CONSIDERING ENVIRONMENTAL VARIABLES IN THE MANAGEMENT OF ATLANTIC SALMON RECREATIONAL ANGLING: A RETROSPECTIVE REVIEW OF A WARM WATER PROTOCOL FOR THE MIRAMICHI RIVER IN NEW BRUNSWICK FROM 1987-2020

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ABSTRACT

Dolson, R., Boudreau, S.A., Tunney, T.D., McDermid, J.L., Breau, C. 2024. Considering Environmental Variables in the Management of Atlantic Salmon Recreational Angling: A Retrospective Review of A Warm Water Protocol for the Miramichi River in New Brunswick from 1987-2020. Can. Manuscr. Rep. Fish. Aquat. Sci. 3278: vii + 50 p.

New Brunswick’s Miramichi River is reputably one of the best recreational Atlantic Salmon (*Salmo salar*) angling rivers in Atlantic Canada. Miramichi salmon are in decline due to anthropogenic and environmental threats. In an effort to maintain a recreational fishery, in-season fisheries management interventions to protect Miramichi salmon during environmentally stressful conditions have been on-going since the 1980s. Throughout the 1990s and early 2000s, salmon mortalities were observed by anglers and conservation staff following warm water (>23^{o}C) events, especially where angling effort was high. In response, in-season interventions were implemented to limit mortalities of salmon from angling during warm and low water events. The resulting, “Protocol for In-season Conservation Measures for Atlantic Salmon during Environmentally Stressful Conditions in the Miramichi Watershed (Warm Water Protocol)”, was formalized in 2015 by Fisheries and Oceans Canada (DFO). The protocol implements a phased approach to restrict angling based on water temperature thresholds (20 and 23^{o}C) while also considering water level, salmon behaviour and observed mortalities, and the weather forecast.

This manuscript provides a retrospective review, from 1987 to 2020, of the development and implementation of a Warm Water Protocol (WWP) for the Miramichi River Atlantic Salmon recreational fishery. This review is a case study in support of DFO’s Ecosystem Approach to Fisheries Management (EAFM) initiative, which aims to understand how environmental and ecosystem variables are considered and implemented in the management of Canada’s fisheries resources.

RESUMÉ

Dolson, R., Boudreau, S.A., Tunney, T.D., McDermid, J.L., Breau, C. 2024. Considering Environmental Variables in the Management of Atlantic Salmon Recreational Angling: A Retrospective Review of A Warm Water Protocol for the Miramichi River in New Brunswick from 1987-2020. Can. Manuscr. Rep. Fish. Aquat. Sci. 3278: vii + 50 p.

La rivière Miramichi, au Nouveau-Brunswick, est réputée pour être l'une des meilleures rivières du Canada atlantique pour la pêche récréative du saumon atlantique (*Salmo salar*). Le saumon de la Miramichi est en déclin en raison de menaces anthropogéniques et environnementales. Afin de maintenir une pêche récréative, des interventions de gestion en cours de saison visant à protéger le saumon de la Miramichi dans des conditions de stress environnemental sont en cours depuis les années 1980. Tout au long des années 1990 et au début des années 2000, les pêcheurs à la ligne et le personnel chargé de la conservation ont observé des mortalités de saumons à la suite d'épisodes de réchauffement de l'eau (>23ºC), en particulier là où l'effort de pêche à la ligne était important. En réponse, des interventions de gestion de la pêche en cours de saison ont été mises en œuvre pour limiter la mortalité des saumons due à la pêche à la ligne pendant les périodes d'eaux chaudes et d'étiage. Le "Protocole pour les mesures de conservation en cours de saison pour le saumon atlantique lors de conditions environnementales stressantes dans le bassin versant de la Miramichi (Protocole d'eau chaude)" qui en a résulté a été officialisé en 2015 par Pêches et Océans Canada (MPO). Le protocole met en œuvre une approche progressive pour restreindre la pêche à la ligne en fonction des seuils de température de l'eau (20 et 23ºC) tout en tenant compte du niveau de l'eau, du comportement du saumon et des mortalités observées, ainsi que des prévisions météorologiques.

Ce manuscrit présente un examen rétrospectif, de 1987 à 2020, de l'élaboration et de la mise en œuvre d'un protocole d'eau chaude (« Warm Water Protocol ») pour la pêche récréative du saumon atlantique dans la rivière Miramichi. Cet examen est une étude de cas à l'appui de l'Approche écosystémique de la gestion des pêches (AEGP) du MPO, qui vise à comprendre comment les variables environnementales et écosystémiques sont prises en compte et mises en œuvre dans la gestion des ressources halieutiques du Canada.

1. BACKGROUND AND APPROACH

The Miramichi River has long been recognized as providing one of the best recreational Atlantic Salmon (*Salmo salar*; Chaput et al. 2016, DFO 2020) angling experiences in Atlantic Canada. However, the salmon population in the Miramichi River is facing increasing threats and declining returns and, as a result, mandatory catch-and-release angling of all adult Atlantic Salmon has been required since 2015 (mandatory release of large salmon implemented in 1984). In response to intermittent low and warm water events on the Miramichi River, and due to a great interest in maintaining access to the recreational fishery, in-season management interventions to protect salmon from additional mortality during environmentally stressful conditions have been used since the 1980s. Management interventions were formalized by Fisheries and Oceans Canada's (DFO) Gulf Region in 2015, through a protocol entitled the, "Protocol for In-season Conservation Measures for Atlantic Salmon during Environmentally Stressful Conditions in the Miramichi Watershed (Warm Water Protocol)". The protocol implements a phased approach to angling restrictions based on water temperature thresholds (20 and 23°C) over a 48-hour period while also considering water level, salmon behaviour and observed mortalities, and the weather forecast (including precipitation).

A retrospective review of the history and use of warm water management interventions on the Miramichi River (from 1987 up to 2020) is presented in this report in support of DFO's Ecosystem Approach to Fisheries Management (EAFM) initiative. In this review, the science information and advice that supported management decisions and protocol development are discussed, including the physiological response of salmon to warm and low water stress, and the implications of different temperature thresholds on angling closures. The effectiveness of the protocol to reduce salmon angling mortality during environmentally stressful conditions, as well as challenges and confounding variables, are also discussed.

The files and publications reviewed for this report were primarily provided by DFO Science and Fisheries and Harbour Management (FHM). Many of the documents and correspondence are draft, internal, or unpublished. A search of the Canadian Science Advisory Secretariat (CSAS) publications database was also conducted using search the words "salmon", "Miramichi", "warm water", "recreational fishing", and "angling mortality". Finally, conversations with DFO Science, Conservation and Protection (C&P), and FHM staff, along with key stakeholders, were conducted to understand the history of development, and current implementation process, of the Warm Water Protocol (WWP) for the Miramichi River. Where relevant, primary literature is also cited to provide context or clarity. An exhaustive search of the primary literature with respect to in-season recreational angling interventions, or salmon response to warm water conditions in other watersheds, was out of scope for this report.

1.1 The Miramichi Watershed

The Miramichi River, located in northeastern New Brunswick, Canada (Figure 1), has a drainage area of approximately 14,000 km^2 and a maximum stream length of 250 km. The river is composed of two major branches: the Northwest Branch which has a drainage area of approximately 3,900 km^2 and the Southwest Branch which has approximately 7,700 km^2 of drainage area (Chaput et al. 2016). The river historically supported one of the largest Atlantic Salmon (*Salmo salar*) run of eastern North America (Chaput et al. 2016, ICES 2022).

The Miramichi River Atlantic salmon run currently supports a recreational fishery along with indigenous ceremonial and subsistence fisheries for Atlantic salmon. The salmon fishery has had a major to the people of the Miramichi Valley and attracts anglers from around the globe. The recreational fishery has considerable economic value to the area and was valued at $32 million dollars in 2006 (DFO 2008), and $20 million in 2015 (DFO 2020). There are an estimated ~700 angling pools and 1,400 km of angling waters in the Miramichi

(Chaput and Swansburg 2004). Some of the angling pools are coldwater refuge pools where adult salmon congregate throughout the late spring and summer prior to moving upstream to spawn in the fall. Anglers target these pools for recreational fishing and WWP was designed based on the idea of limiting catch-and-release recreational angling for salmon in these coldwater pools when salmon are aggregated in these pools warm periods during the summer months. In the river and marine ecosystem there are up to six-year classes of immature fish, and up to nine-year classes of mature fish that contribute to the Miramichi population at any one time (Chaput et al. 2016). The angling season begins on April 15th and extends until October 15th in some stretches of the river. Management measures for the fisheries also include regulations based on the size of the salmon, defined as small salmon (also called grilse or one-sea-winter, 1SW, < 63cm fork length) and large salmon also called multi-sea winter, MSW, >= 63 cm fork length).

1.2 Recreational Angling Mortality

Recreational fishing, including catch-and-release, results in incidental mortality to fish like Atlantic salmon that is considered acceptable during typical environmental conditions (Patterson et al. 2017). The most important factors known to influence post-release mortality are hook time and handling practices (Patterson et al. 2017), with temperature being an additional stressor (Havn et al. 2015). Angling associations and regulating bodies have developed guidance and rules to promote best handling practices to reduce possible post-release mortality (e.g., barbless hooks; see Van Leeuwen et al. 2023). Post-release mortality can be as high as 45-100% when hook time exceeds one hour, and out-of-water handling exceeds five minutes (Patterson et al. 2017). Estimates of incidental post-release angling mortality for various rivers in Atlantic Canada range from 3 to 10% (Bielak 1996; Dempson et al. 2002; Hambrook et al. 2011; Havn et al. 2015). Hambrook et al. (2011) estimated the losses of large salmon from recreational angling by assuming a 30% catch rate in the Miramichi River with 3% mortality. More recently, higher post-angling mortality rates ranging from an average of 16 to 25% have been estimated (Van Leeuwen et al. 2020a,b, Keefe et al. 2021). However, the contribution of catch-and-release angling to mortality was found to be small (2.3 to 2.6%) when catch-and-release is reduced during summer and exceedingly warm periods (Van Leeuwen et al. 2023).

There is substantial evidence that post-release angling mortality is exacerbated, often above acceptable incidental levels, during warm water conditions (Havn et al. 2015). For example, Dempson et al. (2002) noted a 5% increase in mortality of salmon angled above 17.9ºC, compared to incidental mortality. Bielak (1996) provided a synthesis of catch-and-release literature with respect to warm water conditions and noted that while many studies lacked a standardized approach to account for confounding variables, the literature consistently suggested that post-release mortality increased above 20ºC, and significantly above 23ºC. Further confirmation of the impact of increased water temperature, and other factors, on post-angling mortality was presented in a meta-analysis (Van Leeuwen et al. 2020a,b). A variable mortality rate, was presented ranging from 1% to 5% at water temperatures less than 12°C, 4% to 16% between 12°C and 18°C, and 7% to 33% between 18°C to 20°C.

Given the importance of Atlantic Salmon angling to the socio-economic condition of communities in the Miramichi River watershed, and the cultural and social benefits, there is a desire to maintain access to the recreational fishery during warm water events, where risks can be acceptably mitigated to protect salmon. The goal of the WWP is to reduce the catch-and-release mortality of Atlantic Salmon during environmentally stressful conditions to levels compatible with acceptable incidental loss (e.g., not detrimental to stock status or reproductive potential of the population), while maintaining access to the recreational fishery. However, the Miramichi Atlantic Salmon stock has not been meeting the conservation limits (DFO 2015a, 2018a, 2022). Further the level of mortality that is acceptable has yet to be defined, and the proposed harvest decision rules have recently been evaluated as having some elements not compliant with the Precautionary Approach (Breau and Chaput 2023). To that effect, the DFO (2009) policy stated that for a stock below the Limit Reference Point (LRP), removals from all sources should be kept at the lowest level possible to promote stock rebuilding. For a population near or below LRP, the warm water protocol is expected to limit catch-and-release mortality during warm water periods thereby reducing preventable losses that could lead to further population declines.

1.3 History of Environmentally Stressful Condition Interventions in the Miramichi and Other Rivers

Pre - 2010

Recreational angling management interventions on the Miramichi River for salmon in response to stressful environmental conditions may have occurred prior to the 1980's however detailed documentation is lacking. In modern times, the relationship between low and warm water conditions and Atlantic Salmon mortality has been of concern in the Miramichi since 1984 (Bielak 1996), specifically when large mortality events were linked to extremely low water levels. Management interventions to restrict angling during environmentally stressful conditions have occurred on the Miramichi since 1987 (Chaput 2002). Specifically, management interventions were implemented in 1987, 1989, and 1995 to address observed salmon mortality due to extreme low water levels (Figure 2A). The number and type of closures that occurred in 1987 and 1989 are not documented in the resources reviewed for this report. In 1995, entire tributaries and sections of the Miramichi River were closed to angling for between 42 and 59 days (Chaput 2002) due to warm water conditions and Indigenous harvest concerns. In 1999, DFO implemented partial daily closures (no angling after 10 am) for a total of 10 days and coldwater salmon refuge pool closures for 47 days, as a result of observed mortality events (13 mortality events) associated with warm water (Chaput 2002). These closures were implemented based on simple temperature threshold rules: the river was closed when water temperature exceeded 22ºC. The threshold was not applied consistently but rather on an ad-hoc basis. The goal of management intervention in 1999 was to protect salmon from additional angling stress, and thus prevent an increase in catch-and-release mortality, during environmentally stressful conditions, while continuing to allow access to the recreational fishery.

Without a formal rule and standardized process to implement the warm water closure, the interventions were late and the period when salmon needed protection was missed. For example, mortalities were observed starting on July 17, 1999 when water temperatures had exceeded 24ºC for seven days, but consultations on management interventions (e.g., closure) did not occur until July 29. By the time the closure was implemented two weeks had passed (Chaput 2002). In 1999, salmon guide Jason Curtis of the Miramichi Salmon Association (MSA) said that he had observed large (>100) numbers of dead salmon in the Cains River sub-watershed near Black Brook and that he suspected it was related to warm water (J. Curtis, pers. comm. 2020).

Lessons learned during the management interventions of 1987 and 1999 highlighted the need for a standardized process to streamline in-season management interventions and that a defined communication plan for anglers during the temporary closures was essential to successful implementation (Chaput 2002).

Moore et al. (2004) reported that between 1999 and 2001 salmon mortalities likely exceeded 200 annually, but were less than 500, and concentrated in the Southwest Miramichi sub-watershed (near the mouth of the Cains River). Mortality events were likely underestimated across all years due to low detectability and the lack of a standardized monitoring program (Chaput 2002). In 2001, mortalities were observed starting on July 20 and consultations began within a week; however, management interventions (partial daily closure as morning fishing only and coldwater refuge pool closure) were not implemented until August 10th when temperatures had already begun to recede.

2010 to 2020

Cooler air and water temperatures in subsequent years delayed the perceived need for the development of a WWP until 2010. In 2010, nine coldwater pools were closed to angling for seven days. In 2011, the Miramichi Working Group recommended the development of a protocol in the context of the Atlantic Salmon Framework (as mentioned in DFO 2015b). The aim of the protocol would be to provide transparency and consistency in how in-season angling management interventions were implemented (DFO 2015b). Warm water management interventions have occurred every year since 2010 (except 2011 and 2014) until 2019. At the time of the present review, the membership of the Miramichi Working Group could not be located and it is assumed that the Framework being referenced was part of The Wild Atlantic Salmon Conservation Policy (DFO 2009a), however we note that this could not been verified.

In July of 2010, Dr. Rick Cunjak of the University of New Brunswick (UNB) reported to the MSA and DFO Fisheries Managers that he had observed more than 200 dead salmon parr at sites in Otter Brook and Catamaran Brook, a tributary to the Little Southwest Miramichi, associated with day-time water temperatures that exceeded 30ºC. He also reported that salmon parr were aggregating in the thousands in small cold water refugia, with aggregations of fish (~4000-5000) extending in a cloud for ~100 m downstream of Otter Brook. Dr. Cunjak also reported ~ 20 dead adult salmon with adults fighting for position in the coldwater pools. Anglers were also observed fishing within the pools during peak water temperatures periods (see Cunjak 2010, Appendix 1).

An interim WWP was discussed and promoted by stakeholders for use by DFO in 2011, which is described in an internal DFO document (see DFO 2011b, Appendix 1). The document outlines the time of day water temperature recordings should be made, and other field observations to be recorded, including water levels, salmon behaviour, mortalities, and the number of days of high water temperature. Water temperature was to be taken between 6 and 8 pm to estimate the most extreme temperature exposure for salmon. Three management intervention phases were identified based on daily reports of air temperature and the factors listed above. For each phase, responsibilities of DFO FHM, Science, and C&P are outlined with respect to monitoring, advice, stakeholder engagement, and drafting variation orders to restrict angling. The phases were defined as follows:

- Green, when water temperature was <22ºC no closures were recommended;
- Yellow, when water temperature was between 22 and 25ºC, morning angling closures (after 10 am) were recommended; and
- Red, when water temperature was > 25ºC recommendations would be made for river section(s) or entire watershed angling closures (see DFO 2011b, Appendix 1).

A variation of this interim protocol is described in DFO (2011a, Appendix 1), which incorporates the same temperature thresholds, but includes salmon life stages (parr, juvenile, and adult). This document (DFO 2011b, Appendix 1) outlines five phases and is linked to thresholds established by the Reid et al. (2011, Appendix 1) thermal management plan (discussed in Section 2 below). It does not appear that either of the interim protocols were implemented as no closures occurred in 2011.

In spring 2012, the CSAS review of working documents to establish temperature thresholds was completed (published as Caissie et al. 2012, Breau, 2013, Breau and Caissie 2013). A minimum temperature threshold of T_{min} >20ºC was proposed by Science at the meeting and was used in summer 2012 onward. Based on information requests sent to DFO, it appears that in 2012 a 20ºC minimum temperature threshold for two consecutive days was being implemented as the criteria for in-season management interventions (see DFO 2012c, Appendix 1). In 2012, four in-season management interventions occurred on the Miramichi River. Fifteen coldwater pools were closed to angling from the end of July to beginning of September, and morning angling only (5 am to 10 am) was imposed throughout the watershed twice in August. Three pools were closed for the month of September. Correspondence between DFO FHM, C&P, and stakeholders (e.g., MSA and Miramichi Watershed Management Committee, MWMC) demonstrate that water temperature, weather forecast, water level, and salmon behaviours were considered prior to angling interventions (see DFO 2012b, Appendix 1). The NB Aboriginal People's Council were also asked for their opinion on the closures, even though closures would not impact treaty or food, social, and ceremonial (FSC) fishing rights. Stakeholders, while generally supportive of the on-going closures, had begun to suggest that the protocol may be too precautionary and that angling interventions should be removed when there is a forecast of cooler weather as opposed to waiting 48 consecutive hours for realized cooler water temperatures (see DFO 2012c, Appendix 1).

During the 2013 angling season one in-season management intervention was implemented; it closed 22 angling pools for eight days in July (see DFO 2013a, Appendix 1), not including the three pools that closed annually on August 31st. In 2013, the season closure date for the three (plus one – Parks Brook) pools was implemented on July 19th and not August 31st, presumably due to the ongoing warm water event that led to the closures of the other 22 pools. In an internal memo to DFO's Gulf Regional Director General, FHM provided the following rationale for the closure as: observed minimum water temperatures of >20°C for three consecutive days, First Nations and stakeholders were supportive of a closure, and C&P reported observations of salmon aggregating in coldwater refuges. The memo notes that the criteria for an angling closure are met when the minimum water temperature is >20°C for two consecutive days. Three days of warm water threshold exceedances occurred before a variation order to close the fishery was drafted.

No in-season management interventions were documented during the 2014 angling season. At the time of the present review, it is not known what was different about 2014, whether it was environmental or due to management decisions. Beginning in 2015 the current WWP (Section 3 below; DFO 2015b) was implemented and this version continues to be used today. The only material changes to the protocol in the intervening years has been the addition of more coldwater refuge pools between 2016 and 2019, as pools were enhanced or remediated (e.g., see Butruille 2016, Appendix 1; DFO 2019b, Appendix 1). In the 2015 protocol, 23 pools were identified (plus three additional pools that close seasonally on July 1). By 2019, 27 pools were included in the protocol.

Closures occurred every year from 2015 to 2019. In 2015, 23 coldwater pools were closed to angling on three occasions for a total of 11 days, and one morning only angling (6 am to 11 am) restriction was implemented in the entire watershed for four days. In 2016, 25 coldwater pools were closed to angling on one occasion for a total of 20 days (DFO 2016). In 2017, 26 angling pools were closed to angling on two occasions for a total of 13 days. In 2018, 26 angling pools were closed to angling on one occasion for a total of 40 days, and morning fishing only (6 am to 11 am) was imposed on one occasion in the entire watershed for a total of 18 days. Additionally, in 2018, water temperature in the Southwest Miramichi river exceeded 23°C for a total of 57 days. In 2019, 27 coldwater pools were closed to angling on two occasions for a total of 13 days, and morning fishing only (6 am to 11 am) was imposed in the entire watershed on one occasion for a total of 5 days. In all years (2015-2019), three coldwater refuge pools (Sutherland, Quarryville, and Wilson Brook) were closed as per the WWP beginning on July 1 for the duration of the angling season (Table 1). A visual summary of this timeline is provided in Figure 2.

In-season Management Interventions Beyond the Miramichi River

In 2018, the first in-season management interventions were imposed on the recreational Atlantic Salmon fisheries of the Nepisiguit River (New Brunswick) and Margaree River (Nova Scotia). On the Nepisiguit River, one closure was implemented due to a warm water event and a section of the river was closed to all fishing on August 1, 2018 for an unknown number of days. Morning fishing only was imposed in sections of the Nepisiguit River in 2019 for a total of 14 days. Two angling closures were imposed on the Margaree River in 2018, from the highway bridge in East Margaree upstream to the Forks, excluding tributaries, on two occasions for an estimated total of 15 days (exact number is unclear; Table 1; DFO 2018b, Appendix 1). No closures were implemented 2019, but interim intervention criteria for the Margaree (>20°C for two days) were exceeded.

Discussions began with provincial representatives (New Brunswick and Quebec), stakeholders, scientists, Aboriginal representatives, and DFO in 2018 to evaluate the need for a WWP for the Restigouche River (New Brunswick and Quebec). Several meetings were held, and interim criteria were established, but no closures were implemented in 2018 or 2019. The interim criteria would apply only to waters in New Brunswick.

1.4 Principles and Policies Guiding Atlantic Salmon Science and Management on the Miramichi

This section provides a brief chronological overview of the key principles and policies guiding the science and management of Atlantic Salmon in the Gulf Region of DFO, which includes the Miramichi River watershed. Only policies that have a direct relevance to environmental conditions are outlined, or those that are relevant to the current implementation of the WWP.

Fishing regulations relevant to the recreational fishery are defined in the *Maritime Fishing Regulations*. A number of in-season management measures can be implemented by way of variation orders. The number of salmon by size which can be retained on a daily and seasonal basis is one such management measure. By way of a variation order, the mandatory catch-and-release of large salmon has been obligatory since 1984 on the Miramichi River and throughout the Maritime provinces (Bielak 1996). The seasonal retention limit for small salmon has been modified by variation order; it was eight small salmon up until 2013. In 2014, seasonal small salmon retention limit was reduced to four per angler in the Miramichi and subsequently to zero in 2015 throughout the Gulf Region.

In 2009, DFO released “A Fishery Decision-Making Framework Incorporating the Precautionary Approach” (DFO 2009b), which outlines an approach to develop harvest strategies and determine allowable catch of fish in commercial, recreational, and subsistence fisheries. The precautionary approach uses stock reference points that are linked to stock and ecosystem indicators to manage exploitation and meet Canada’s international commitments to international best practices (e.g., North Atlantic Salmon Conservation Organization agreement, NASCO, CNL(98)46). Uncertainty is to be accounted for in the development of reference points and harvest control rules. Also published in 2009 was the Wild Atlantic Salmon Conservation Policy with the goal to restore and maintain healthy populations of the species focused on wild, sea-run populations in Atlantic Canada through conserving populations, genetics and habitat (DFO 2009b). The Policy focuses on actions that ensure sustainable use benefits, incorporate the best available science, encourage shared stewardship, and incorporates a precautionary approach.

In 2011, the Miramichi Watershed Management Committee (MWMC), a committee of recreational and industry stakeholders, DFO, NB government and First Nation representatives developed the Northwest Miramichi Watershed Management Plan (Hambrook et al. 2011). The goal of the plan is to guide salmon management such that the recreational and Aboriginal fisheries are sustainable into the future. The plan provides stakeholder and industry perspectives on several key issues including the need for revised management approach of the Indigenous FSC fisheries including funding for full wardens, data collection, and management advisors. The plan also recommends that a WWP be developed for all tributaries of the Northwest Miramichi and that the protocol should outline, clearly, when restrictions would be implemented. The plan supports escalating angling restrictions based on water temperature starting with reduced daily catch limits in specific pools and progressing to morning angling only, and finally total watershed closure to angling. However, total closures were noted as a last resort and possibly detrimental to salmon given that it would restrict all anglers on the water and increase the opportunity of poachers.

The stated goal of the Atlantic Salmon Integrated Management Plan for the Gulf Region (2008 to 2012; DFO 2008) was to restore and maintain healthy and diverse salmon populations and their habitat for the benefit and enjoyment of all Canadians in perpetuity. Specifically, the plan focused on actions that would facilitate maintaining and restoring habitat and ecosystem integrity. For example, an increased focus on collaboration with the Province of New Brunswick and partners encouraged the development of river- or salmon fishing area (SFA)-specific management plans. DFO committed to monitoring the effectiveness of restoration efforts during this time. The plan estimated that angler catch in the Gulf Region was between 4 and 7% of annual total returns and that nearly three quarters of all salmon recreational fishing effort in New Brunswick occurred in the Miramichi River.

In 2011, DFO FHM requested science advice on what temperature threshold to use in a WWP (C. Breau, pers comm. 2020). The resulting science advice, presented in 2012, was founded on, and by, Breau (2013), Breau and Caissie (2013), and Caissie et al. (2012), which described the water temperature triggers for closures, in addition to advice on the number of days to initiate and reopen fisheries closures, The WWP for the Miramichi River, finalized in 2015, followed directly from the work in 2012, and guides salmon management interventions during environmentally stressful conditions as discussed in Section 3.

In 2012, DFO outlined a, “Framework for a salmon management plan for New Brunswick (Miramichi and Restigouche Watershed)” (see DFO 2012d, Appendix 1). The objective was to work through a structured process to develop a renewed integrated management plan incorporating the new (at the time) information, policies, science advice (e.g. water temperature thresholds), and threats to manage the Atlantic Salmon fishery on the Miramichi and Restigouche Rivers consistent with the goals and objectives of the Atlantic Salmon Integrated Management Plan for 2008-2012 (DFO 2008). The resulting draft document called for the development of decision rules to support in-season management interventions in the recreational fishery during environmentally stressful conditions. Low water levels and flow are highlighted in this document as an important stressor, as much as temperature (see DFO 2012d, Appendix 1). The drafted renewed plan, which does not appear to have been published as a stand-alone document, indicates that DFO Science could evaluate the effectiveness of a series of possible management interventions (e.g., partial daily closures) and thresholds for opening and closing the fishery.

In response to declining Atlantic Salmon populations throughout Atlantic Canada, a special report on the status of wild Atlantic Salmon was prepared by the Minister’s Advisory Committee on Atlantic Salmon in 2015 (Roach et al. 2015). This report summarizes the advice received from scientists, managers, stakeholders, and Indigenous representatives during stakeholder and rightsholder meetings held in Quebec City, QC, Halifax, NS, and St. John’s, NL. Sixty-one recommendations were developed to guide Atlantic Salmon conservation, protection, science, and the enforcement of, or being in compliance with, associated policy and regulatory frameworks. The Wild Atlantic Salmon Research and Innovation Fund was recommended to support science and stewardship to protect and enhance salmon populations and to enhance partnerships and collaboration. Food web interactions and the threat from increased predation (e.g., Grey Seal) were also discussed; however, not all contributors agreed on the existing information related to predation or the most effective management actions (Roach et al. 2015). An interim report by the same committee also recommended that all recreational fishing in the Gulf Region be restricted to catch-and-release only. This recommendation was implemented during the 2015 angling season (Roach et al. 2015).

In 2019, DFO released the Wild Atlantic Salmon Conservation Implementation Plan in which it is stated that salmon abundance had decreased since 1995 to a low of 0.4 - 0.7 million fish. The goal of the implementation plan was to meet the objectives of the Wild Atlantic Salmon policy by defining key actions to restore and maintain healthy Atlantic Salmon populations in Canada (DFO 2019c). The plan introduces 18 action items to implement salmon conservation under the themes of ecosystem integrity, science and research, and human interactions (DFO 2019c). Habitat factors such as water flow and water temperature are identified as important biological foundations that are necessary to produce and support healthy wild salmon populations and that should be considered in both salmon science and management. Each of the 18 actions are laid out in actionable targets with dates of completion identified between 2019 and 2021 (DFO 2019c).

A draft Integrated Fisheries Management Plan (IFMP) for Atlantic Salmon in SFAs 15 to 18 for 2020 and beyond was under development (DFO 2020) and not yet available as of this publication. The draft Plan states that in 2015 the value of the recreational fishery was estimated at $20 million dollars. Importantly, the Plan states that the total number of salmon taken in the Gulf Region is unknown and that management decisions and thresholds are thus based on incomplete information. The Plan also calls for continued implementation of the WWP on the Miramichi River.

2. THE SCIENCE OF ENVIRONMENTALLY STRESSFUL CONDITIONS FOR ATLANTIC SALMON

The relationship between low and warm water conditions and Atlantic Salmon mortality has been of concern for DFO in the Miramichi since at least 1984 (Bielak 1996) specifically when large mortality events became linked to extremely low water levels. We note that there is evidence of salmon preferring cool water (<22ºC) from earlier (e.g. Gibson 1966). Given the importance of the recreational and subsistence fisheries for salmon on the Miramichi and other rivers in the Gulf Region (e.g., Restigouche, Margaree), DFO undertook a focused assessment of the role of water temperature and flow on Atlantic Salmon recovery and mortality (e.g., Bielak 1996; Breau 2013; Appendix 1; DFO 2012a). This section provides a brief chronological overview of the history of DFO led science, spanning over 10 years, that examined the relationship between environmentally stressful conditions, salmon survivorship, and recreational angling.

One of the first reviews of how recreational angling in combination with environmentally stressful conditions may affect Atlantic Salmon is presented in Bielak (1996). The manuscript begins with a summary of historical management interventions on the Miramichi during times of perceived environmental stress. For example, on the Miramichi, DFO's C&P would take daily water temperature readings and if salmon were congregated the officers would recommend a closure for a specific area or time period to DFO fisheries managers. However, this process was criticized for being inconsistently applied (Bielak 1996). Bielak (1996) provides a review of the scientific literature on angling induced mortality associated with stressful environmental conditions. The author reports that angling mortality was most often associated with warm water events above 20ºC with significantly more deaths of adult salmon occurring when water temperatures were 23ºC and above, but that most studies did not adequately control for confounding variables (e.g., acclimation and starvation) and thus a definitive threshold could not be established. The review highlights a study that found post-angling mortality was almost zero across rivers when water temperatures were below 6ºC. However, mortality due to angling during the summer on the Upsalquitch River (in the Restigouche River watershed) was estimated at ~5%, and on the Miramichi River at 16ºC was found to be 12% (3 out of 25 salmon died). The Canadian Atlantic Fisheries Scientific Advisory Committee (CAFSAC, a precursor to the CSAS process) assumed an overall and general catch-and-release mortality rate of 5% for Atlantic Salmon; with 3% on Miramichi and 6% on Restigouche Rivers (Bielak 1996). Bielak (1996) reports that the 5% rule was based on a 1985 New Brunswick Department of Natural Resources study from a coldwater tributary of the Miramichi that never breached warm water thresholds (e.g., >21ºC). Bielak (1996) provided a retrospective analysis of the number of closure days that would have occurred in previous summers on the Miramichi based on closure criteria of 22ºC (mean daily water temperature). In the Southwest Miramichi in 1995, the recreational fishery would have been closed for 51 days (Bielak 1996). The author notes that some anglers suggested that because salmon are less likely to take a fly during warm water events, additional physiological stress is functionally reduced negating the need for closures. The effect on salmon from angler presence in coldwater refuge pools during warm water events is unknown. Bielak (1996) recommends that assumptions about catch-and-release fishing be verified and a clear process for communicating closures and re-openings should be developed. The report concludes with unanswered questions related to warm water stress and recreational angling, including: the impact of late season angling on spawning success, potential difference in physiological response to fishing between 1SW and MSW fish, the mortality rate associated with angling in different water temperatures, and life stage responses to angling stress.

In 1998, DFO Science evaluated the effects of hook and release angling on Atlantic Salmon with some consideration of the effects under different environmental conditions (DFO 1998). The report notes that in Newfoundland in 1998 a temperature threshold of 18ºC was used to trigger a closure of catch-and-release angling on some rivers. The angling mortality in Newfoundland was assumed to be 10%, as compared to the 3% estimated for the Miramichi River. The report summarizes the caveats which must be considered when interpreting in-situ estimates of angling post-release mortality (immediate and delayed) including recovery time in tanks, handling techniques, artificial hooking, etc. DFO (1998) reported that salmon that have just entered freshwater have high post-angling mortality (~25% at 16ºC). No research was available to summarize the effects of angling on long-term survival or reproductive success; however, anecdotally, angled salmon have been observed several months after angling and on spawning grounds, and angled adults taken to hatcheries are able to produce viable young. In the Saint John River, the potential egg deposition loss was estimated as less than 1% based on losses due to angling mortality (DFO 1998). The report notes that research is required to understand the effects of catch-and-release on salmon at water temperatures above 22ºC and that efforts should be directed to understand the sublethal and cumulative effects of water chemistry and temperature on post-angling recovery and mortality (DFO 1998).

Low flow and warm water conditions resulted in angling closures in Newfoundland beginning in 1975 (Dempson et al. 2001). In fact, between 28-70% of all salmon rivers in Newfoundland had been affected by annual temporary closures with a loss of up to 35-65% of fishing days in some years. No temporal trend was observed in the number of closure days but of the 10 greatest observed impacts (number of closure days), five occurred during 1995-1999 (Dempson et al. 2001). The paper cites Elliott (1991) that published thermal tolerance values for juvenile salmon under controlled conditions whereby incipient lethal temperatures was between 24.8-27.8ºC and feeding ceased above 22.5ºC. In Newfoundland, temporary angling closures were imposed when water temperatures exceeded 23ºC between 1975 and 1988, and a formal threshold was established at 22ºC in 1989 (Dempson et al. 2001). It is unclear why a 18ºC threshold was used in 1998 (DFO 1998). In 2002, an impact-control experiment in Newfoundland evaluated the role of water temperature and flow on post-release angling mortality in Atlantic Salmon (Dempson et al. 2002). The authors found that 8.2% of angled salmon died post-release across all water temperatures, but that mortality increased to 12% when mean water temperatures rose above 17.9ºC (range = 9.5 to 22.1ºC). However, angler handling practices and hook time was not consistent across all fish captured for the impact portion of the study (control fish were captured in a trap net). No salmon captured in the control group perished.

In the early 2000s Chaput and Swansburg (2004) prepared a large synthesis on the impacts of climate change on in-season stock models and salmon management in Atlantic Canada, with a focus on increasing fishing access opportunities for Atlantic Salmon. The paper included multiple chapters focusing on various scientific questions. For example, in Chapter 1 the authors aimed to assess which model type improved the accuracy of in-season run estimates by incorporating the effect of environmental conditions (e.g., ice area, ocean temperature, discharge, and freshwater temperature) on data collected between 1981-2001. Chapter 2 focused on assessing if an environmental variable (discharge) influenced the availability of salmon to the recreational fishery on the Miramichi. They found that in years with increased duration or magnitude of low flow events, access to the recreational fishery may be limited (Chaput and Swansburg 2004).

Moore et al. (2004) evaluated the post-release mortality of angled Atlantic Salmon in response to warm and low water conditions in the Black Brook pool and the Cains River (Southwest Miramichi sub-watershed). The role of dissolved oxygen was also examined in the second year of the study (2003). Adult salmon mortalities observed in the study area included 131 in 1999, 250 in 2001, 17 in 2002, and 36 in 2003. Most mortalities in all years were associated with temperatures > 20ºC and discharge (flow) < 26 m^3/s (Moore et al. 2004). The authors suggest that when water temperature is > 20ºC, mortalities may increase if discharge falls below 50 m^3/s. However, nearly all fish sampled in 2001 were infected with Furunculosis, a pathogen that increases mortality during stressful conditions for salmon, and the disease cannot be ruled out as a major contributor to the observed deaths between 1999-2003. In 2003, the positive Furunculosis infection rate of dead salmon in the study area was between 17% in June and 71% in July.

Summer low flow conditions often co-occur with warm water events and are associated with Atlantic Salmon mortality on the Southwest Miramichi (SWM) River. Caissie et al. (2004, Appendix 1) assessed a 2 km section of the Cains River in 2003 and 2004. The authors note that conditions observed in 2003 were above the long-term average for discharge, whereas low flows (<20 cm/s) were observed in the summer of 2004. Further, they found that dissolved oxygen concentrations matched patterns in water temperature where dissolved oxygen was higher with increased discharge, and that minimum dissolved oxygen concentrations were observed in the early morning (6 am; see Caissie et al. 2004, Appendix 1).

During the stakeholder engagement process related to warm water events on the Miramichi (2010-2012), the MSA prepared and presented a thermal management plan to guide the implementation of a WWP (see Reid et al. 2011, Appendix 1). The plan was presented on November 15, 2011, at a meeting between DFO and Miramichi stakeholders. The management plan relied on a predictive model which estimated "water temperature tomorrow" based on water temperature of the current day along with the forecasted air temperature. The model was created using data from 2006-2011 (except 2008) and considered Julian day, humidity, precipitation, daily minimum and maximum air and water temperature in a regression analysis where: *Predicted water temp tomorrow = 0.0360 + (0.189 * Forecasted air temp tomorrow) + (0.829 * Actual water temp today),* the R^2 of the equation was 0.896. The model was promoted as a tool to forecast how long a warm water management intervention may last (up to 4 days ahead). The plan also presented the results of a thermal mapping study from 28 loggers placed throughout the watershed and estimated temperatures for other locations based on DFO Science's permanent monitoring station at Doaktown, NB. The result was a map illustrating two zones with upstream cooler tributaries (Zone 2) and downstream warmer tributaries (Zone 1). Based on this information, though it was not ultimately adopted by DFO, as discussed in Section 3 below, the management plan proposed the following management interventions for warm water events in 2011:

1) Close Indian Town Brook (Quarryville), Wilson's Brook, and Sutherland Brook annually on July 1.
2) When forecasted average daily water temperature > 22ºC at Doaktown for four days: Close 12 lower river pools (Zone 1), angling must take place with barbless hooks, and retention catch of small salmon is limited to one fish per day. The pools which were recommended for closure included: Buddie's Brook, Salmon Brook Pool, Mill Brook at Pumphouse Pool, Grey Rapids Pool, Morse Pool, Donnelly Brook Pool, Bett's Mills Brook, Porcupine Pool, Little Otter Brook at Brophy Pool, Big Hole Brook, and Black Brook pool.
3) When forecasted average daily water temperature > 23ºC at Doaktown for four days: Morning fishing only in Zone 1 from sunrise to 11 am, with barbless hooks and retention catch limit of one small salmon per day: previously closed pools remain closed.
4) When forecasted average daily water temperature > 25ºC at Doaktown for four days: Total closure of Miramichi watershed for fishing of any species.

In 2011, a request was sent by DFO FHM for Science to provide guidance on the establishment of temperature thresholds for closures of recreational fisheries on the Miramichi River during warm water events. In March of 2012, DFO Science along with Fisheries Managers, stakeholders, Indigenous organizations, academics, and watershed organizations participated in a regional science peer review meeting to evaluate the science of water temperature thresholds for Atlantic Salmon and to propose in-season management intervention thresholds and strategies. Three working papers (Breau 2013, Cassie et al 2012 and Breau and Caissie 2013) presented by the authors at the meeting formed the Science Advisory Report (SAR, DFO2012b; DFO 2012a) that summarized the existing science regarding salmon physiology with respect to water temperature and angling and highlighted uncertainties and unknowns associated with the various management scenarios. Breau and Caissie (2013) outlined the process reflected in the advisory report (DFO 2012b) for developing the proposed threshold, where DFO FHM requested science advice on what environmental thresholds could be used to trigger management actions in the Miramichi and Restigouche Rivers. DFO Management also asked what, given the size of rivers in Miramichi and Restigouche, are feasible options for managing salmon under environmentally stressful conditions.

To address these questions, the regional peer review meeting focused on the following scientific review: physiological and metabolic rates of salmon in relation to duration and level of warm water stress and causes of mortality (Breau 2013); possible temperature benchmarks above which risk of mortality increases under stressful conditions (Breau and Caissie 2013); summary of environmental characteristics of Miramichi and Restigouche rivers (Cassie et al. 2012); evidence that salmon are susceptible to angling during warm water periods and that interventions can be used to manage risk of mortality; and finally, evaluation of fishery management options (DFO 2012a). The review states that while the critical temperature of adult Atlantic Salmon (T_{crit}) is unknown, it is likely very close to 23^{o}C, and that recovery from exhaustive exercise between 20 and 23^{o}C takes at least four hours. The report states that evidence suggests that a minimum daily water temperature of 20^{o}C is the most important threshold for physiological stress, recovery, and reducing catch and release angling mortality in Atlantic Salmon. The SAR proposes that in-season management interventions should be considered when the daily minimum water temperature exceeds 20^{o}C for 48 consecutive hours (DFO 2012a). As the science of salmon response to warm water was on-going (e.g., Bielak 1996 to Breau 2013), water temperature was monitored in many locations throughout the Miramichi. However, one station was chosen to represent the Miramichi watershed as a whole for the purpose of a implementing an in-season management intervention. The station is located in Doaktown, NB on the Southwest Miramichi and it was chosen due to its long term data availability. The data was hosted by the Miramichi River Environmental Assessment Committee which could be accessed in real time, and also because its thermal profile was warmer than other locations and represented a precautionary measure of water temperature that is variable across the watershed (DFO 2012a). Importantly, temperature is not monitored in any of the salmon pools that are protected in the WWP. The report notes that the 20^{o}C threshold should be evaluated for rivers that have a cooler thermal profile such as the Restigouche because those salmon may be adapted to cooler waters and thus may have a lower T_{crit} (DFO 2012a).

Breau (2013) synthesized the larger salmonid literature, as no values were available for adult Atlantic salmon, to establish threshold temperatures based on fish physiology which has since informed DFO's in-season management response to recreational salmon angling during warm water events on the Miramichi River. The report aimed to define the optimal (T_{opt}) and critical (T_{crit}) water temperatures for adult Atlantic Salmon to inform in-season angling closures based on temperature induced physiological responses and the salmon's ability and time needed to recover. Adult and juvenile salmon respond to warm water events by seeking out cool and coldwater thermal refuges (e.g., pools, tributary outlets, seeps) to achieve optimal physiological performance through thermoregulation. Angling induces an extreme form of exhaustive exercise and physiological distress which can lead to mortality. For example, Breau (2013) cites a 2009 ICES study that demonstrated increased post-angling mortality of pre-spawn adults when water temperature was above 17^{o}C and that temperature was the most important factor in predicting mortality. Breau (2013) reports that survival of salmon is further impacted when dissolved oxygen is reduced during periods of warm water. The author reports that when average water daily temperature in the Miramichi was >23^{o}C and minimum nighttime temperature was >18^{o}C, juvenile salmon began to aggregate in coldwater refuge pools. Juvenile salmon tended to remain aggregated throughout the day when minimum nighttime temperatures remained above 20^{o}C for two consecutive nights (48 hours). T_{crit} for juvenile (2 + years) salmon was found to be 24^{o}C and T_{crit} for adult salmon was assumed to be 25^{o}C, where physiological effects occur between 20-25^{o}C if no coldwater refuge is available. Adult salmon T_{crit} is assumed because the literature does not provide a definitive threshold for adult Atlantic Salmon and 25^{o}C is based on adult Pacific salmon aerobic scope change associated with increased mortality. In adult Pacific salmon, T_{crit} has been determined to be water temperatures ~ 6 to 7°C above the long-term average for the river. Thus, in the Little Southwest Miramichi where average summer temperature is 18.5°C, T_{crit} of adult Atlantic Salmon is predicted to be 25°C, if the relationship with aerobic scope is similar across all salmonid species. Breau (2013) acknowledges that T_{crit} for adult salmon may in fact be reached at a lower temperature and further studies should focus on defining this value. In 2019, studies evaluating T_{crit} for adult Atlantic Salmon were conducted and the results are currently being analyzed (C. Breau. pers. comm. 2020). Breau (2013) found that when minimum daily water temperature remained above 18°C, salmon were no longer able to recover from the physiological stress, and links to angling stress were not specifically addressed. Acclimation temperature, exposure time, and the magnitude of the stress the fish experiences will all influence recovery time and survivorship. Breau (2013) states that a major source of uncertainty relates to the physiological recovery and cumulative stress response of salmon during warm water events. Based on the review, Breau (2013) recommended a minimum water temperature (T_{min}) of 20°C as a management threshold above which angling restrictions should be imposed in order to facilitate salmon physiological recovery at night. A T_{min} threshold is recommended to be used in combination with salmon aggregation behaviour as a signal for management action. Some anglers have argued that in-season management interventions restricting angling when water temperatures are >23°C are unnecessary because salmon do not often take a fly during warm water events. However, Breau (2013) reported that salmon have been caught when temperatures exceed 23°C, although greater effort is required (i.e., lower CPUE). Following the presentation of salmon physiological responses to water temperature (Breau 2013), Breau and Caissie (2013) developed an adaptive protocol for management to use. These findings were presented at the 2012 CSAS (DFO 2012b) with the participation of DFO FHM and stakeholders.

Breau and Caissie (2013) present a DFO science report in support of setting defined temperature thresholds to guide in-season Atlantic Salmon recreational fishing management interventions during warm water events. The report also evaluated the impact (e.g., number of closure days) of imposing a 20°C daily minimum water temperature threshold for closures based on historical water temperatures in the Miramichi. Breau and Caissie (2013) state that when the minimum daily water temperature (T_{min}) exceeds 20°C for two consecutive days (48 hours) a fishery closure should be initiated. Similarly, fishery re-opening should not occur until T_{min} has been less than 20°C for at least 48 hours. A Gulf Region variation order can be used to close specified areas to recreational angling for a defined period of time, or until the variation order is revoked. Based on historical water temperatures, on average, angling closures would have occurred between zero and five times per year, ranging in length from one to 24 days for the Little Southwest Miramichi and from nine to 31 days on the Southwest Miramichi. Breau and Caissie (2013) note that the effectiveness of past closures cannot be evaluated because there is no standardized monitoring of salmon mortalities associated with recreational angling or warm water events. The authors also note two important points: 1) when spatially explicit closures are used (e.g., pools) the closures only protect fish inside the pool and not fish using smaller patches of cool water such as those provided by hyporheic exchange or groundwater seepage, and 2) the amount of cumulative stress salmon experience as a result of repeated warm water events is unknown.

Caissie et al. (2012) provides water temperature profiles of the Miramichi and Restigouche River systems to facilitate an understanding of the thermal regime and water quality impacts on fisheries management decisions. Water quality and temperature are temporally and spatially variable throughout a river system, which can influence the effectiveness of management interventions in a given space or time, such as angling closures due to high water temperature. Using data from 21 monitoring sites in each river, Caissie et al. (2012) reported the average temperature of the Miramichi was 19.4°C compared to 16.5°C in the Restigouche. The authors assumed that water temperatures above 23°C were stressful for salmon and water temperatures < 20°C facilitated recovery. The Miramichi River is shallower than the Restigouche and thus subjected to greater diel water temperature variability (Caissie et al. 2012).

Brodeur et al. (2015) predicted the impact of climate change on water temperatures and critical thresholds for salmon in the Miramichi River. The authors found that over the next century mean annual air and water temperatures in the Miramichi River watershed are likely to increase by 4.4 and 3.2^{o}C, respectively. This could translate into water temperatures exceeding critical salmon thresholds (23^{o}C and 20^{o}C), by an additional 21 to 41 days per year, respectively (Brodeur et al. 2015). The authors also suggest a warming climate will decrease dissolved oxygen concentrations as well as influence the acidity of streams, further impacting developing salmon eggs.

In 2017, Patterson et al. (2017) undertook a review of the science of fishing-related incidental mortality, including recreational angling, for Pacific Salmon. The authors note that the ability of salmon to recover after an angling encounter (e.g., rest in suitable conditions without increased risk or predation or pathogens), more so than the physiological stress endured during angling, may be the causal mechanism of mortality. This may be especially true when the ability to recover interacts with injury or disease, or potentially environmental factors (Patterson et al. 2017). However, the magnitude of the response to angling is largely dependent on its hook time and handling practices. The report also finds that unlike natural mortality which impacts stressed, weak, or diseased fish, angling does not, and contrarily may disproportionately affect previously healthy fish. Further, the evidence presented suggests that there is a non-linear response of fishing mortality in fisheries as temperature increases, where above 21^{o}C mortality of angled fish will increase despite variation in capture and handling techniques (Patterson et al. 2017). The authors note that little evidence exists to describe the relationship between dissolved oxygen and fishing mortality due to the interaction between dissolved oxygen and temperature. Based on a review of the literature the authors ranked the mortality risk associated with extrinsic factors such as temperature and fishing mortality. At temperatures between 20-22^{o}C, 35-45% of the mortality risk is due to the collapse of aerobic scope, reduced mobility, recovery time, and increased risk of infection, whereas at water temperatures >22^{o}C , 45-100% of the risk of fishing mortality was associated with the cessation of migration, vulnerability to predation/recapture, suppressed stress response, and an increase in infections and disease risk (Patterson et al. 2017). Importantly, the authors note that almost nothing is known about the consequence of multiple fishery interactions (e.g., cumulative effect) on an individual fish.

3. A WARM WATER PROTOCOL FOR THE MIRAMICHI RIVER

The development of a “Protocol for In-season Conservation Measures for Atlantic Salmon during Environmentally Stressful Conditions in the Miramichi Watershed (Warm Water Protocol)”, began in 2011 (see Section 7 – Timeline) as a result of a recommendation from the Miramichi Working Group (DFO 2015b). The protocol was informed by the CSAS process whereby DFO Fisheries and Harbour Management requests science advice from DFO Science. However, prior to the CSAS process several stakeholders were engaged and discussing potential protocol options.

During the CSAS process in 2011-2012, DFO FHM and DFO Science developed a set of explicit questions with respect to developing criteria and guidelines for managing in-season angling of Atlantic Salmon on the Miramichi during environmentally stressful conditions. The questions that DFO Science needed to answer were:

1. Based on historical events, what association is there between warm water and or low water conditions and salmon mortality?
2. Can benchmarks of water temperature thresholds be used to trigger management actions to open or close fishing waters?
3. What management measures could be used to manage closures: whole river closures, portions of the river susceptible to warm water, or partial daily closures? (see DFO 2011a, Appendix 1).

In response, DFO Science categorized the science advice that would best address management questions, including:

1) Information on the physiology and metabolism of Atlantic Salmon, causes of warm water mortality, and benchmarks for stress and recovery,
2) Thermal and discharge profiles of the Miramichi and Restigouche River watersheds, and
3) Possible environmental triggers for the management of environmental stress (see Chaput 2011, Appendix 1).

DFO Science also recommended evaluating the effectiveness of possible management actions including the time and waters chosen for in-season management, partial daily closures (6 - 11am), the utility of a focus on cool water areas, and other proposals. The proposed framework to complete the CSAS process included three phases: a preliminary workshop with stakeholders in May 2011 to develop objectives and management scenarios; develop technical science advisory reports regarding management questions; and, develop various management scenarios to be evaluated at the winter 2012 regional advisory process meeting (see Chaput 2011, Appendix 1).

The result of this process was a series of CSAS Research Documents (Caissie et al. 2012; Breau 2013; Breau and Caissie 2013) and a CSAS Science Advisory Report (DFO 2012a). A 2013 draft protocol developed by DFO FHM (see DFO 2013b, Appendix a), following stakeholder input, was finalized in 2015 (DFO 2015b). The protocol was updated in 2019 to include additional pools (five since 2015) and to re-define the pool boundaries. Stakeholder input was especially influential with regards to the identification of the coldwater refuges to be protected under the protocol and the establishment of a tiered approach to in-season management options (DFO 2016).

The 2015 protocol considers salmon physiology, behaviour, and environmental considerations. All of the variables are considered in concert before a decision is made by DFO FHM to either close or open angling restrictions. The variables are discussed with C&P for on the ground information, including salmon behaviour, and with the MSA and the MWMC to evaluate the possible socio-economic impact of closures (e.g., see DFO 2013a, Appendix 1; see Lavoie 2017, Appendix 1).

Table 2 outlines the variables considered when a warm water event occurs on the Miramichi River, including water temperature, water level, forecast (including precipitation), salmon behaviour, and observed mortalities. The protocol does not distinguish between grilse and salmon and applies equally to all life history strategies. The process is triggered when DFO FHM reviews the real-time water temperature information from one permanent weather monitoring station located at Doaktown, NB, in the vicinity of the DFO Science station and which has been operated by the Miramichi River Environmental Assessment Committee since 2014. The data is available online and is monitored Monday through Friday by DFO FHM. If the minimum daily water temperature (20ºC) is observed over a consecutive 48-hour period, and in concert with meeting other criteria, DFO FHM will reach out to C&P to assess whether salmon are demonstrating aggregating behaviour. Fisheries and Harbour Management will also review the weather forecast and reach out to the two key stakeholder groups to assess their opinion on closing the fishery, based on the threshold breached, to either close pools or impose total fishing restrictions from 6 – 11 am. The forecast is an important component of the process, because short closures (e.g., 1 – 2 days) are not favored by stakeholders. Thus, if the forecast suggests a warm water event may only last one day, stakeholders may recommend keeping the fishery open. This is particularly true when a closure may occur on a Friday and roll into the weekend unnecessarily due to administrative restrictions of rescinding a variation order on a weekend. However, the ultimate decision to close a fishery to protect salmon remains with DFO. In-season management measures are accomplished with a Gulf Region variation order which DFO Fisheries Management drafts. The Miramichi River stakeholders, lodges and camp owners assist DFO with alerting anglers to the closure. All parameters listed in Table 2 are monitored daily Monday through Friday during the warm water season. Variation orders to close a fishery can be prepared and implemented within 2 days.

Similarly, it takes at least 3 days to open a closed fishery (e.g., at least 48 hours below minimum temperature threshold plus a day to draft and post the re-opening variation order).

The protocol describes 26 coldwater refuge pools (Figure 1) for which the stage 2 (yellow shading, Table 2) applies relative to the 20^{0}C threshold. Stage 3 (red) applies to sections of the main river and tributaries which are closed to all but morning angling (6 – 11 am) relative to the 23^{0}C threshold. Three pools close seasonally on July 1 regardless of the current conditions in the Miramichi. Appendix 2 provides the descriptions of all coldwater refuge pools included in the updated 2019 draft of the protocol. The list of pools included in the protocol has increased over the period from 2015 to 2019 due to thermal habitat enhancement and remediation work, completed largely by the MSA.

In discussion with stakeholders, several management intervention proposals in the 2013 draft WWP were altered or removed from the final 2015 version, which include: 1) removal of the stage 4 management action, 2) lowering of the stage 3 criteria, and 3) the list of protected pools (see DFO 2013b, Appendix 1). For example, the stage 4 management intervention for warm water events when minimum daily water temperature > 24^{o}C for 48 hours would have resulted in a complete angling closure throughout the watershed (see DFO 2013b, Appendix 1). This management intervention does not appear in the 2015 protocol as a decision rule (DFO 2015b). That is, there is no temperature threshold above which no salmon fishing is permitted under the 2015 protocol. Also, in the 2013 protocol the criteria for a stage 3 (morning only angling only) intervention (between 22 and 24^{o}C) differed compared to the 2015 protocol (>23^{o}C for 48 hours), and the timing of morning only fishing interventions was one hour earlier in the 2013 draft (5 am to 10 am). It is unclear why the timing of the morning angling only intervention was changed based on the correspondence reviewed for this report. The reason for the removal of stage 4 management intervention (complete closure) was to limit the number of closure days on the river due to warm water events and to limit the socio-economic impacts to the fishery.

3.1 Review of Implementation

In the early 2000s, Chaput and Swansburg (2004) evaluated the social and economic effects of warm and low water fisheries closures on the Miramichi River that occurred during 1995 to 2001. In 1995, partial closures in a section of the Northwest Miramichi resulted in a loss of 13% of total potential fishing days from that area and an estimated lost revenue of $41,000. In 2001, closures resulted in a loss of 6% of total potential fishing days and lost revenue of $8,000 in Crown Reserve waters of the Northwest Miramichi. The authors also reviewed the response of stakeholders to a survey of the effectiveness of in-season closures and report that >50% of outfitters, retailers and anglers supported closures in general, but felt that closures were ineffective because they were not accompanied by additional protection (e.g., enforcement) on the river. Most respondents believed that warm and low water conditions are stressful for salmon, but that closures may not assist in salmon protection because fish are unlikely to take a fly during stressful conditions (but see Breau 2013 for data on catch of salmon during warm water). While both outfitters and retailers reported decreased revenue during summer closures, most reported an increase in fall and spring activity making total lost revenue hard to estimate (Chaput and Swansburg 2004). Chapter 4 of the same report presents adaptive management strategies to protect salmon during environmentally stressful conditions. The authors note that stakeholders largely felt that all land users should participate in salmon conservation such as the forestry sector during riparian removal activities, or on-water users (e.g., canoe events). This view was supported by Dr. Rick Cunjak who suggested boating and paddling restrictions be imposed during warm water events (see Cunjak 2010, Appendix 1). Importantly, stakeholders felt that the benefit of in-season management interventions must be explicit and timely. For example, the closures of 2001 occurred after mortalities and peak water temperatures were observed and did not prevent fishing in the main river where mortalities were observed (Chaput 2002). Overall, the authors found from 1999 to 2002 the in-season angling closures were slow to be implemented, missed the hottest warm water period, and were applied *ad hoc* with no criteria specified at the start of the season (Chaput and Swansburg 2004). The authors conclude by noting that in-season angling restrictions will not protect all salmon from environmentally stressful conditions, but protection is a function of those fish likely to be caught during stressful conditions if a closure was not enforced. There is no recent information on angler, outfitter, or lodge owner opinion of the WWP, nor information on the amount of lost revenue due to warm water angling closures.

In practice, the WWP is implemented in a collaborative process with stakeholders where discussions occur with DFO regarding the length of closures, the forecast, and possible impacts to local operators and guides. For example, in 2017 DFO FHM staff (e.g., see Lavoie 2017, Appendix 1) discussed the impact of implementing a coldwater pool closure due to environmentally stressful conditions during the week but where conditions were set to improve on Saturday. Due to administrative timelines and processes, the weekend angling opportunities would be lost and thus a decision was made to not invoke the WWP (see Lavoie 2017, Appendix 1). As another example, DFO FHM presented the state of current conditions in the Miramichi to stakeholders through email on the July 24, 2017 and inquired if the stakeholders (MSA and MWMC) were in favor of re-opening the coldwater refuge pools to angling (see Butruille 2017, Appendix 1). During these exchanges, FHM communicates with C&P to discuss the observed behaviour of salmon (e.g., aggregation or not), observed mortalities, and water level, and considered information in concert with minimum water temperature and the forecast. This process has been followed throughout 2015 to 2019 with streamlining of the process occurring over the years (e.g., memos to the Regional Director General are no longer required prior to drafting a variation order to close the fishery for the purposes of implementing the WWP on the Miramichi River).

The published and internal material reviewed in support of this report did not provide specific evidence for why coldwater pools are the primary spatial management unit used for protection during warm water events. There is no information available to assess if pool closures would be more or less effective at protecting salmon than entire river sections. Further, Breau and Caissie (2013) note that pool closures only protect fish in the pools and not those using smaller patches of cool water such as hyporheic exchange or groundwater seepage.

Since the adoption of the WWP in 2015 no formal monitoring of salmon mortalities during warm water events has occurred. C&P conducts *ad hoc* surveys of salmon mortalities during patrols, but no standardized monitoring occurs. C&P Renous detachment staff reported no observed mortalities in 2015, 2018, or 2019 (2016 and 2017 unavailable; G. Bateman pers. comm 2020). Jason Curtis (salmon guide, MSA) reported mortalities of salmon near the mouth of the Cains River near Blackville;16 mortalities (most salmon, few grilse) in 2016, 9 salmon and 2 grilse mortalities in 2017, 11 salmon mortalities in 2018, and 1 salmon mortality in 2019. It was suggested that specific lodges may have information on observed mortalities at specific fishing pools, but this data is not collected consistently by DFO. Data on daily salmon mortalities, water temperature, and dissolved oxygen in a section of the Cains River was collected from 2000 to 2007 by Jason Curtis, with support from DFO. The environmental data was published by DFO (see Caissie et al. 2004, Appendix 1) and mortality information was available between 1999-2003: in 1999, 131 mortalities were observed (partial count, unclear if this is a total or an estimate from within the study area); in 2001, 250 mortalities were observed of which 108 were in the study area; and in 2003, 36 mortalities were observed in the study area. The authors noted increased mortalities when water temperature exceeded 23ºC and when discharge was < 50 cm/s. Without consistent monitoring it is impossible to assess if the warm water protocol has been effective in reducing salmon mortalities associated with angling during warm water events. In addition to the lack of monitoring, understanding changing salmon dynamics and population declines will be important to assess the effectiveness of the protocol. For example, Jason Curtis reported that he has observed a “fraction of the fish” in pools today compared to early 2000s. He suggested that McKenzie Brook, Mersereau Brook, and Morse Brook were observed to contain 10-20 aggregating salmon in recent years, compared to the early 2000s when he observed hundreds (J. Curtis. pers. comm. 2020). Additionally, there is a perception that fewer anglers have fished the Miramichi River since 2015 when catch-and-release only restrictions were implemented. It is not known whether a reduction in salmon available to anglers due to population declines will impact the relative number of salmon that are angled, and thus the proportion of fish potentially exposed to angling during warm water events.

The changing conditions in the Miramichi River have not been addressed since the protocol was developed in 2015. For example, a stakeholder has suggested that the Doaktown water monitoring station located upriver may no longer accurately reflect downriver conditions where observed water temperatures exceed protocol thresholds (20ºC), but the pools remain open because Doaktown temperatures have not exceeded the threshold (J. Curtis pers. comm. 2020). The protocol relies on real-time water temperature readings from the single monitoring station at Doaktown. It is unclear if the Doaktown water monitoring station still offers the best location to observe water temperatures that influence watershed wide management actions. It does not appear that the number of closures per year has increased in duration since 2010 (Table 1).

In terms of implementing a quantitative WWP there are still several criteria that are considered subjectively. For example, quantitative thresholds for water level, maximum air temperature (forecast), precipitation, salmon aggregations, and mortality are not provided in the protocol and are left to the discretion of the DFO FHM team with stakeholder and C&P input. Discharge and water level are known to impact water quality (e.g., temperature and dissolved oxygen concentration) which can affect salmon survivorship and post-exhaustive exercise recovery (Breau 2013). Caissie et al. (2004, Appendix 1) described the discharge profile of the Miramichi River and its potential impact on salmon thermal stress, but was unable to provide definitive evidence of a discharge or water level that could be used as an environmental threshold for use in a WWP (D. Caissie pers. comm 2020). Similarly, there is no existing guidance for a threshold of salmon aggregations, or amount of precipitation that would lead to sufficient water temperature reduction. Additionally, the diel nature of some water quality variables are not accounted for in the protocol. For example, in-river dissolved oxygen concentrations are known to reach daily minima in the early morning (e.g., 6 am) when angling is allowed, even during warm water events (Chaput and Swansburg 2004), despite knowledge that decreased dissolved oxygen can impair salmon recovery (Breau 2013).

A formal internal or published evaluation or review of the WWP and its effectiveness does not appear to have taken place since its implementation in 2015.

3.2 Challenges and Contributing Factors

This section provides a brief overview of some of the challenges and contributing factors that may influence the implementation, and effectiveness of the WWP.

In 2005, TAP Environmental Resources Inc., was contracted to assess known and suspected sites in the Miramichi River watershed that functioned or could function as coldwater refuges, had on-going sedimentation or bank erosion issues, or sites with fish passage issues. TAP was also asked to develop a remediation plan for identified sites. TAP (2005) found that nine existing coldwater refuge sites would benefit from enhancement. These coldwater sites were: Porter Brook, Mill Brook, Donnelly Brook, Pats Brook, Burntland Brook, and Pump House Brook. While identified as coldwater refuges, the authors cautioned against enhancements at Porcupine Brook, Hurley Brook, and Big Rocky Brook due to geomorphological concerns regarding downstream flow as well as the sustainability of installed enhancement features (TAP 2005). Many of the pools recommended by TAP are pools that became protected under the WWP (Appendix 2). Based on the TAP assessment and other local information, the MSA undertook several coldwater refuge pool enhancements over the past ten years including eight enhancements between 2015 and 2017 (seven in the SWM and one in the NWM). All of the pools enhanced by the MSA are protected under the WWP and are thus important salmon holding and aggregation pools. The enhancement projects involved regrading and instream work and placement of material near brook outlets to increase energy or outflowing cold water into the mainstem river (MSA Undated). Most projects involved extensive rechanneling of the brook mouth and shoreline (MSA, undated). The MSA, the University of New Brunswick, and the Northshore Micmac District Council plan to enhance 11 additional pools (Carr et al. 2019) between 2020 and 2024; the location of the pools to be enhanced are not known. In 2019, the City of

Miramichi released its climate change adaptation strategy which identifies support for salmon thermal habitat enhancement as a priority (City of Miramichi 2019).

Pool enhancements may have an important role in habitat management for Atlantic Salmon in the Miramichi River, and yet, to date, no effectiveness studies or follow up monitoring has occurred to determine whether enhancement of instream structures are resilient and sustainable, or if the enhancements have resulted in an increase or decrease of salmon survivorship. Such effectiveness studies were recommended by Kurylyk et al. (2014), which reviewed ideas and motivation for pool enhancement and including approaches and techniques used in the Miramichi River. Anecdotally, salmon continue to use these pools post-enhancement, but no pre-construction assessments of juvenile or adult use was conducted and no post-construction monitoring information is available to assess if the enhancements have functioned as an improved refuge for salmon (T. Linnansarri pers. comm. 2020). Parr and juveniles typically overwinter at the mouth of coldwater tributaries in shallow pools that have low to moderate flow (Cunjak 1996; Cunjak et al. 1998) as well as the lee side of islands and backwater areas. Enhanced coldwater refuges (e.g., rechannelling a coldwater brook mouth) may result in changes to this important overwintering habitat. For example, frazil ice accumulates more often and to greater depths in deep pools compared to shallow pools, and deep pools restrict flow and lead to the development of hanging ice dams. If a coldwater habitat enhancement project alters the depth of a tributary mouth pool (e.g., make it deeper or shunt flow) the habitat may become unsuitable for parr and juvenile salmon in winter (Cunjak 1996; Cunjak et al. 1998). The enhancement work done on pools protected under the WWP confounds a potential review of the protocols effectiveness because post-angling mortalities could be related to changes in the hydrological functioning of the pool and tributary mouth, change in salmon behaviour or use of the altered pool, and the impact of warm water events on the altered pool.

Angling effort and behaviour are key determinants of post-angling mortality, especially during environmentally stressful conditions (Patterson et al. 2017). Changes in angling effort across years may confound an assessment of the effectiveness of the WWP because an observed decrease in mortality may be due to reduced angling effort as opposed to effective implementation of the protocol. For example, stakeholders have suggested that recreational angling effort has decreased since the catch-and-release only fishery was imposed in 2015 (J. Curtis. pers. comm. 2020). The province of New Brunswick provides angling statistics for Crown reserves in the Miramichi between 2015 and 2019 (Province of New Brunswick 2015; 2016; 2017; 2018; 2019) and Dubee et al. (2011) provides an estimate of angling effort and catch rate from 1990 to 2011 (Table 3). Over the past five years there is an observed decrease in angling effort with a minimum of rod hours in 2018 (9,766). From 1990 to 2011, angling effort was consistently above 15,000 rod hours per year, except for 1995 when rod hours were 11,794. However, the Crown reserve angler effort represents only a small portion of the total annual angling effort on the Miramichi (Moore et al. 1995). The last province wide (New Brunswick) angler survey was conducted in 1997 (Chaput et al. 1998). And in addition to the effort of anglers recall that recreational anglers have not been able to retain large Atlantic salmon since 1984 and grilse since 2015. In 2011, anglers released 88% of their catch captured on Crown reserves (Dubee et al. 2011).

As described in Section 2 above, Brodeur et al. (2015) predicted that over the next century mean annual air and water temperatures in the Miramichi River watershed are likely to increase by 4.4 and 3.2ºC, respectively, resulting in salmon critical temperature threshold being exceeded by an additional 21 to 41 days per year. This increase in the number, duration, and magnitude of environmentally stressful events that Atlantic Salmon are exposed to may or may not be mitigated by the management interventions in the WWP. For example, it is not known if 48-hours of water temperatures <20ºC would be sufficient for salmon recovery if the daytime temperatures in the coldwater refuge pools have increased by ~3ºC.

4. WARM WATER PROTOCOL TO PROTECT ATLANTIC SALMON IN OTHER SOUTHERN GULF RIVERS

In response to increasing water temperatures and environmentally stressful conditions observed in other important salmon rivers WWPs have been developed for three additional rivers in the Gulf Region. The rivers include the Margaree in Nova Scotia, the Nepisiguit in New Brunswick, and the Restigouche which borders the provinces of New Brunswick and Québec. A brief description of the draft protocols is provided with insights into the decision-making process provided by internal DFO memos and meeting summaries.

4.1 Margaree River

The interim Warm Water Protocol for the Margaree River (Nova Scotia) was developed by DFO in partnership with Nova Scotia Department of Fish and Aquaculture, Margaree Salmon Association, Nova Scotia Salmon Association, and Atlantic Salmon Federation (see DFO 2019d, Appendix 1). The protocol was developed through a series of meetings that occurred between November 2018 and June 2019. The protocol was developed in response to an increasing number of low and warm water events. The protocol is based on existing knowledge of Atlantic Salmon biology and physiology and the Miramichi River WWP. The Margaree River is defined by the Northeast (NE) and Southwest (SW) branches which join ~15 km from the ocean. The SW branch is the outlet of Lake Ainslie, the largest lake in Nova Scotia, but it is shallow and warms in the summer. The upper 25 km of the NE branch is a sanctuary and permanently closed to angling. The in-season management interventions were proposed for three sections of the river including, 1) the "lower" section (main stem) of the river including water up to Doyle's Bridge in the NE branch, 2) below Creamery Bridge (SW branch) and the Gallant River below the East Margaree Bridge, and 3) the "upper sections" were defined as above Doyle's Bridge up to the Cemetery Bridge (NE branch). The protocol states that the primary water temperature data used to inform closures will be collected from stations below Margaree Forks where the two branches merge. If closure conditions are met, DFO will discuss the weather forecast and water level with the warm water committee (including those who developed the protocol) and if in agreement (e.g., not likely to be a short-term closure) a variation order will be developed and issued. A full business day is required between committee agreement and publishing a notice to anglers of a closure. In November 2018, it was debated whether the SW branch should be considered for closure measures because it is generally warmer than the NE branch and salmon do not enter the SW Branch until autumn. Ultimately, the SW was included in the protocol (see DFO 2019d, Appendix 1). The protocol relies on a water temperature threshold above or below 20ºC over 48 hours prior to management interventions. The Margaree WWP uses three temperature thresholds for management intervention where: 1) < 20ºC allows continued angling access to the river, 2) > 20ºC for 48 hours (and unfavorable forecast, low water and fish aggregating at Gallant River pool) results in a closure to angling for all species in lower sections of the river and in SW branch, and 3) >23ºC for 48 hours results in continued closures in lower sections and SW branch and additional closure of upper sections of NW Margaree River. Stakeholders suggested that the protocol also include a definition of when DFO will engage them to discuss possible closures and agreed it would occur when minimum water temperature had exceeded 20ºC for 48 hours.

4.2 Nepisiguit River

The interim 2019 warm water 'strategy' for the Nepisiguit River (see DFO 2019e, Appendix 1) was developed by DFO in partnership with the Nepisiguit Salmon Association (NSA) and the Atlantic Salmon Federation (ASF). The strategy was developed through a series of meetings that occurred during April to June 2019. The strategy outlines management interventions and action to be taken if/when environmentally stressful events occur in the Nepisiguit River in the summer of 2019. The interim strategy was to be reviewed at the end of summer 2019 and adapted if needed for future seasons. Similar to the Miramichi River WWP, this strategy provides an overview of salmon thermal tolerances and introduces the concept of incipient lethal, critical, and optimal temperatures for Atlantic Salmon. Importantly, this strategy suggests that the critical temperatures (T_{crit}) is ~24ºC for Atlantic

Salmon (see DFO 2019e, Appendix 1). The thermal profile of the Nepisiguit River is partially unknown and long term data were not available to identify the most effective areas for protection. Therefore, in the 2019 strategy, and until more detailed information is known on the temperature regime of the Nepisiguit River, the entire portion of the river used by salmon was included in the area of in-season management angling interventions. Stakeholders (e.g., NSA) and the Rightsholder (Pabineau First Nation, PFN) participate in daily water temperature data collection and report to DFO. The strategy outlines that prior to the implementation or removal of management angling interventions a conference call will be held with DFO, PFN, NSA, and the province of NB to discuss conditions, but the final decision is made by DFO. The partners of the strategy agreed that T_{min} will be assessed as the average of the four temperature monitoring stations. The partners will install and monitoring water temperature and report their findings to DFO. The phased approach to implementing angling management interventions is: 1) where average $T_{min} < 20^oC$ allow the continued access to the river with normal angling rules, 2) where average $T_{min} > 20^oC$ for 48 hour, DFO implements morning angling only (6 - 11 am) restrictions in the Nepisiguit River from the dam at Grand Falls downstream to the mouth, and 3) where average $T_{min} > 23^oC$ for 48 hours, DFO implements a full closure for fishing for all species in the river from the dam at Grand Falls to the mouth. DFO will engage partners to discuss closing or opening angling restrictions after 24 hours of observed water temperature above or below the 20 and 23^oC thresholds.

4.3 Restigouche River

A discussion between DFO, the provinces of New Brunswick and Québec, and the Restigouche Watershed Management Council occurred in late 2018 after warm water periods occurred during the summer in the Restigouche River. A result of these discussions was a draft warm water strategy for the Restigouche River that outlined interim measures that could be implemented in 2019 under environmentally stressful conditions (see DFO 2019f, Appendix 1). The strategy was to be reviewed after the 2019 angling season. The area proposed for management interventions under the strategy is defined based on existing, but spatially limited, thermal information (INRS, 2014). The strategy states that increased water temperature monitoring is required to better understand priority areas for management (e.g., the warmest) in the watershed in the future. For 2019 angling season, the sections of the river believed to experience the warmest water temperatures are the focus of the strategy and are defined as: 1) the main stem of the Restigouche River from the mouth of the Kedgwick River downstream of the tidal waters located at the Canadian National Railway (CN) bridge, below the confluence of the Restigouche and Matapedia Rivers, 2) the Upsalquitch River from the confluence with the main Restigouche channel upstream to the Upsalquitch forks; this sections is less likely to be subjected to warm water conditions but was included because there is a real time temperature station on the river. During periods of warm weather and low water conditions, water temperature will be monitored daily by partners using real time loggers. Loggers are found at: the mouth of the main Restigouche River below the mouth of the Kedgwick River (on the opposite bank of the confluence to avoid cold water outflow from the Kedgwick). Another logger will be installed in the Main Restigouche in 6-mile Brook area. A final logger will be placed in the Upsalquitch River downstream from the forks. Partners will report or provide links to real-time water temperature data to DFO. In 2019, the average of the two T_{min} records from both loggers will be used as a management threshold for action in the Main Restigouche. Environment and Climate Change Canada has two real time water level monitoring stations on the Restigouche and water level will be considered along with the weather forecast when temperature thresholds are exceeded. DFO will organize a conference call between Province of NB, GMRC, and the Restigouche River Watershed Management Council after 24 hours of minimum water temperatures exceeding 20^oC. Final management action decisions will be made by DFO. The threshold for management intervention presented in the strategy are: 1) where average $T_{min} < 20^oC$ access is maintained in the river with normal angling rules, 2) where $T_{min} > 20^oC$ for 48 hours, DFO will implement morning angling only (6 - 11 am) in the main Restigouche River, and 3) where $T_{min} > 23^oC$ for 48 hour, DFO will implement a full closure for fishing for all species in the Main Restigouche River (see DFO 2019f, Appendix 1).

5. TIMELINE OF KEY EVENTS

Figure 2 provides a timeline summary of the key events and decision-points that have occurred due to warm water events on the Miramichi River since 1987.

6. CONCLUSION AND RECOMMENDATIONS FOR FUTURE REVIEWS

This report provides a retrospective review of the development and implementation of the Warm Water Protocol for the Miramichi River in New Brunswick, Canada. The review was completed in support of DFO's Ecosystem Approach to Fisheries Management (EAFM) initiative which aims to evaluate how environmental and ecosystem variables are considered in the development of science advice and subsequent decision-making process. The WWP was a management tool developed between 2011 and 2015 to reduce Atlantic Salmon recreational angling mortality on the Miramichi River associated with environmentally stressful conditions. The development of the protocol relied on science advice that evaluated salmon physiological response to warm and low water conditions and the effectiveness of various management scenarios. Specifically, water temperature, water level, precipitation, and weather forecast are the environmental and ecosystem variables considered in the final protocol. The science advice process directly influenced the decision-making process and protocol development to establish a 20^{o}C water temperature management threshold; however, discussions with stakeholders did influence protocol development and altered the final management interventions. Stakeholders played a large role in the development of the protocol and are largely supportive of the current management interventions and criteria. Stakeholders are extensively involved with the protocol's implementation. Additional research on the influence of confounding variables will be required to evaluate the effectiveness of the WWP to reduce Atlantic Salmon recreational angling mortality. The protocol is a solution that was proactively implemented by DFO FHM in the absence of total science surrounding angling during warm water events (e.g., lack of definitive thresholds for some variables) and is relatively easy to implement. Thus, protocol implementation represents a precautionary approach to fisheries management of the Atlantic Salmon recreational fishery on the Miramichi that is collaborative with DFO Science and C&P, and stakeholders.

With respect to the lessons learned from conducting this review, the following recommendations are provided for the consideration of DFO Science and FHM to facilitate future initiatives;

- Date all internal documents, standardize the file naming convention, and improve the information management practices;
- Provide an accounting of key decision points within a document. For example, when version 1 of a document offers a set of criteria and they appear differently in version 2, include a comment or track changes of why this change occurred and;
- When stakeholders, Rightsholders, or working groups are mentioned in documents, include or describe the membership;
- Effectiveness monitoring of the Warm Water Protocol to determine if, and how much, the protocol is reducing mortality of salmon. This would allow for revisions of the WWP or its application.

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TABLES

Table 1: Retrospective of the number and type of in-season recreational angling closures and observed salmon mortalities that have occurred on the Miramichi (NB), Margaree (NS), and Nepisiguit (NB) between 1987-2019. Total mortalities represent a minimum value as the whole river was not checked.

Year	Close Date	Open Date	Closure days	Variation Order	Location	Close type	Reason	Source	Total Mortalities	Source
1987	NA				NA		Low Water	Chaput 2002		
1989	NA				NA		Low Water	Chaput 2002		
1995	31-Jul	28-Sep	59		Southwest Miramichi	Closed river section	Low/warm water and Indigenous harvest	Chaput 2002		
1995	09-Aug	28-Sep	50		Southwest Miramichi	Closed river section	Low/warm water and Indigenous harvest	Chaput 2002		
1995	09-Aug	26-Sep	48		Northwest Miramichi	Closed river section	Low/warm water and Indigenous harvest	Chaput 2002		
1995	09-Aug	20-Sep	42		Northwest Miramichi	Closed river section	Low/warm water and Indigenous harvest	Chaput 2002		
1999	31-Jul	10-Aug	10		Miramichi	Fishing closed after 10 am	Warm water and observed mortalities	Chaput 2002	131 dead salmon	Moore et al 2004
1999	23-Jul	08-Sep	47		Southwest Miramichi	Pool closure (N = 2)	Warm water and observed mortalities	Chaput 2002		
2001	10-Aug	18-Aug	8		Miramichi	Closed main river and tributaries	Warm water and observed mortalities	DFO 2018c; Appendix 1		
2001	10-Aug	31-Aug	21		Miramichi	Pool closure (N = NA)	Warm water and observed mortalities	DFO 2018c; Appendix 1	250	Moore et al 2004
2010	10-Jul	15-Sep	Season		Miramichi	Pool closure (N = 3)	Warm water and salmon aggregation	DFO 2018c; Appendix 1		
2010	24-Jul	31-Jul	7		Miramichi	Pool closure (N = 9)	Warm water and salmon aggregation	DFO 2018c; Appendix 1	> 200 parr, 3 MSW, 7 salmon	Cunjak, R.
2012	27-Jul	03-Sep	38	VO 2012 - 059	Miramichi	Pool closure (N=15)	Warm water and salmon aggregation	DFO 2018c; Appendix 1		
2012	05-Aug	14-Aug	9		Miramichi	Few tributaries; Fishing closed after 10 am until 5 am	Warm water and salmon aggregation	DFO 2018c; Appendix 1		

Year	Close Date	Open Date	Closure days	Variation Order	Location	Close type	Reason	Source	Total Mortalities	Source
2012	15-Aug	25-Aug	10		Miramichi	Fishing closed after 10 am until 5 am	Warm water and salmon aggregation	DFO 2018c; Appendix 1		
2012	03-Sep		Season	VO 2012 - 069	Miramichi	Pool closure (N=3)	Seasonal closure	DFO 2018c; Appendix 1		
2013	17-Jul	25-Jul	8		Miramichi	Pool closure (N = 22)	Warm water and salmon aggregation	DFO 2018c; Appendix 1		
2013	19-Jul	25-Sep	68		Miramichi	Pool closure (N = 4)	Warm water and salmon aggregation	DFO 2018c; Appendix 1		
2015	01-Jul		Season	VO 2015 - 049	Miramichi	Pool closure (N = 3)	Seasonal closure	DFO 2018c; Appendix 1		
2015	14-Jul	17-Jul	3	VO 2015 - 049	Miramichi	Pool closure (N = 23)	Warm water and salmon aggregation	DFO 2018c; Appendix 1		
2015	17-Aug	19-Aug	2		Miramichi	Pool closure (N = 23)	Warm water and salmon aggregation	DFO 2018c; Appendix 1		
2015	20-Aug	24-Aug	4		Miramichi	Fishing closed after 11 am until 6 am	Warm water and salmon aggregation	DFO 2018c; Appendix 1		
2015	25-Aug	31-Aug	6		Miramichi	Pool closure (N = 23)	Warm water and salmon aggregation	DFO 2018c; Appendix 1		
2016	01-Jul		Season		Miramichi	Pool closure (N=3)	Seasonal closure	DFO 2018c; Appendix 1		
2016	26-Jul	15-Aug	20	VO 2016 - 050	Miramichi	Pool closure (N = 25)	Warm water and salmon aggregation	DFO 2018c; Appendix 1	16 (most salmon, few grilse)	Curtis, J.
2017	01-Jul		Season		Miramichi	Pool closure (N=3)	Seasonal closure	DFO 2018c; Appendix 1		
2017	20-Jul	27-Jul	7		Miramichi	Pool closure (N = 26)	Warm water and salmon aggregation	DFO 2018c; Appendix 1	9 salmon, 2 grilse	J. Curtis
2017	03-Aug	09-Aug	6		Miramichi	Pool closure (N = 26)	Warm water and salmon aggregation	DFO 2018c; Appendix 1		
2018	01-Jul		Season	VO-2018-081	Miramichi	Pool closure (N=3)	Seasonal closure	DFO 2018c; Appendix 1		
2018	05-Jul	21-Aug	47	VO-2018-051	Miramichi	Pool closure (N = 26)	Warm water and salmon aggregation	DFO 2018c; Appendix 1		
2018	24-Jul	11-Aug	18		Miramichi	Fishing closed after 11 am until 6 am	Warm water and salmon aggregation	DFO 2018c; Appendix 1	11 salmon	J. Curtis

Year	Close Date	Open Date	Closure days	Variation Order	Location	Close type	Reason	Source	Total Mortalities	Source
2018	03-Aug			VO-2018-100	Margaree River	River section; type unknown	Warm water	DFO 2018b; Appendix 1		
2018	10-Aug			VO-2018-101	Margaree River	River section; type unknown	Warm water	DFO 2018a; Appendix 1		
2018	01-Aug			VO-2018-062	Nepisiguit River	River section; Fishing closed after 11 am	Warm water and salmon aggregation	DFO 2019g; Appendix 1		
2019	01-Jul	31-Dec			Miramichi	Pool closure (N=3)	Seasonal closure	DFO 2019g; Appendix 1		
2019	19-Jul	23-Jul	4		Miramichi	Pool closure (N=27)	Warm water and salmon aggregation	DFO 2019g; Appendix 1	1 salmon	J. Curtis
2019	30-Jul	08-Aug	9		Miramichi	Pool closure (N=27)	Warm water and salmon aggregation	DFO 2019g; Appendix 1		
2019	01-Aug	06-Aug	5		Miramichi	Fishing closed after 11 am until 6 am	Warm water and salmon aggregation	DFO 2019g; Appendix 1		
2019	30-Jul	13-Aug	14		Nepisiguit River	Morning fishing only	Warm water and salmon aggregation	DFO 2019g; Appendix 1		
2019	29-Jul	02-Aug	4		Margaree River	Not closed, but thresholds breached	Warm water and salmon aggregation	DFO 2019g; Appendix 1		

Table 2: Closure Criteria of the Miramichi Warm Water Protocol, 2015 (Reproduced with permission. DFO, 2015). Three stages of management interventions are outlined based on temperature thresholds. Stage 1 is shaded in green, Stage 2 in yellow, and Stage 3 in red.

	Parameters recorded / observed	Information collected	Management action
Stage 1	**Minimum Daily Water temperature**	**< 20ºC**	Maintain access to the waters while respecting the current management plan for the Miramichi River.
			Implement angling restrictions to 3 pools (Listed in Appendix 2) on July 1 of each year as per management plan.
Stage 2	**Minimum Daily Water temperature**	**≥ 20ºC ≤ 23ºC** **2 consecutive days ***	Implement angling restrictions to all 26 pools defined in Appendix 2. ** 2 days = 48 hours, but the minimum temperature needs to be breached only once during a one-hour period.*
	Water levels	Water levels are lowering	
	Long term forecast (next 7 days)	High daily temp Warm nightly temp Limited chance of rain	
	Fish behaviour	Fish congregating in cold water refuges	
Stage 3	**Minimum Daily Water temperature**	**> 23ºC** **2 consecutive days**	Implement angling restrictions from 11:01am until 6:00am the following day. Maintain existing closures to 26 pools defined in Appendix 2.
	Water levels	Low water levels	
	Long term forecast (next 7 days)	High daily temp Hot nightly temp Few to no chance of rain	
	Fish behaviour	Fish congregating in cold water refuges Mortalities observed	

Table 3: Annual estimates of total catch and effort for grilse and salmon on the Miramichi River in Crown reserves (Northwest Miramichi, Sevogle, and Little Southwest Miramichi) from 2006 to 2019 (Dubee et al., 2011; Province of New Brunswick, 2015; 2016; 2017; 2018; 2019). Catch rate is an estimate of grilse and salmon captured per rod day. Rod hours is the total number of rod hours across all reserves. *The 2011 catch rate estimate is an average from the three reserve areas, whereas all other years are the minimum and maximum catch rates.

Year	Catch Rate (catch/rod day)	Rod Hours
2019	0.23-0.37	11,259
2018	0.08-0.22	9,766
2017	0.18-0.28	12,677
2016	0.22-0.38	15,397
2015	0.2-0.31	15,372
2011	0.77*	17,304
2010	NA	15,839
2009	NA	20,047
2008	NA	19,145
2007	NA	18,895
2006	NA	18,867

FIGURES

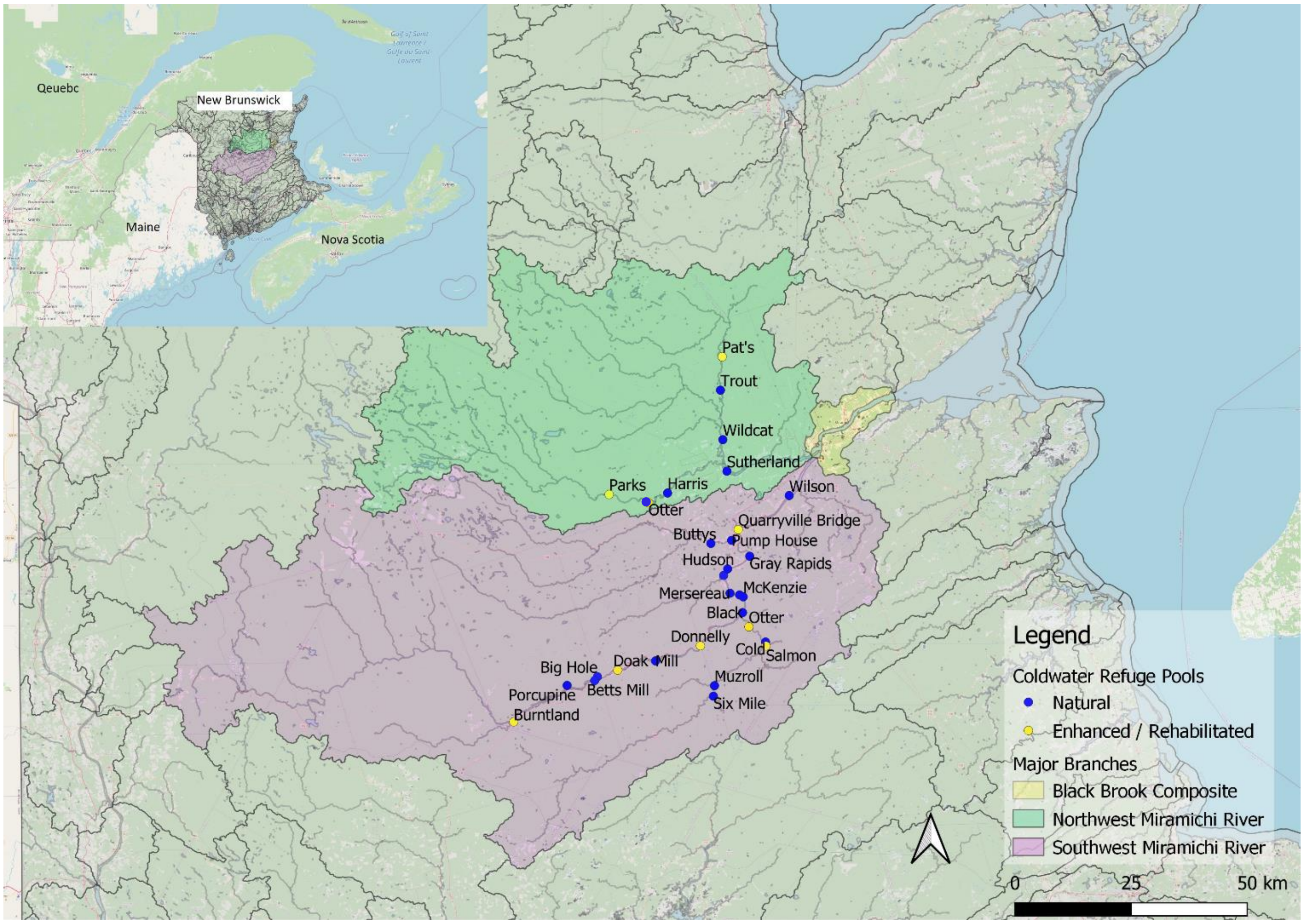

Figure 1: Location of coldwater refuge pools protected under the Warm Water Protocol (DFO, 2015) in the Miramichi River, NB. The most downstream pools, Quarryville (Indian Town) Brook, Wilson's Brook, and Sutherland Brook, close annually on July 1 as per management plan (Appendix 2). Pools that have been enhanced or rehabilitated to improve coldwater refuge properties are shown in yellow.

A)

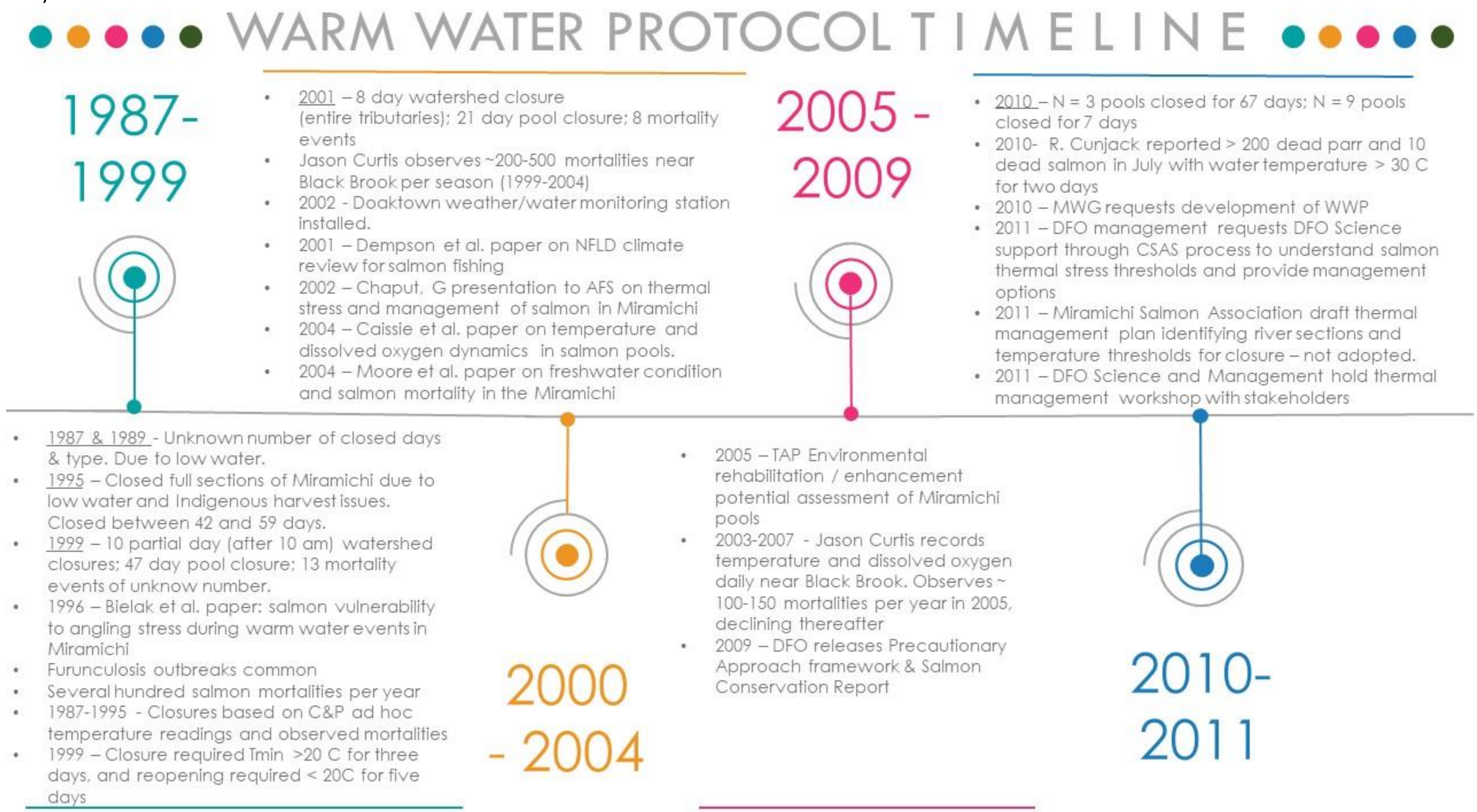

Figure 2A: Timeline of events, observations, and management interventions that occurred between A) 1987 and 2011 and B) 2012-2020 on the Miramichi River (NB) and other important salmon rivers in Atlantic Canada. Years that are underlined highlight an in-season management intervention.

B)

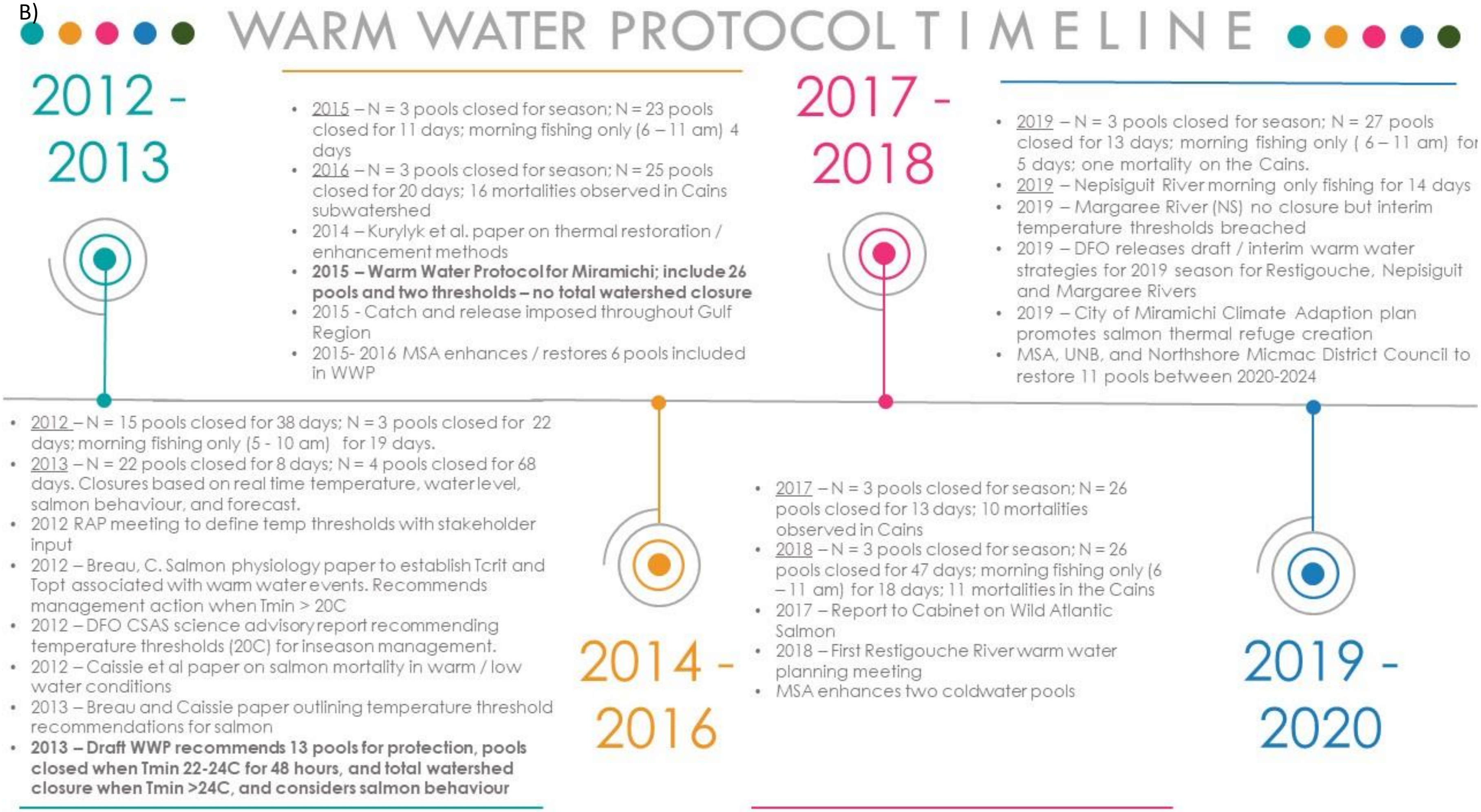

Figure 2B: Timeline of events, observations, and management interventions that occurred between A) 1987 and 2011 and B) 2012-2020 on the Miramichi River (NB) and other important salmon rivers in Atlantic Canada. Years that are underlined highlight an in-season management intervention.

APPENDIX 1:

An annotated bibliography of unpublished material and correspondence cited in the above report. All of the information summarized below was provided by DFO FHM and DFO Science, Gulf Region.

1) Butruille, F. 2016. “RE: Salmon pool closures July 2016”. Message to Philip Donovan of Fisheries and Oceans Canada and several stakeholders. July 25, 2016. Email.

Email from Frederic Butruille to Philip Donovan asking for confirmation to add two additional coldwater refuge pools to list of salmon pools for closure on the Miramichi in July 2016. The pools were proposed by the Miramichi Salmon Association (MSA). Philip responded that his section has no issue with the additional pools being included. Frederic and MSA worked together on wording to define the boundaries of the new pools to include in the closure list.

2) Butruille, F. 2017. “RE: Reopening of cold pools?”. Message to Mark Hambrook of the Miramichi Salmon Association, Debbie Norton of the Miramichi Watershed Management Council, and Ceclie Lavoie of DFO. July 24, 2017. Email.

In this correspondence email chain Frederic relayed that minimum daily temperature (T_{min}) at night was <20C at Doaktown for the past two nights, but with warm day/nights in the forecast for the upcoming seven days. Frederic asked for a recommendation on keeping the pools closed or to re-open. Mark responded that the pools should re-open if conditions of Warm Water Protocol are met to ensure public support of the process and to close the pools if temperatures once again increased. Frederic replied that DFO C&P observed salmon were still holding in pools which is also a criterion of the protocol and so pools would remain closed and a new evaluation would occur on July 25th. Debbie Norton responded that she was unaware salmon behaviour were criteria in the protocol and stated she believed the criteria were solely based on temperature. Frederic replied with the criteria table from the WWP outlining behaviour is considered. Mark responded that he had just observed Inadiantown Brook and only observed 9 grilse and 2 salmon in the flume of the brook. He observed 25 salmon several days ago. His argument is that fish have dispersed from the coldwater refuges and that pools should reopen. Cecile replied that DFO C&P reported seeing hundreds of fish still aggregated in other pools and the recommendation is to continue the closure.

3) Caissie, D., Moore, D., Curtis, J., and Chaput, G. 2004. Water temperature, discharge, and dissolved oxygen dynamics within a salmon pool of the Miramichi River (2003-2004). Fisheries and Oceans Canada, Moncton, NB. Unpublished, 4 p.

A 2003-2004 study that evaluated water temperature, discharge, and dissolved oxygen (DO) in a known salmon aggregation pool in the Southwest Miramichi River. The report also recorded observed salmon mortalities from the mouth of the Cains River for approximately 5 km downstream. The river at the site is wide (25-50 m) and shallow (0.2-2m), and slow moving. Black Brook Pool which is one of the largest holding pools for salmon is just upstream of the study site. Water temp was monitored in the study area, in Black Brook Pool and upstream in the Cains River. DO was monitored in the pool in 2003 from late July until mid Sept. The area was surveyed each day for salmon mortalities. In 1999 and 2001 the report states that observed salmon mortalities exceeded 200 but were probably less than 500 and were concentrated in the Southwest Miramichi subwatershed. Specifically, a holding pool between the mouth of the Cains River and Blackville had an "unprecedented" number of mortalities. The report also provides a summary of recent observed mortalities in the study area ; in 1999 = 131 dead salmon were observed (partial count, location unknown, from whole watershed); 2001 = 250 mortalities, 108 of which came from study area; 2002 = 17, and 2003 = 36 salmon from the study area. The authors suggested that mortality was correlated to limnological factors in the following ways: in 1999 discharge was < 26 CMS (low) during observed mortalities and temperature was > 23C; in 2001 discharge was < 20 CMS in nearly all cases of observed mortality and the maximum daily water temperature was > 22C in most cases; in

2003 discharge and temperature were closer to long term averages but mortalities were observed when temperature was > 23C (52%) and nearly always > 20C (88%). There was nearly 100 mm less rainfall in 2001 compared to 2002 during July and August. While no viral diseases were attributed to the salmon mortalities observed directly in the study area, the freshwater bacteria that causes Furunculosis was found on nearly all fish in 2001. Because this pathogen increases mortality during stressful physiological conditions the observed mortality, its effect cannot be ruled out as a factor in the observed deaths. In 2003, the number of positive tests for bacteria on salmon increased from 17% in June to 71 % in July. The authors suggest that 50 cms appears to be a threshold below which mortalities may occur if temperatures are >20C (when low flow is consistent for more than short periods of time).

4) Chaput, G. 2011. "RE: DRAFT agenda for data gathering workshop to being work associated with the development of environmental thresholds for managing Atlantic Salmon fisheries - Miramichi and Restigouche". Message to DFO Science, the province of New Brunswick, University of New Brunswick, and Miramichi River stakeholders. May 16, 2011. Email.

This email chain provides information from Gerald Chaput of DFO to 16 other colleagues including science & management staff in DFO, First Nation representatives (AAROM), UNB researchers, provincial authorities, and other stakeholders (MWMC). The email pertained to an upcoming workshop to develop a path forward to gather data in support of developing environmental thresholds for Atlantic Salmon recreational fisheries. The meeting was held on May 18, 2011 in Sillikers, NB. Presentations were delivered by 1) Cindy Breau on metabolism and physiological response of adult salmon to high temperatures, and 2) Daniel Caissie on temperature characteristics and monitoring data in the Miramichi and Restigouche. The presentation by Cindy was a working paper that was the preliminary foundation for the 2012 CSAS report. The group also discussed possible thresholds for temperature and identified knowledge gaps. The group also prioritized possible management scenarios to be evaluated in support of the planned February 2012 advisory process meeting. Background material provided in the email outlines what DFO FHM requested in terms of science advice for environmental thresholds to manage Atlantic Salmon, including: 1) What environmental thresholds could be used to trigger management actions to open or close Atlantic Salmon fisheries?, and 2) Given the size of rivers, what are the options available for managing Atlantic Salmon fisheries during environmentally stressful conditions. Based on the above questions, DFO Science proposed to provide peer reviewed science considering the following: 1) physiological/metabolic information for salmon associated with level and duration of stress and probability of survival, 2) Possible temperature benchmarks associated with probability of mortality, 3) environmental characteristics of the Miramichi and Restigouche Rivers, 4) possible environmental triggers associated with environmental stress on Atlantic Salmon, 5) Evidence that salmon are susceptible to angling during warm water events and levels of mortalities associated with catch and release fishing, 6) evaluation of fishery management options considering required frequency and duration of management actions, and 7) outline uncertainties and other considerations.

5) Couturier, G. 2011. "RE: Nov 16th 2011 Meeting at Miramichi Conservation Centre". Message to DFO science and management staff and stakeholders including Mark Hambrook of the Miramichi Salmon Association. November 18, 2011. Email.

An email chain provided by G. Chaput that summarizes the meeting outcomes from a November, 16th 2011 meeting with stakeholders and DFO regarding the development of a Warm Water Protocol. DFO science was not involved in the meeting. The thresholds and management actions (called phases in the email chain) as presented by Miramichi Salmon Association's Jenny Reid were worked into a table of explicit actions based on criteria which was discussed at the meeting. The potential pools to be protected were also discussed. At this meeting stakeholders advocated for moving the full closure of the three most downstream coldwater pools from August 1 to July 1. Each management phase for in-season management interventions was based on a temperature criteria being met for four consecutive days (predicted) based on Doaktown water / air temperatures. The thresholds were: 22 (close 12 pools and impose gear/time limits), 23 (close all waters outside of morning fishing 6am-11am, and 25C (close the watershed fully). The goal of the meeting was to provide a summary of recommendations for science at a 2012 RAP meeting. Following the meeting on November 20th, Mark Hamburg from the MSA replied that a total closure at 25C would result in long durations of closed fishing which would limit fishing opportunities and cause an unacceptable economic impact in the watershed. He recommended morning fishing only (Phase 2) be implemented until predicted temperatures > 28C. His rationale was that > 24C salmon do not take a fly. Finally, Scott Douglas of DFO responded (internally within DFO) that if the temperature protocol development was going to be created based on external science, then DFO FHM should rescind its request for DFO Science to develop a protocol and cancel the CSAS process.

6) Cunjak, R. 2010. "RE: High temps and salmon". Message to Mark Hambrook and Jenny Reid of the Miramichi Salmon Association. July 11, 2010. Email.

Dr. Rick Cunjak from the University of New Brunswick emailed his observations of salmon mortalities from the Little Southwest Miramichi River on July 11, 210 to Mark Hambrook of the MSA and to Frederic Butruille of DFO. At UNB student's study site Rick observed water temperatures > 30C for 2 days and nighttime temperatures did not fall below 20C. Rick and the student observed the following mortalities: 10 dead adult salmon including 3 MSW females, and > 200 dead parr at Otter Brook and Catamaran Brook. Salmon parr were seen aggregating in "the thousands" in small cool water refugia. Adults were often observed in the crowded refuge pools. All fish were nosing into the cool water inflow. Salmon parr aggregating immediately downstream of Otter Brook was ~ 4000-5000 fish and extended in a "cloud" of fish for ~ 100 m. Dr. Cunjak also observed anglers fishing during peak water temperatures and suggested it was an education problem and not related to angler indifference. Dr. Cunjak also suggested rivers/pools need to be closed to recreational boats/paddling in addition to just angling during warm water events. Finally, he advocated that closures are needed during warm water periods, even if it only saves on female. He also suggested mitigation measures like pumping cool water into the river may be required.

7) DFO. 2011a. Internal document: "Question from DFO FAM". Fisheries and Oceans Canada, Moncton, NB. Unpublished, 2 p.

This document is a scan of a file provided by M. Vinneau in 2020, that is said to be written in 2011. The document is a draft that likely was revised at a later date. It is undated and titled "Questions from DFO FAM" which was presumably delivered to DFO Science in support of the CSAS process for the development of the Warm Water Protocol. DFO FHM proposed the following questions for DFO Science to address:

1) Based on historical events, what association is there between historical warm water and low water conditions and salmon mortality?
2) Can benchmarks of water temperature and water level that signify likely salmon mortalities be developed?
3) What temperature thresholds could be used to trigger management actions to open or close fishing waters?
4) What management measures could be used to manage closures: whole river, portions of rivers susceptible to warm water, partial daily closures, etc?

An approach is proposed in the document to define basic science and management questions that DFO FHM requires in order to support the development of the WWP. Specifically, the following information is proposed to be gathered to address the above questions:

1) Information on salmon physiology and metabolism and the causes of warm water mortality (e.g., temp benchmarks for stress and recovery),
2) Thermal and discharge profile of Miramichi and Restigouche Rivers,
3) Possible environmental triggers to management environmental stress and evidence (e.g., that fish are caught during warm water periods, and that catch and release can result in mortality)

DFO Science also proposed to evaluate the effectiveness of possible management interventions i) relative to salmon mortalities and time closures, ii) relative to within season frequency of management interventions, and iii) relative to the time and area of rivers which would be closed. Three options were proposed for evaluation: i) partial daily closures (6- 10 am), ii) focus on cool water areas, iii) other FAM proposals.

The document also briefly lists possible data sources that could be reviewed to support the information gathering process.

8) DFO. 2011b. Draft Protocol Threshold Indicators for closure of Salmon pools/Section of Rivers. Fisheries and Oceans Canada, Moncton, NB. Unpublished, 14p.

This document provided by M. Vienneau in 2020 that was filed with 2011 correspondence. It is called "Threshold indicators for closure of Salmon Pools/Section of Rivers". It is undated and it is unclear where this information was presented or developed. The document outlines field observations that need to be recorded to support warm water threshold decisions, including: water levels, salmon refuge pools, mortalities, number of days of high water temp, fish stress, behaviour, movement of fish into pools, and poaching. This document talks specifically about data collection of water temperature in the Restigouche. Time, date, temperature, and mortalities are to be recorded. Instructions for water temperature recording provided are: take the water temperature reading in the mid-water column and at 10 cm depth under surface, in still water, and not downstream of coldwater tributaries; temperature should be taken at 8 am and 6 pm to determine minimum and maximum temperatures. Report to be submitted daily to DFO FHM. A next step was proposed to define river sections within 100 m of refuge pools. Three coding levels are available to determine management interventions: Green = < 22C water temp at night and cooling water temp with average water levels, and limited fish mortality; Yellow = water temp 22-28C but where air temp at night is less than (not provided), and water temperature is less than (not provided); and water level is (missing information), and considering observed mortalities. Red = 25-28C upper lethal limits and considering other variables as listed during the yellow stage. The threshold levels appear to be based on the Miramichi Salmon Association’s thermal management plan air to water temperature model (see Reid et al 2011). For each phase the document outlines responsibilities for DFO Science, DFO C&P and DFO FAM where green everyone is on alert and monitoring conditions; during yellow = DFO Science monitors air and water temp and reports of field observations, DFO C&P monitor fish movement in pools and fish mortalities, and DFO FAM initiates consultations with watershed groups and science. During this phase DFO Science and C&P also make recommendations on closures to DFO FAM for immediate closures to specific waters. Based on recommendations. DFO FAM drafts a variation order for specific water closures and consider limiting fishing after 10 am. The document also suggests DFO should provide camp managers with a code of conduct for anglers fishing during warm water events. During the red phase all the steps of yellow are taken but the management response is to use the variation order to close waters and either full sections or the entire watershed to fishing during specific times.

9) DFO. 2012b. Decision memo to Regional Director of Gulf Region, dated July 20, 2012. Fisheries and Oceans Canada, Moncton, NB. Unpublished, 4 p.

A July 20, 2012 decision memo that provides information in support of the variation order, VO 2012 059, to close the recreational fishery on the Miramichi River due to warm water conditions. The decision memo to DFO Gulf’s Regional Director General and provides a summary of warm water conditions on the Miramichi starting on July 13. It recommended closing the coldwater refuge pools on July 23, 2012 due to forecasted high temperatures, aggregating salmon, and limited forecasted precipitation. DFOC&P provided evidence that fish were starting to aggregate, but that "it has not reached critical stage". In the summary, the rational was provided that a recent science peer reviewed showed that adult salmon are stressed when temps >23C and require night time temps of <20C to allow for recuperation. It states that water temperature was collected in real time in Doaktown, NB. DFO Management sought input from C&P, NB Wildlife Federation, MSA, and MWMC, all agreed it would be beneficial to close the pools. NB Aboriginal People's Council were not opposed to the closures, but required more information about where closures would occur. Fourteen pools were proposed to be closed. Supporting information with the decision memo included weather forecast, water temperature for the month of July, criteria for fishery closures, and notice to fish harvesters.

10) DFO. 2012c. Informal request on in-season closure on the Miramichi River [EKME:2649658]. Fisheries and Oceans Canada, Moncton, NB. Unpublished, 7 p.

A summary document called "Informal request on in-season closure on the Miramichi River". The document is undated, but information contained within suggests it was written around August 21, 2012. The document is cited as EKME: 2649658. The document provides a brief summary of the DFO Science advice that in-season fishing management interventions occur when water temperatures exceed a 20C threshold for more than 48 hours. The document outlines that DFO monitors weather and works with multiple sources to understand the situation on the river, including stakeholders and C&P. The document outlines the existing closure and opening criteria for the recreational fishery where, closed = water temperature at night > 20C for two consecutive days and open = when water temperature is less than 20C for two consecutive days. The document states that salmon coldwater refuge pools were closed on July 23 (but it was actually 27th). It does not say if pools were ever reopened. On August 5, 2012 daily closures of the entire river system were implemented from 11 am to 4 am. On August 14, 2012 the area of the VO was expanded to include the Little Southwest Miramichi and South Branch of SW Miramichi River. While stakeholders were supportive in July 2012, this document states that as of mid-August, many were concerned with on-going and expanding closures that are impacting current and potential business. Stakeholders suggested that the protocol is too precautionary and that openings should occur when forecasts call for cooler weather. List of stakeholders engaged are listed and a conclusion is provided that existing protections remain in effect until water temperatures / conditions improve based on daily monitoring.

11) DFO. 2012d. Framework for a salmon management plan for New Brunswick (Miramichi and Restigouche Watershed). Fisheries and Oceans Canada, Moncton, NB. Unpublished, 11 p.

This is a draft internal DFO document entitled a “Framework for a salmon management plan for New Brunswick (Miramichi and Restigouche Watershed)” that was prepared in 2012. The document states that, "The objective of this note is to layout a framework for an operational plan for the management of the salmon fishery for the Miramichi and Restigouche rivers that is consistent with the management goals and objectives described in the Atlantic salmon Integrated Management Plan (2008-2012) Gulf Region” . Further, it notes that decision rules for the opening and closing of the fishery based on water levels and water temperature would be developed. DFO Science would evaluate and inform DFO FHM of potential benchmarks or triggers that support the conservation limits and requirements for the salmon populations in the two rivers. However, DFO FHM would select the thresholds and develop decision rules based on a cost/benefit analyses. In this document low water level is cited as the major environmental concern to salmon from increased angling stress, as opposed to temperature. The report states that rivers with early-run salmon are more likely to be affected by warm water events. It also states that stress from warm and low water conditions can result in increased salmon mortality in the catch and release fishery, increased opportunity for foul-hooking, and increased mortality from general disturbance of fish by a variety of water uses (fishing, canoeing, tubing, etc.). A suite of possible pre-defined management actions (for example, closure of only portions of rivers most susceptible to warm water events, partial daily closures for ex after 10:00 AM) are proposed to be evaluated by DFO Science. The suite of management scenarios to be considered should be determined by the level of information available, the spatial scale of environmental variability, and the spatial scale of management feasibility. It is also suggested that DFO Science could assess the association between historical warm water and low water conditions and salmon mortalities and develop benchmarks of water temperature and water level most likely to result in future salmon mortalities. This work could be started in January 2011 and peer reviewed analyses completed in early May 2011.

12) DFO. 2013a. Decision memo to Regional Director General of DFO’s Gulf Region, dated July 16, 2013. Fisheries and Oceans Canada, Moncton, NB. Unpublished, 14 p.

This memo was written to provide background and science information to DFO Gulf's Regional Director to support a decision on closing coldwater refuge pools in the Miramichi River on July 17. 2013. The state criteria used to implement a closure is stated as minimum nightly water temperatures exceeding >20C for three consecutive nights, DFO C&P observing salmon aggregating in pools, and high temperatures in the forecast. The memo states that "peer reviewed science advice shows that an adult salmon is stressed when water temperatures exceed 23C and nighttime temps need to be below 20C to allow salmon to recovery". The memo states that stakeholders were engaged were supportive of the closures proposed coldwater pools. Camp owners and guides represented by the Miramichi Watershed Management Committee were "generally" supportive of the closures. Five attachment tables are included in the decision memo, including: real time water temperature readings from Doaktown, and water levels; reports from DFO C&P on salmon behaviour; air temperature and rain forecast for Doaktown; criteria for management intervention during warm water temps; and a draft notice to anglers outlining the closure. The memo states that DFO C&P reported that, "Anglers are starting to chase the fish to these refuge areas as the fishing has slowed throughout the rest of the system…[but that] no dead fish have been seen and so that is a positive". Twenty-two pools were proposed for closing.

13) DFO. 2013b. DRAFT - Protocol for Inseason Intervention in Angling Activities during Environmentally Stressful Conditions to Atlantic Salmon in the Miramichi Watershed (Warm Water Protocol). Fisheries and Oceans Canada, Moncton, NB. Unpublished, 24p.

This draft document outlines the first formal compilation of a Warm Water Protocol for the Miramichi River. The entire document is not summarized here, but rather important points where the 2013 draft protocol differs from the published final 2015 protocol are provided. Fifteen cold water pools are described in the 2013 WWP (compared to 26 in final 2015 version). Another difference is that the three most sensitive pools (Wilson Brook, Indian Town Brook, and Sutherland Brook) were proposed to be closed for the season starting on August 31 (instead of July 1 as in the 2015 version). All of the 15 coldwater refuge pools identified to be protected during warm water events in the 2013draft were included in the 2015 version. There are significant differences amongst the 2013 and 2015 version protocols related to the proposed water temperature. For example, criteria proposed in 2013 are: when minimum daily water temperatures observed at Doaktown are >20 and <22C for 2 consecutive days, a closure is implemented on 15 coldwater refuge pools; when water temperature is observed between >22 and <24C for 2 days, the angling is restricted to between 5 am to 9:59 am in all waters and the pools remain closed; and when water temperatures are >24C for 2 consecutive days, then angling restrictions to the entire watershed for all species are implemented. Opening criteria use the same temperature thresholds. The largest difference in criteria between the 2013 and 2015 protocols is the removal of the fourth threshold of >24C where the entire watershed is closed. This management intervention is not in the 2015 draft as a set decision rule.

14) DFO, 2018b. Notice to Recreational Anglers for angling closure on the Margaree River (NS), August 9, 2018.

A public notice to anglers outlining the closure of portion of Margaree River to Atlantic Salmon angling due to high water temperatures. This notice altered anglers to extension of the closed area. The closure affects angling for all species in the closed area and is cited as Maritimes VO 2018-101. The closure is stated as effective from August 10th at 4:00 pm (but notice released on August 9th).

15) DFO. 2018c. Miramichi warm water closures – recent history. Fisheries and Oceans Canada, Moncton, NB. Unpublished, 3 p.

This internal document appears to have been written by DFO FHM staff and provides a history of recent salmon pool closures in the Miramichi River watershed. It is broken up into a timeline:

Before 1995

- Some ad hoc closures have occurred but have not been fully documented.

1995

- Warm summer/fall where water levels were observed to be very low, but the closures mostly resulted from issues regarding aboriginal fishing, and should not be directly attributed to the water temperature or level.
- Dungarvon and Renous (including north and south branches) rivers (closed August 9-September 28).
- The north and south branches Renous river remained closed for the season, as well as the Dungarvon upstream from Furlong Bridge)
- Northwest Miramichi and Big Sevogle rivers (closed August 10-end of season)
- Little Southwest Miramichi rivers (closed Aug 10 to 25)

The following closures were implemented between 1999 and 2011, although the decision process leading to these closures was not based on the WWP, which didn't exist at the time. Observation of distressed salmon by DFO C&P in the field, or problematic angler behaviour (jigging) was the primary trigger.

1999

- Two coldwater pool closures from July 24 to August 10, plus morning fishing only (6 a.m.-11 a.m.) from July 31 to August 10 on most rivers and tributaries of the Miramichi system.

2001

- The main river and many tributaries were closed to all angling starting August 11. From August 18, the main river and tributaries were reopened but closures were applied to some cold water pools and the whole Quarryville pool on the main Southwest Miramichi. By the end of August, most closures were lifted.

2010

- Tree coldwater pools closures occurred from July 10 till end of season. Nine additional coldwater pools closed on July 24, and reopened on July 31.

2012

- July 27 to September 3: closure of 15 cold water pools
- August 5 to 14: restriction of angling to early morning hours only (5:00 to 10:00 a.m.) in Bartholomew, Big Sevogle, Cains, Dungarvon, Little Southwest not including tributaries, Renous, North Branch Renous, South branch Renous, North Branch Southwest Miramichi, South Branch Southwest Miramichi, Main southwest Miramichi, Northwest Miramichi rivers. The previously closed 15 cold water pools remained closed
- August 15 to 25: early morning fishing only (5:00 to 10:00 a.m.) was extended to tributaries of the Little Southwest. The previously closed 15 cold water pools remain closed
- September 3 to end of season: additional closure of 3 cold water pools (Indiantown Brook, Wilson Brook and Sutherland Brook).

2013

- July 17 to July 25: closure of 22 cold water pools
- July 19 to end of season: four additional cold water pools closed (Indiantown Brook, Wilson Brook , Parks Brook and Sutherland Brook)

2015

- July 1st to end of season: closure of three cold water pools, now as per annual schedule (Indiantown brook, Wilson Brook and Sutherland Brook)

- July 14 to 17: closure of 23 additional coldwater pools
- August 17 to August 19: closure of 23 coldwater pools
- *August 20 to 24: early morning fishing only restriction (6 to 11 a.m.) on all the Miramichi rivers and tributaries. The previously closed 23 cold water pools remained closed
- August 25 to 31: closure of 23 coldwater pools (end of the 6 a.m. to 11 a.m. only restriction)

2016

- July 1st to end of season: closure of three coldwater pools closed as per schedule (Indiantown Brook, Wilson Brook and Sutherland Brook)
- July 26 to August 15: closure of 25 additional coldwater pools

16) DFO. 2019b. Protocol for In-season Conservation Measures for Atlantic salmon during Environmentally Stressful Conditions in the Miramichi Watershed (Warm water protocol) - 2019 update v6. Fisheries and Oceans Canada, Moncton, NB. Unpublished, 12 p.

The 2019 update to the WWP for the Miramichi River watershed did not result in material changes to the proposed thresholds, or criteria for closures. Rather the changes in v6 (2019) are related to the definition of the coldwater refuge pools. Additionally, in the 2015 v5 version, 26 in-season coldwater refuge pools including three seasonally closed pools are defined. Whereas in the 2019 v6 protocol, 31 pools including the three seasonal pools are defined and included in the management measures. The increase in number of protected coldwater pools was based on NGOs and stakeholder groups who have provided input into the list over the years as well as a result of "enhancement" work on coldwater pools that have enhanced the habitat capacity to function as a coldwater refuge. Much of this work was carried out by the Miramichi Salmon Association (MSA). New pools include Pat's Brook (NWM), Otter Brook (LSWM), and Hudson Brook (SWM). The definition of each pool was also updated in 2019 to reflect a definition that included bank to bank coverage so that anglers could not fish a pool from an "open" side of the bank. The 2019 version of the protocol also included maps with boundaries of the coldwater pools.

17) DFO. 2019d. Protocol for In-season conservation measures for Atlantic Salmon during Environmentally Stressful Conditions in the Margaree River (Warm Water protocol) – May 2019. Fisheries and Oceans Canada, Moncton, NB. Unpublished, 17 p

Document outlines the WWP for the Margaree River (Nova Scotia) developed in partnership with DFO, NS Department of Fish and Aquaculture, Margaree Salmon Association, Nova Scotia Salmon Association, and Atlantic Salmon Federation. The management files for this protocol included versions 1 through final (v6) across a time frame from Nov 2018 to June 2019. Each version is not described here but significant changes are noted. The protocol was developed in response to increasing low water and high temperatures events in the Margaree River, resulting in angling closures in 2018. The protocol is based on existing knowledge of Atlantic Salmon biology and physiology and the Miramichi River WWP. The Margaree River consists primarily of a Northeast and Southwest branch. They merge approximately 15 km from the ocean. In November 2018, the proposed river sections where in-season management actions would occur during environmentally stressful conditions were proposed as: 1) the "lower" sections of the river including water below Doyle's Bridge (NE branch) , 2) below Creamery Bridge (SW branch) and the Gallant River below the East Margaree Bridge. 3) The "upper sections" were defined as above Doyle's Bridge up to the Cemetery Bridge (NE branch). Water temperature monitoring data to inform closures are to be collected from stations below the Forks (NE / SW merge). If closure conditions are met, DFO will discuss the weather forecast and water level with the Margaree River warm water committee and if in agreeance (e.g., not likely to be a short-term closure) a variation order will be developed and issued. A full business day is required between committee agreement and notice to anglers of a closure. The document notes that it was debated among the committee whether or not the SW branch should be considered for closures during warm water events because it is generally warmer than the NE branch. The initial protocol proposed using a 48 hour below (opening) or above (closing) 20C as threshold for management actions. Comments received on earlier drafts of the protocol asked what criteria (e.g., temperature threshold) would be used to implement morning fishing only restrictions and the role of DFO C&P on the river. A February 4 2019 draft utilized large portions of the Miramichi WWP and adapted language and location information to the Margaree River. It was noted that a description of the temperature profile of the Margaree River is required as well as the location of Margaree water temperature monitoring station. The proposed closing criteria in protocol dated February 4, 2019 is: < 20C maintain access to river, > 20C for 48 hours (and unfavorable forecast, low water and fish aggregating at Gallant River pool) = closure to angling for all species in lower sections of the river and in SW branch, >23 C for 48 hours = maintain closures in lower sections and SW branch and additional close upper sections of NW Margaree River. Opening criteria consisted of observed water temperatures where < 23C twice in 48 hour period = open upper NE sections, and < 20C twice in 48 hours = open lower sections of the river. Significant changes in the March 7th 2019 version of the draft protocol include removal of text referring to angling success during warm water periods where it was noted that the original Miramichi version may have mis-interpreted science advice confounding angling success and mortality. The March 7th 2019, draft proposed three river management sections: 1) from East Margaree high bridges upstream to Creamery Bridge on SW; upstream to Doyle's bridge on the NE; the Gallant River upstream from confluence with Margaree to highway bridge on East Margaree Road, 2) Doyle's bridge upstream to Big Interval Bridge on NE Maragree River, and 3) SW Maragree upstream from Cabot Trail Bridge (Creamery Bridge) to Scottsville Bridge. Also proposed monitoring station was upstream in river section 1. It was noted that the protocol should explicitly state when consultation will start with committee members (e.g., when one day of >20C daily minimum water temperature, T_{min}, has occurred) with respect to implementing a closure. This draft also removed the "twice during 48-hour period" from re-opening requirements and just simply stated that daily minimum temperature must be below 23C or 20C for two consecutive days to trigger reopening. Closure criteria in the March 7th 2019 draft was proposed as: when T_{min} is < 20C maintain access in all river sections; when T_{min}>20C or 2 days = close angling for all species in sections 1 and 3; and when T_{min} >23 C for 2 days = maintain section 1 and 3 closures and implement closures in section 2. This version of the protocol is very nearly identical to the final draft, with minor changes, but not that effected the criteria for closure.

18) DFO. 2019e. Nepisiguit River strategy for managing angling in period of warm water in 2019 - June 2019. Fisheries and Oceans Canada, Moncton, NB. Unpublished, 5 p.

This document outlines an interim 2019 warm water strategy for the Nepisiguit River developed in partnership with DFO, Nepisiguit Salmon Association, and Atlantic Salmon Federation. The management files for this protocol includes version 1 through final (v3) across a time frame from April to June 2019. The strategy outlines management actions to be taken if/when warm water / environmental stressful events occur in the Nepisiguit River in the summer of 2019. It is to be reviewed at the end of summer 2019 and adapted if needed for future seasons. Similar to other river WWPs, this strategy provides an overview of salmon thermal tolerances and introduces the concept of incipient lethal, critical, and optimal temperatures for Atlantic Salmon. In the April 2019 draft, the area covered by the management strategy is proposed as: "For 2019, and until more detailed information is known on the temperature regime of the Nepisiguit river, the entire portion of the river used by salmon will be subject to potential restrictions. In Gulf Variation Orders it is described as ‘Nepisiguit River from the dam at Grand Falls downstream to the mouth’. " The Nepisiguit Salmon Association will monitor water temperature daily and report to DFO. During warm water events the Pabineau First Nation will also monitor temperature daily at the counting fence. When temperatures approach and exceed temperature thresholds, water level and forecast will also be monitored daily. However, water temperature is the primary factor considered when making closure and opening decisions on the Nepisiguit River. Prior to implementation or removal of management actions a conference call will be held with PFN, DFO, NSA, and the province of NB, with a final decision made by DFO. Closure criteria are proposed as: 1) when T_{min} < 20C = maintain access to river with normal angling rules, 2) when T_{min} >20C for 48 hours = implement morning angling only (6 - 11 am) in the Nepisiguit River from the dam at Grand falls downstream to the mouth, and 3) when T_{min} >23C for 48 hours = implement a full closure for fishing for all species in the river from the dam at Grand Falls to the mouth. In a June 5 version of the strategy both NSA and PFN committed to provide daily water temperature readings: the NSA at

3 locations, and PFN at the counting fence. Because the thermal profile of the Nepisiguit is not well understood due to limited historical monitoring, the partners of this strategy agree that T_{min} will be assessed as the average of the 4 temperature monitoring stations. There is no real-time water level monitoring on the Nepisiguit and so observations will be made manually by the NSA and PFN and communicated to DFO. A June 5th version of the protocol has only one material change to the closure/opening criteria which is that T_{min} is defined as the mean T_{min} over a 48 hour period from 4 monitoring stations. In a June 10th version of the strategy it is stated that a conference call with the warm water committee would occur 24 hours after T_{min} >20C.

19) DFO. 2019f. Gulf Region / Restigouche River strategy for managing angling in periods of warm waters in 2019 – June 2019. Fisheries and Oceans Canada, Moncton, NB. Unpublished, 8 p.

A draft warm water strategy for the Restigouche River that was submitted for discussion on interim measures to be implemented in 2019. A discussion between DFO, the provinces of New Brunswick and Quebec, and the Restigouche Watershed Management Council occurred in late 2018 after warm water periods were observed that summer. The strategy was to be reviewed after the 2019 summer season. The area to be managed under the strategy in the Restigouche river is defined based on existing, limited thermal information. Monitoring efforts will be increased to better understand priority areas for management (e.g., warmest) in the watershed in the future. For 2019, the sections of the river believed to experience the warmest water temperatures are the focus o the strategy. The managed area of the river proposed in the strategy is: 1) below the mouth of the Kedgwick River downstream towards the boundary of tidal waters located at the Canadian National Railway (CN) bridge, which is located below the confluence of the Restigouche and Matapedia Rivers, 2) the Upsalquitch River from the confluence with the main Resitgouche channel upstream to the forks; however, this sections is less likely to face warm water conditions but is included because there is a real time temperature station on the river. The strategy notes that further information is required to determine if sections 1 and 2 of the river should be further divided for management purposes and that the definitions will be reviewed with an increase in data. During periods of warm weather and low water conditions, water temperature will be monitored daily using real time loggers. Loggers are found at the mouth of the main Restigouche River below the mouth of the Kedgwick River (on the opposite bank of the confluence to avoid cold water outflow from the Kedgwick). Another logger was to be installed in the Main Restigouche in 6-mile Brook area. A final logger will be placed in the Upsalquitch River downstream from the forks. In 2019, the average of the two T_{min} records from both loggers will be used as a management threshold for management interventions in the main section of the Restigouche river. It is stated that the utility of using T_{min} as an average from several loggers would be reviewed following the summer of 2019. Environment Canada has two real time water level monitoring stations on the Restigouche river and water level will be considered along with the weather forecast when temperature thresholds are breached. DFO will organize a conference call between Province of NB, GMRC, and the Restigouche River Watershed Management Council after 24 hours of water temperatures exceeding 20C. Final management action decisions will be made by DFO. The proposed closure criteria are: 1) T_{min} < 20C = maintain access to river with normal angling rules, 2) T_{min} >20C for 48 hours = implement morning angling only (6 - 11 am) in the main Restigouche River, 3) T_{min} >23C for 48 hours = implement a full closure for fishing for all species in the Main Restigouche River.

20) DFO. 2020. DRAFT - Integrated Fisheries Management Plan. Atlantic Salmon in Salmon Fishing Areas 15 to 18, Version 14. Fisheries and Oceans Canada, Moncton, NB. Unpublished, 62 p.

Integrated Fisheries Management Plan for Atlantic Salmon, version 14, being developed by DFO Gulf Region in the winter of 2020 is summarized here. This is a draft document and objectives and priorities described may change. The initial pages of the report go through the existing committees, the history of human interaction with Atlantic Salmon, and introductory material (life stage, range, habitat requirements, etc). The IFMP outlines that index rivers for estimating salmon abundance in the Gulf Region are the Restigouche River (SFA 15A), Northwest Miramichi River (SFA16A), Southwest Miramichi River (SFA 16A) and Margaree River (SFA 18B). The plan reports that in 2015 an estimated 90% of all salmon anglers were from NB and spent ~ $ 20M on recreational fishing. Non-resident anglers made up 10% and contributed $4 M. Objectives related to ecosystem restoration and management are also provided, including implementation of WWP. Harvest decision rules are not in effect because the entire Gulf Region operates under a catch-and-release only model; however, since 2017 river specific management plans have been in development that outline specific harvest rules for each river/watershed in the plan that relates to daily and season catch limits. The WWP was applied in the Miramichi beginning in 2015; and starting in 2019 in the Margaree River (Cape Breton).

21) Lavoie, C. 2017. “RE: Decision needed - Cold water pool closure”. Message to Mark Hambrook of the Miramichi Salmon Association and Frederic Butruille of DFO. July 18, 2018. Email.

Cecile Lavoie of DFO FHM asked Mark Hambrook of the MSA to provide a recommendation on closing the salmon pools on the Miramichi on the eve of July 18. Debbie Norton of the Miramichi Watershed Management Committee (MWMC) had not yet replied with her recommendation. The MWMC asked about the temperature in the pools but did not elaborate on a recommendation. Similarly, DFO C&P suggested salmon were beginning to aggregate in pools, but that aggregations had not reached a critical stage and did not provide recommendation on whether or not to close the pools. Cecile noted that if the pools were to close at midnight on the 18th, they would remain closed throughout the weekend and into the next week (Mon-Tuesday) due to two night T_{min} <20C requirement and processing time. Mark replied keeping the pools closed until Saturday sounded reasonable for the salmon, but lamented that administration takes time and the public does not support a delay in opening (e.g., if closure goes until Saturday it would be at least Tuesday before a re-opening could occur, regardless of conditions). Given that he suggested not closing the pools and “waiting it out” to ensure angling continued. Cecile informed Frederic that based on internal discussions, management agreed to leave the pools open for the weekend despite water temperatures exceeding the WWP threshold (20C).

22) Reid, J., Couturier, G., Hambrook, M., Gillespie, G., Whitty, B., and Sturgeon, K. 2011. Development of the thermal management plan for the Miramichi - Development of Thermal Scenarios. Miramichi Salmon Association. South Esk, NB. Unpublished, 11 p.

This document was developed by the Miramichi Salmon Association (MSA) and presented to DFO FHM at a November 2011 stakeholder meeting. The MSA developed a predictive water temperature model to inform in-season management restrictions for Atlantic Salmon on the Miramichi River during warm water events. The model was created using water temperature and air temperature to predict "water temperature tomorrow" based on water temperature of the current day, and forecasted air temperature for the following day ("air temperature tomorrow"). The model was created using water temperature data from 2006-2011 (expect 2008), and considering Julien day, humidity, precipitation, daily min/max water temp, and daily min/max air temp in a regression analysis. Explicitly, the model uses predicted water temp tomorrow = 0.0360 + (0.189 * Forecasted air temp tomorrow) + (0.829 * Actual water temp today), the R2 of the equation was 0.896. The model can be run iteratively to build a weekly forecast (e.g., figure out tomorrow's temperature and put it in as "actual water temp today" and use the subsequent day's air temp predictions). The model can be used to understand if management triggers are exceeded and forecast for potentially how long the situation will last (up to the last reliable day of a weather forecast ~ 4 days). The report also presents a thermal map of the Miramichi based on DFO and MSA 2011 data from 28 temperature loggers placed in the main stem of the rivers, away from cold water inputs. Temperature logger data was correlated with ECCC's water monitoring station at Doaktown and the regression results were then used to estimate water temperature at other locations, assuming Doaktown temperature was measured at 23C. The resulting points were used to create a rough map of the Miramichi River with two zones, Zone 2 = upstream cooler tributaries, and Zone 1 = downstream warmer tributaries (less than -2C difference to +2C difference from Doaktown at 23C). The MSA proposed four management actions to protect salmon during warm water events based on this report and when forecasted water temperatures meet action thresholds for four days:

i) Close Indiantown Brook, Wilson's Brook and Sutherland Brook annually on July 1
ii) When forecasted average daily water temp > 22C at Doaktown for four days: Close 12 lower river pools and angling must take place with barbless hooks and live release limit of 1 fish per day. Pools = Buddie's Brook, Salmon Brook Pool, Mill Brook at Pumphouse Pool, Grey Rapids Pool, Morse

Pool, Donnelly Brook Pool, Bett's Mills Brook, Porquepine Pool, Little Otter Brook at Brophy Pool, Big Hole Brook, and Black Brook pool.

iii) When forecasted average daily water temp > 23C at Doaktown for four days: Morning fishing only in zone 1 from sunrise to 11 am, with barbless hooks and one live release per day limit

iv) When forecasted average daily water temp > 25C at Doaktown for four days: Total closure of Miramichi watershed for fishing of any species

The report provides a summary table of when different management actions would be triggered based on observed water temp at Doaktown, with predicted air temp and water temp. The report also summarizes how many days of closures (pools and total closures) would have occurred between 2006-2011 based on above thresholds (and illustrated with higher and lower thresholds).

APPENDIX 2:

Summary of coldwater refuge pools protected in 2019 under the Warm Water Protocol for the Miramichi River (DFO 2019b, Appendix 1).

Northwest Miramichi River

Sutherland Brook (Annual closure beginning July 1)

The waters of the Northwest Miramichi River inside a line drawn from a point on land at grid reference 285336E 5202332N located approximately 100 meters upstream from the mouth of Sutherland Brook, then across to the north side of the river at grid reference 285560E 5202535N then downstream from grid reference 285719E 5202415N to grid reference 285505E 5202205N located approximately 100 meters downstream from the mouth of Sutherland Brook and Sutherland Brook upstream to the Highway 420 bridge. (North American Datum 1983).

Wilson Brook (Annual closure beginning July 1)

A portion of the waters of the north side of the Southwest Miramichi River inside a line drawn from a point on land at grid reference 298589E 5196806N located approximately 100 meters downstream from Wilson Brook, southward to grid reference 298667E 5196744N and upstream to grid reference 298518E 5196616N and northward to grid reference 298437E 5196676N located on land approximately 100 meters upstream from Wilson Brook and including the waters of Wilson Brook upstream 100 meters of its mouth, an area locally known as the Bear Den. (North American Datum 1983).

Quarryville and Indian Town Brook (Annual closure beginning July 1)

The waters of the Southwest Miramichi River inside a line drawn from a point on land at grid reference 287787E 5189991N located approximately 300 meters downstream from Quarryville Bridge across to the north side of the river at grid reference 287692E 5190123N upstream to grid reference 287239E 5189734N and to grid reference 287361E 5189590N located approximately 300 meters upstream from Quarryville Bridge and Indian Town Brook upstream to highway 108 bridge. (North American Datum 1983).

Wildcat Brook

The waters of the Northwest Miramichi River area located at the mouth of Wildcat Brook including a portion of the said brook. This specific area consist of a portion of the Northwest Miramichi River inside a line drawn from (1) 47.000480, -65.8298870 to (2) 47.000430, -65.829030; then to (3) 46.999130, -65.828810; to (4) 46.998660, -65.830280; to (5) 47.000120, -65.831040 and then to (6) 47.000480, -65.829870. (North American Datum 1983).

Trout Brook

The waters of the Northwest Miramichi River area located at the mouth of Trout Brook and including a portion of the said brook. This specific area consists of a portion of the Northwest Miramichi River inside a line drawn from (1) 47.094440, -65.836300; to (2) 47.093860, -65.835850; then to (3) 47.092760, -65.835850 to (4) 47.092760, -65.836940; and then to (5) 47.094310, -65.837300. (North American Datum 1983).

Pat's Brook

The waters of the Northwest Miramichi River in Wayerton, located at the mouth of Pat's Brook and including a portion of the said brook. This specific area consists of a portion of the Northwest Miramichi River inside a line drawn from (1) 47.157920, -65.831090 to (2) 47.156390, -65.830860; then to (3) 47.156480, -65.831540 to (4) 47.157310, -65.832650; and then to (5) 47.157730, -65.832270. (North American Datum 1983).

Little Southwest Miramichi River

Harris Brook

The waters of the Little Southwest Miramichi River area located at the mouth of Harris Brook and including a portion of the said brook. This specific area consist of a portion of the Little Southwest Miramichi River inside a line drawn from (1) 46.899000, -65.983680; to (2) 46.898490, -65.982390; then to (3) 46.897450, -65.983290 to (4) 46.897420, -65.984250; then to (5) 46.897750, -65.984820 and to (6) 46.898380, -65.984520. (North American Datum 1983).

Parks Brook

The waters of the Little Southwest Miramichi River area located at the mouth of Parks Brook and including a portion of the said brook. This specific area consists of a portion of the Little Southwest Miramichi River inside a line drawn from (1) 46.896300, -66.146360; to (2) 46.895320, -66.145140; then to (3) 46.894660, -66.145710 to (4) 46.895020, -66.147740; and then to (5) 46.895940, -66.147400. (North American Datum 1983).

Otter Brook

The waters of the Little Southwest Miramichi River area located at the mouth of Otter Brook and including a portion of the said brook. This specific area consists of a portion of the Little Southwest Miramichi River inside a line drawn from (1) 46.541760, -66.186060 to (2) 46.538810, -66.183290; then to (3) 46.538530, -66.183760 to (4) 46.538160, -66.188560; and then to (5) 46.540100, -66.190240. (North American Datum 1983).

Southwest Miramichi River

Gray Rapids Brook

The waters of the Southwest Miramichi River area located at the mouth Gray Rapids Brook and including a portion of the said brook, locally known as Pete brook. This specific area consists of a portion of the Southwest Miramichi River inside a line drawn from (1) 46.778620, -65.755930 to (2) 46.778430, -65.754390; then to (3) 46.776210, -65.753750 to (4) 46.776080, -65.753940; and then to (5) 46.777280, -65.756390. (North American Datum 1983).

Hudson Brook

The waters of the Southwest Miramichi River area located at the mouth of Hudson Brook and including a portion of the said brook. This specific area consists of a portion of the Southwest Miramichi River inside a line drawn from (1) 46.754160, -65.815750 to (2) 46.753100, -65.815010; then to (3) 46.752430, -65.817000 to (4) 46.753410, -65.817690; and then to (5) 46.754040, -65.817440. (North American Datum 1983).

Bartholomew River

The waters of the Southwest Miramichi River located at the mouth of Bartholomew River and including a portion of the said river. This specific area consists of a portion of the Southwest Miramichi River inside a line drawn from (1)46.753280, -65.825290 to (2) 46.741090, -65.825560; then to (3) 46.737990, -65.830320 to (4) 46.738760, -65.830670; and then to (5) 46.743420, -65.826940. (North American Datum 1983).

Mersereau's Brook

The waters of the Southwest Miramichi River area located at the mouth of Mersereau Brook and including a portion of the said brook. This specific area consists of a portion of the Southwest Miramichi River inside a line drawn from (1) 46.707990, -65.809990 to (2) 46.706910, -65.808430; then to (3) 46.706040, -65.809700 to (4) 46.705970, -65.810200; and then to (5) 46.707020, -65.811270. (North American Datum 1983).

Morse Brook

The waters of the Southwest Miramichi River area located at the mouth of Morse Brook and including a portion of the said brook. This specific area consists of a portion of the Southwest Miramichi River inside a line drawn from (1) 46.705150, -65.784350 to (2) 46.704770, -65.781910; then to (3) 46.701410, -65.782550 (4) 46.701400, -65.782770; and then to (5) 46.703910, -65.784540. (North American Datum 1983).

McKenzie Brook

The waters of the Southwest Miramichi River area located at the mouth of McKenzie Brook and including a portion of the said brook. This specific area consists of a portion of the Southwest Miramichi River inside a line drawn from (1) 46.700890, -65.773220 to (2) 46.700590, -65.772120; then to (3) 46.699700, -65.771740 to (4) 46.698960, -65.773020 and then to (5) 46.700050, -65.774490. (North American Datum 1983).

Black Brook

The waters of the Southwest Miramichi River area located at the mouth of Black Brook and including a portion of the said brook. This specific area consists of a portion of the Southwest Miramichi River inside a line drawn from (1) 46.671200, -65.775600 to (2) 46.670760, -65.774460; then to (3) 46.668800, -65.772960 to (4) 46.668610, -65.773060; and then to (5) 46.669880, -65.776730. (North American Datum 1983).

Donnelly Brook

The waters of the Southwest Miramichi River area located at the mouth of Donnelly Brook and including a portion of the said brook. This specific area consists of a portion of the Southwest Miramichi River inside a line drawn from (1) 46.608390, -65.893110 to (2) 46.608120, -65.890600; then to (3) 46.604950, -65.890640 to (4) 46.604450, -65.891110; and then to (5) 46.605200, -65.894390. (North American Datum 1983).

Bett's Mill Brook

The waters of the Southwest Miramichi River area located at the mouth of Betts Mill Brook and including a portion of the said brook. This specific area consists of a portion of the Southwest Miramichi River inside a line drawn from (1) 46.541760, -66.186060 to (2) 46.538810, -66.183290; then to (3) 46.538530, -66.183760 to (4) 46.538160, -66.188590; and then to (5) 45.540100, -66.190240. (North American Datum 1983).

Mill Brook

The waters of the Southwest Miramichi River area located at the mouth of Mill Brook and including a portion of the said brook. This specific area consists of a portion of the Southwest Miramichi River inside a line drawn from (1) 46.578510, -66.016130 to (2) 46.576250, -66.016080; then to (3) 46.576250, -66.018710 and to (4) 46.578540, -66.018670. (North American Datum 1983).

Big Hole Brook

The waters of the Southwest Miramichi River area located at the mouth of Big Hole Brook and including a portion of the said brook. This specific area consists of a portion of the Southwest Miramichi River inside a line drawn from (1) 46.548180, -66.179410 to (2) 46.548170, -66.178900; then to (3) 46.547030, -66.177820 to (4) 46.54280, -66-179950; then to (5) 46.546210, -66.179950 and to (6) 46.547410, -66.180170. North American Datum 1983).

Porcupine Brook

The waters of the Southwest Miramichi River located at the mouth of Porcupine Brook and including a portion of the said brook. This specific area consists of a portion of the Southwest Miramichi River inside a line drawn from (1) 46.533500, -66.258030 to (2) 46.524800, -66.257920; then to (3) 46.524440, -66.259860 to (4) 46.526550, -66.261300; and then to (5) 46.532960, -66.274850. (North American Datum 1983).

Doak Brook

The waters of the Southwest Miramichi River in the Doaktown area located at the mouth of Doak Brook and including a portion of the said brook. This specific area consists of a portion of the Southwest Miramichi River inside a line drawn from (1) 46.560270, -66.121080 to (2) 46.559090, -66.121550; then to (3) 46.558650, -66.123310 to (4) 46.559370, -66.123700; and then to (5) 46.560650, -66.123280. (North American Datum 1983).

Burnt Land Brook

The waters of the Southwest Miramichi River area located at the mouth of Burnt Land Brook and including a portion of the said brook. This specific area consists of a portion of the Southwest Miramichi River inside a line drawn from (1) 46.461240, -66.413030 to (2) 46.460470, -66.410000; then to (3) 46.460120, -66.410310 to (4) 46.459850, -66.413060; and then to (5) 46.460220, -66.413730. (North American Datum 1983).

Renous River

Old Pump House

The waters of Renous River area located at the pump house. This specific area consists of a portion of the Renous River inside a line drawn from (1) 46.808610, -65.804820 to (2) 46.808110; -65.804280 then to (3) 46.807200, -65.806030 and to (4) 46.807620, -65.806540. (North American Datum 1983).

Butty's Brook

The waters of the Renous River area located at the mouth of Butty's Brook and including a portion of the said brook, area locally known as Duffy's Brook. This specific area consists of a portion of the Renous River inside a line drawn from (1) 46.802540, -65.862080 to (2) 46.802020, -65.861960; then to (3) 46.800970, -65.863260; to (4) 46.800990, -65.863590; then to (5) 46.802090, -65.864310; and to (6) 46.802630, -65.864050. (North American Datum 1983).

Cains River

Otter Brook

The waters of Cains River area located at the mouth of Otter Brook and including of the said brook, this is also locally known as Brophy's Place. This specific area consists of a portion of the Cains River inside a line drawn from (1) 46.643420, -65.756890 to (2) 46.642980, -65.756300; then to (3) 46.642640, -65.756230 to (4) 46.642030, -65.758100; and then to (5) 46.642520 to -65.758540. (North American Datum 1983).

Cold Brook

The waters of the Cains River area located at the mouth of Cold Brook and including a portion of the said brook. This specific area consists of a portion of the Cains River inside a line drawn from (1) 46.614460, -65.710590 to (2) 46.613300, -65.709830; then to (3) 46.612830, -65.710800 to (4) 46.612980, -65.711720; and then to (5) 46.614360, 65.711550. (North American Datum 1983).

Salmon Brook

The waters of Cains River area located at the mouth of Salmon Brook and including a portion of the said brook. This specific area consists of a portion of the Cains River inside a line drawn from (1) 46.607100, -65.709370 to (2) 46.606690, -65.705970; then to (3) 46.606540, -65.706080 to (4) 46.605610, -65707370; to (5) 46.604650, -65.710780 to (6) 46.605330, -65.713150 and then to (7) 46.606900, -65.711240. (North American Datum 1983).

Muzzroll Brook

The waters of the Cains River area located at the mouth of Muzroll Brook and including a portion of the said brook. This specific area consists of a portion of the Cains River inside a line drawn from (1) 46.530720, -65.852620 to (2) 46.530160, -65.851590; then to (3) 46.528940, -65.852730 to (4) 46.529540, -65.854050; to (5) 46.530160, -65.854360 to and then to(6) 46.530330, -65.854200. (North American Datum 1983).

Six Mile Brook

The waters of the Cains River area located at the mouth of Six Mile Brook and including a portion of the said brook. This specific area consists of a portion of the Cains River inside a line drawn from (1) 46.510360, -65.855590 to (2) 46.509970, -65.855000; then to (3) 46.508960, -65.855870 to (4) 46.509170, -65.857060; and then to (5) 46.509560, -65.857240. (North American Datum 1983)