and temporal sampling scales for the network based on physiographic variables;
- Evaluate the network adequacy: the interpolation performance.

Considering the whole network (100% of data set used), the results of her research showed that:

- When using interpolations methods in a multivariate space to estimate daily temperatures, Root Mean Square Error (RMSE): ranged from 0.51°C (mean annual temperature) to 1.43°C (30-day maximum temperature) for Haute Savoie; and from 1.7°C (mean annual temperature) to 3.3°C (30-day maximum temperature) for USGS network.
- An examination of water temperature along the Rivière Ouelle showed the presence of four discrete reach-scale thermal 'links' bounded by distinct hydromorphological units (Dugdale et al. 2013).

Rapid emergence of temperature monitoring networks in rivers & streams across North America
Dan Isaak, USDA Forest Service Rocky Mountain Research Station, Boise Aquatic Sciences Laboratory

Most protocols are suitable for seasonal monitoring during low-flow periods (none for annual monitoring), so the majority of existing temperature data consists only of one or two short sampling periods at a specific site. Moreover, existing protocols have several additional limitations:

- They are expensive to implement in terms of number of site visits that are required for maintenance.
- They are obtrusive, as they require metal bars and steel cables be left in the stream.
- They are often positioned on the streambed, where they are more prone to abrasion by substrates during floods.

In recent decades, the advent of inexpensive, miniature digital sensors made collection of stream temperature less complicated and more affordable. During his presentation, D. Isaak described a simple protocol that uses underwater epoxy to attach sensors to the downstream sides of boulders and cement bridge supports, which then serve as protective anchors. He also presented the materials required to establish annual temperature monitoring sites on streams and rivers (Isaak et al. 2013). Most minilogs are very efficient to monitor water temperature as well as being relatively inexpensive. They are small in size, with a relatively good accuracy (+/-0.2˚C), large memory and they generally have a long battery life (5 years). Most minilogs have efficient data retrieval and some have a portable data shuttle to download the data in the field. During field deployments, temperature sensors must be shaded to avoid biased measurements caused by sunlight striking the sensor. Details about the protocol training materials are available in a short video at: http://www.youtube.com/watch?v=vaYaycwfmXs&feature=youtu.be

Across the Rocky Mountain region, the protocol was used to establish 563 monitoring sites on rivers and streams. In order to document retention rates of the sensor, 72 sites established with PVC canisters were revisited one year later. In low-gradient streams (<3%), approximately 90%

of sensors were successfully retained; whereas 78% of sensors were retained in steeper streams (>3%) (Isaak et al. 2013).

In the northwest USA, large regional databases (>3000 sites monitored by numerous resource agencies) of summer temperature measurements exist and could be used to build regional temperature models. However, the sample locations are often non-randomly distributed and strongly clustered in space. As such, this spatial dependence could strongly bias the regional water temperature predictions. Recently, a new class of spatial statistical network model that incorporates covariance structures has been developed (e.g., Ver Hoef et al. 2006). This model describes distances over which measurements are correlated and partially redundant. Moreover, the spatial models can use a mixed model approach for residual errors, thereby allowing multiple covariance matrices to be combined in a robust and flexible covariance structure (Ver Hoef and Peterson 2010).

Once the spatial model is fitted to the data (originating from a stream temperature database), a variety of outputs can be derived that are useful for research and management. These include: a) spatially continuous maps of stream temperature for addressing water quality concerns, b) accurate, local assessments of climate change impacts, c) thermal habitat maps for aquatic species, and d) spatially explicit representations of model precision.

Summary of presentations: highlights

Before introducing the format and objectives for the breakout sessions, N. Bergeron provided a summary of the presentations highlighting key topics and identifying information gaps that needed to be discussed.

- Why is monitoring going to be conducted? Is it for basic information, planning and policy information, support management decisions and/or other purposes?
- What are the potential research topics that could optimize water temperature monitoring networks in the future?
- For water temperature monitoring metadata database development: What indicators will be used in view of supporting decision making process? What are the representative sampling sites? What information is required for site description (e.g., drainage area, canopy, etc.)? What are the frequency and the timing of sampling? What kind of probes can be used? What is needed to design and implement a metadata database?
- What are the meteorological and hydrological information required to optimize the water temperature monitoring network?
- Are there needs other than those associated with salmon management that may influence the design of the network (e.g. drinking water)?
- How does water temperature differ in time and space within the region?
- Is groundwater a significant factor in the thermal process in eastern Canadian rivers?
- Which thermal stress metrics are most affecting the salmonids's life in the region?
- How can we adjust and refine our water temperature monitoring networks so that we can better support climate change adaptation planning, and therefore reduce the risks associated with climate change impacts?

- How do we define the threshold values to be physiologically and behaviorally relevant to eastern Canadian rivers juvenile salmon populations?
- What are the statistical methods that could be used for data analysis and network evaluation?
- What is practical in terms of the human and funding resources strategy for monitoring?
- What are the priority next steps needed to enhance the reporting/communications of monitoring information?

BREAKOUT SESSIONS

The breakout groups were organized so that each had representation from industry, government and the research community. Each breakout session had central themes that were guided by a set of questions intended to stimulate discussions and recommendations. Session participants created lists of key elements of a successful water temperature monitoring project after discussing several points. The key elements and recommendations are listed in Tables 1 and 2 and grouped into categories.

PATH FORWARD

Following the summary of discussions from Breakout session #2, A. St-Hilaire spoke briefly to the workshop participants. He highlighted the need to identify a key question that would provide guidance and give focus to the project. He also noted that there is a need to identify new sources and approaches to funding.

A number of recommendations emanated from the discussions. The last roundtable discussion focused on the preferred option for furthering the objectives of the workshop. They are summarized in Table 3. It was then decided that a steering committee would be formed with a geographical representation beyond Atlantic Canada (e.g., CRI-CIRSA). The mandate of the steering committee would be to:

- Find the Principal Coordinator for the project.
- Develop a vision statement that will provide a common framework for the committee to work within.
- Clarify potential research themes and sub themes that will guide the project.

CONCLUSION

The material presented and the discussions that took place can be summarized as follows:

- This dialogue between hydrologists, biologists, industry representatives and government agencies was a successful first step towards understanding the state of the science and the possible linkages (between the disciplines) that could potentially be utilized to further develop a water temperature network in eastern Canada.
- Discussions on the topics of temporal and spatial scales created more questions than provided answers. Further discussions are required to ensure there is a common understanding and agreement about scale issues.
- The "pilot project" needs an overriding question that will give it focus and guide the next steps. Two case studies were identified: The Restigouche and Miramichi drainage basins. Both systems sustain important salmon populations, already have some water temperature monitoring sites and have some thermal imagery data. Case studies should ideally begin in the summer of 2014, with the deployment of sensors.
- The newly struck working group should report back to all participants about who will be leading this initiative and what the next steps will be.

Table 1. Breakout session-Day 1: Network Research objectives and themes

	Recommendations
Why do we need to monitor?	- Fisheries management can be one the objectives of the regional network for monitoring stream water temperature.
Where should we monitor? Network design	- Validation (representatively) of the existing water temperature measurement stations. - Identify a network of salmon rivers that will serve as the network's observational framework. - Identify which part of river can give the best water temperature network. - River regions establishment: including genetic or physiographic factors.
What should we integrate as knowledge to optimize the water temperature monitoring network?	- Conduct a more comprehensive inventory of project metadata for current and past water temperature monitoring. ArcGIS projection will help the visualisation, management, creation, mapping and analysis geographic data. - Impact of catchment releases on juvenile survival and on production success. - Refine the water temperature threshold that helps identify and account for the effect of cold water refugia from groundwater or tributary inputs. - Telemetry technologies can be used to acquire information on fish behaviour. - Explore water temperature monitoring in estuarine zones during salmon transition from fresh to seawater. - Patterns of salmon migration and residency. - Timing of spring fry emergence. - Effects of river temperature and climate warming on juvenile survival and adult migration. - Remote electronic monitoring (video camera) is a new tool for fisheries management. - Short-term prediction of thermal stream events. - Historical temperature index related to population structuring.

Table 2. Breakout session-Day 2: Network Logistics, funding and associated structure

	Recommendations
Database management	- Develop baseline datasets that would be required to be usable in a regional network analysis. - Consistent, long-term monitoring data. - Stakeholder involvement: providing real time data from e.g.: EC database; DFO and Memorial University. - Effective data sharing and reporting: partnerships between federal and provincial governments. - Effective data storing: ASCII formats - Simple and updated every year.
Staff	- Hire people for deployment, data input and management. - Government can provide staff for deployment and retrieval. - Need training.
Coordination	- Need a volunteer lead to avoid redundancy (e.g., INRS, CRI, CIRSA, steering committee of max 5 people).
Equipment	- Identify needs in each watershed using USGS or World Meteorological Organization standards. - Use existant infrastructure : e.g. Centre d'Expertise Hydrique de Québec (CEHQ). - Use of appropriate technology: real-time probes (e.g., ONSET), server. - Choose the most representative stations in terms of access, size of the site, sensitive areas that need information on fishery closure criteria, historical information.
Analyses	- Standardizing quality assurance and quality control (QAQC) protocols. - User-defined. - Reporting every 5 years and publishing state of network every year
Funding	-Crowdsourcing to support a water temperature network for Altantic Salmon streams. Microryza (https://www.microryza.com/) is a potential way the scientists can use to fund community science.

Table 3. Roundtable discussion: To-Do list

	To-Do
Path	- Pilot study. - Ground work.
Duration	- 1-2 year(s).
Ground work	- Install probes at hydrometric stations. - Optimizing network: best combination stations/minimum redundancy of the network. - Testing protocols (overwintering, buy the very expensive or the cheapest). - Standard operating procedures. - Database structure. - An expanded network/project must be included to maintain momentum.
Data provision	- Focus on meta data. - Stakeholder involvement is required to acquire data: e.g. region, major network [Water Survey (Dave Hutchinson), Centre d'Expertise Hydrique du Québec (CEHQ, W. Larouche). DFO on a number of rivers in NF (K. Clarke), New Brunswick (D. Caissie) & Nova Scotia (K. Garroway). Nova Scotia Department of the Environment (NSDOE, R. Savoie)]. One resource from industry needs to be identified.
Pilot study rivers	- Restigouche (21 stations): could be a good candidate (interprovincial). Work underway with CEHQ, WSC, lots of data. - Miramichi (21 stations): data already exist, been studied extensively by R. Cunjak, D. Caissie et al., already has a warm water management protocol that could be upgraded.
Coordination	- Collaboration between CRI-CIRSA. CRI and CIRSA do not have infrastructure or funding, but both are willing to lead the steering committee. Steering committee: 5-7 people max. Steering committee should develop a short mission statement. Strong cross-representation but not necessarily all-representative. Should include initially two coordinating bodies. Other members should have to provide tools/ideas to grow the project.
Outcome	- Maps, specific protocols, testing transferability from sub-watersheds, forecasting.
Funding	- Local: watersheds, industries.
Communication	- Initiate a FACEBOOK group by Carole-Anne Gillis. - Create a mailing list.

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REFERENCES

Benyahya, L., A. St-Hilaire, D. Caissie, N. Bergeron, R.A. Curry, K. Clarke, N. El-Jabi and S. Dugdale, 2014. Development and Implementation of a Water Temperature Monitoring Network for Atlantic Salmon (*Salmo salar*) Rivers in Eastern Canada. Workshop prepartion document, INRS-ETE. pp 21

Breau, C., R.A. Cunjak and S.J. Peake, 2011. Behaviour at high water temperatures: can physiology explain movement of juvenile Atlantic salmon (*Salmo salar*) to cool water? Journal of Animal Ecology 80: 844–853.

Dugdale, S.J., N.E. Bergeron, A. St-Hilaire, 2013. Temporal variability of thermal refuges and water temperature patterns in an Atlantic salmon river. Remote Sensing of Environment 136: 359-373

Isaak, D.J., D.L. Horan, S.P. Wollrab, 2013. A simple protocol using underwater epoxy to install annual temperature monitoring sites in rivers and streams. Gen. Tech. Rep. RMRS-GTR-314. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 21 p.

Jacobs, J., 1974. Quantitative measurement of food selection. Oecologia (Berl) 14:413–417

Maheu, A., D. Caissie, A. St-Hilaire, N. El-Jabi, 2013. River evaporation and corresponding heat fluxes in forested catchments. Hydrological Processes. DOI: 10.1002/hyp.10071

Ver Hoef, J.M., and E.E. Peterson, 2010. A moving average approach for spatial statistical models of stream networks. Journal of the American Statistical Association 105:6-18.

Ver Hoef, J.M., E.E. Peterson, and D.M. Theobald, 2006. Spatial statistical models that use flow and stream distance. Environmental and Ecological Statistics 13:449-464