Risky Refugia? Effects of Aquatic Invasive Species on Cold-Water Refugia Use by Juvenile Atlantic Salmon (*Salmo salmar*)

By

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Project Original Goals and Plans

The initial objective of this project was to explore the effects of aquatic invasive species on the habitat utilization and behavior of juvenile Atlantic salmon and brook trout (age 1-2+) within identified cold-water refugia. Throughout the summer of 2022, our plan involved sampling the LaHave watershed in Nova Scotia to 1) identify cold-water anomalies; 2) confirm sites serving as cold-water refugia; and 3) characterize habitat within and around thermal refugia identified. For the subsequent year, in 2023, we aimed to deploy underwater video cameras and acoustic telemetry within the cold-water refugia identified in the summer of 2022. The deployment of acoustic telemetry gear was intended to track and compare the occupancy and residency of smallmouth bass, Atlantic salmon, and brook trout within thermal refugia. Additionally, we intended to deploy underwater video cameras to assess the abundance of smallmouth bass and investigate the fine-scale behaviors of juvenile Atlantic salmon and brook trout in response to habitat use and abundance of smallmouth bass. Our overarching goal was to utilize this data to describe the habitat use of thermal refugia by aquatic invasive species, specifically smallmouth bass, and examine the concomitant effects on the habitat use and behaviors of juvenile Atlantic salmon and brook trout utilizing these habitats for thermoregulation.

Project Completion to Date, Achievements and Developments

LaHave

In the summer of 2022, we prioritized sites that would be surveyed for the identification of cold-water refugia. Sites were selected using existing temperature data from HOBO loggers deployed by the Nova Scotia Salmon Association (NSSA), ArcGIS flow accumulation layer, satellite imagery of areas that indicated alcoves or channels, and local community members and anglers. This work identified 13 potential sites, from the bottom of New Germany Lake to North King Street Bridge, that would be surveyed for cold-water anomalies.

On-site surveys were conducted using a combination of infrared imagery by drone flights and thermistor probes along lengths of the river that spanned approximately 2-25 km upstream and downstream from the sites selected. Kathryn Smith, contracted by the NSSA, was our drone operator and completed drone flights at 6 of the 13 sites. As drone flights only capture the surface water temperature, Kristen Cyr surveyed all 13 sites by walking in a criss-cross pattern through the river with a thermistor probe to identify temperature at various depths.

Despite identifying two sites that were cold-water anomalies, these sites did not meet the criteria for the project (i.e., appropriate depth and width of river for acoustic telemetry; and low dissolved oxygen, indicative of unsuitable salmonid habitat). As a result, we focused our efforts on the Margaree River, Cape Breton, Nova Scotia. This watershed was chosen given the recent increasing distribution of invasive smallmouth bass, presence of Atlantic salmon, and recorded high temperatures in the Southwest which would trigger the need for thermoregulation in cold-water refugia by salmonid species.

Margaree

Site Selection, Survey, & Cold-water refugia Identification

Since moving our efforts to the Margaree, this project has been successful in 1) sampling and characterizing water quality parameters throughout the Southwest Margaree; 2) identifying cold-water anomalies and cold-water refugia; 3) building relationships with local rightsholders and stakeholders for co-production; and 4) determining effective gear types and deployment methods for use in the summer of 2024. Using the same methods applied in the summer of 2022 to prioritize sites, we identified 13 potential sites for temperature surveys (Fig. 1). However, it was local rightsholders and stakeholders, and the ArcGIS accumulation layer that led to the identification of all 13 sites, as HOBO logger data did not record any cold-water anomalies and satellite surveys did not identify suitable alcoves or channels.

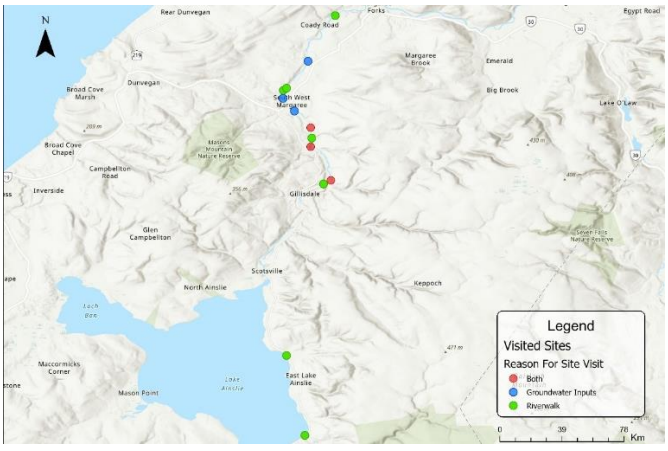

Figure 1 Sites throughout the Southwest Margaree that were selected for temperature surveys as a result of local rightsholder and stakeholder knowledge (riverwalk; green), ArcGIS accumulation layer (groundwater inputs; blue), or both (red).

Of the 13 sites, we opted to sample 11, excluding the two sites within the tributaries that flowed into Lake Ainslie (Fig. 1; Fig. 2). This decision was due to the improbable likelihood of juvenile

Atlantic salmon utilizing cold-water refugia within a lake, and therefore both detections and camera observations would be limited (pers. Comm. Edmund Halfyard). Sites were sampled to characterize water quality characteristics using a YSI (Fig. 2). Notably, sites were not uniformly sampled in terms of frequency or timing, as the YSI was borrowed from the Atlantic Water Network, constraining the sampling schedule. All 11 sites were also surveyed to identify cold-water anomalies through drone flights equipped with infrared imagery (Fig. 3). Additionally, four of these sites were sampled using underwater cameras to validate the aggregation of salmonids during warm temperature events (Fig. 3).

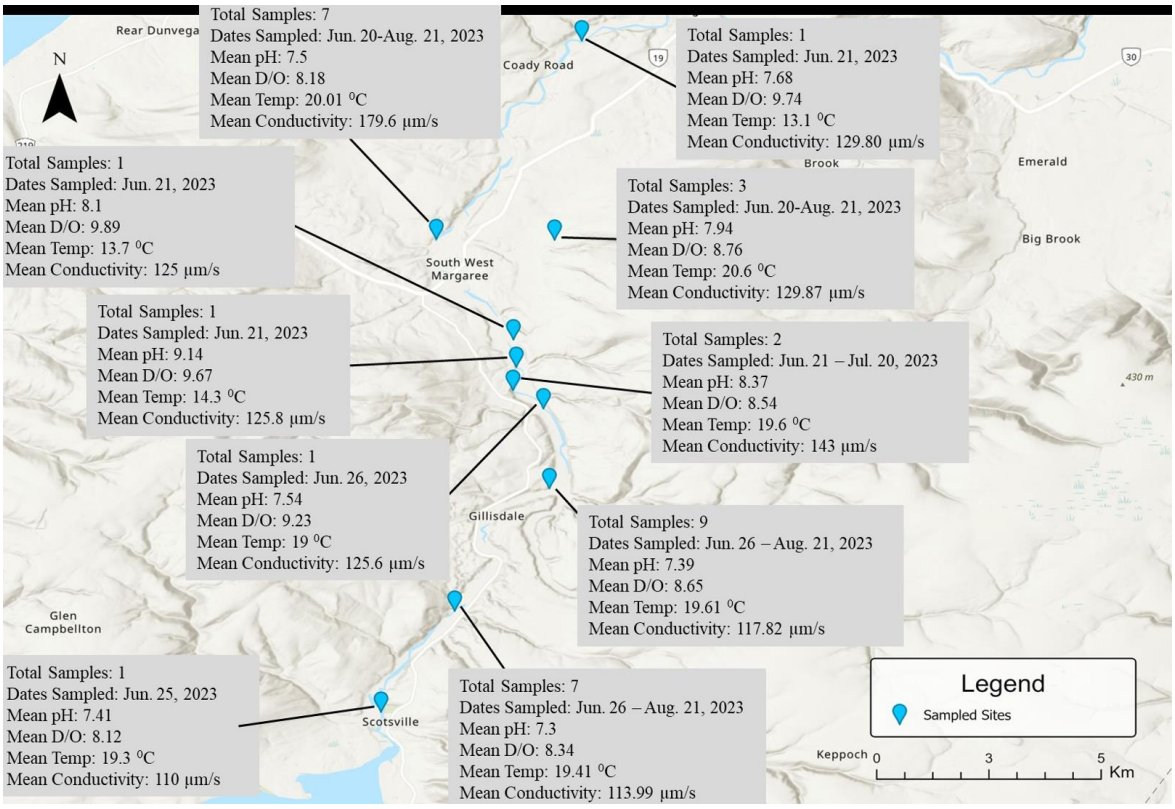

Figure 2 Sites sampled for cold-water refugia and water quality characteristics throughout the southwest Margaree from June to August 2023. Sites were sampled a different number of times (total samples), and throughout different periods (dates sampled). Mean values are calculated for the dates sampled at each site, and therefore not suitable for comparison across sites.

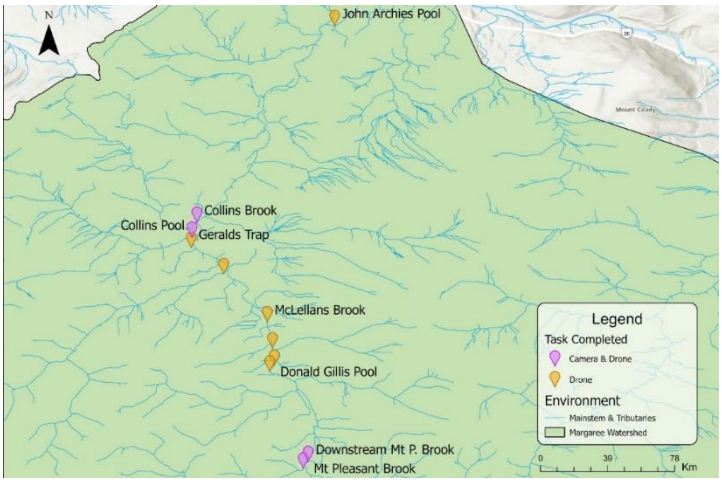

Figure 3 Sites that were identified through riverwalks and local knowledge, and subsequently surveyed to identify cold-water refugia using drone flights (orange), and at some sites also deploying underwater cameras (purple).

Drone flights verified the presence of two cold tributary plumes that could potentially serve as cold-water refugia (Fig. 4). However, YSI surveys (not depicted in Fig. 2) confirmed that only one of the two sites exhibited suitable characteristics for Atlantic salmon. Collins Brook was one of the cold tributaries, but it was recently dammed by a beaver, resulting in low dissolved oxygen levels at the site. Furthermore, the deployment of cameras at this site did not reveal any aggregations of fish. In contrast, at Mount Pleasant Brook, cameras successfully identified salmonid species utilizing the tributary plume, which had suitable habitat characteristics for salmonid species (Fig. 5). Upon confirmation of the cold-water refugia, HOBO loggers were deployed inside and outside the tributary plume, which showed nearly 3 degrees difference in the average and maximum temperature for July (Fig. 5; Table 1). Additionally, despite the HOBO logger outside the tributary plume recording temperatures greater than 23 ^{0}C for a quarter of the month, the temperatures inside the plume were above 23 ^{0}C for less than 1% of the time in July (Table 1).

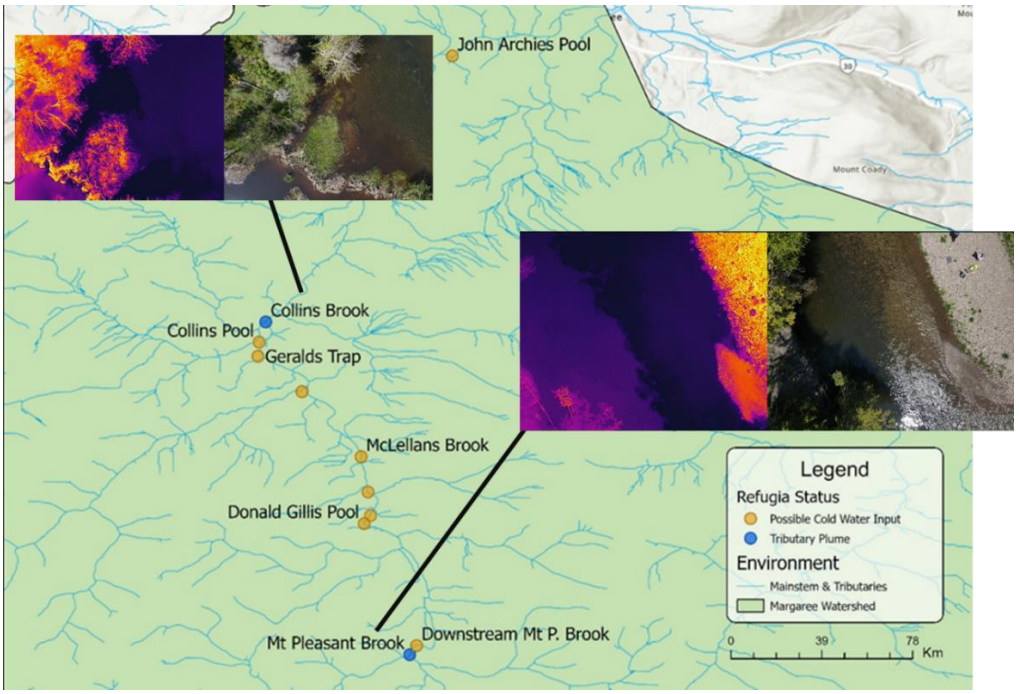

Figure 4 Characterization of cold-water anomalies using drone- and walking river surveys with YSI at the 11 selected sites. The results of infrared imagery included for sites that were identified as tributary plumes.

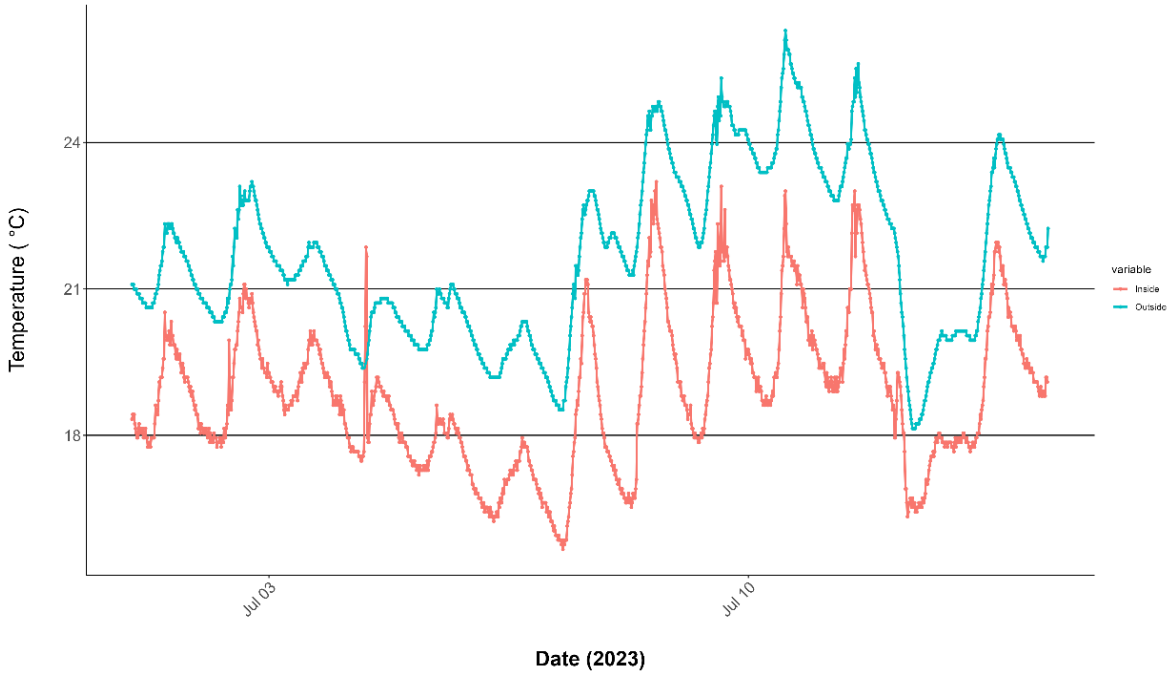

Figure 5 Temperature results collected from HOBO loggers that were deployed inside (pink), and outside (blue) of a tributary plume at Mount Pleasant Brook, Southwest Margaree, during July 2023.

Table 1 Summary of temperature recorded with HOBO loggers that were deployed inside and outside a tributary plume at Mount Pleasant Brook, Southwest Margaree for July 2023. SD is the standard deviation, Max is the maximum temperature recorded, and Proportion >X is the proportion of the month spent above 20 ^{0}C or 23 ^{0}C.

Location	Average	SD	Max	Proportion > 20 ^{0}C	Proportion > 23 ^{0}C
Inside	18.83	1.52	23.20	21.11	0.39
Outside	21.71	1.76	26.29	81.32	26.93

Co-production

Throughout the summer, we actively collaborated with local rightsholders and stakeholders in co-producing the project. Our engagement encompassed participation in river walks, local events, lunch meetings, and the facilitation of a workshop. These activities proved instrumental in establishing meaningful relationships with key partners, such as the Margaree Salmon Association, Cheticamp River Salmon Association, Department of Oceans and Fisheries, Unama'ki Institute of Natural Resources, Nova Scotia Department of Fisheries and Aquaculture, local Gaspereau Fishers, Atlantic Salmon Federation, and community anglers. The cultivation of these relationships played a pivotal role in shaping the project in alignment with shared values among all partners, leading to adjustments in methods and the inclusion of additional species, such as brown trout. The collective contributions aimed to yield more impactful outcomes, enhancing the project's applicability to Atlantic salmon conservation.

Troubleshooting gear

This summer, we conducted a successful range test of the acoustic receivers at our site. While additional testing is still required, Innovasea has expressed confidence in using a more fine-scale tracking approach. Therefore, if our second round of range testing is successful, instead of tracking residency and occupancy we plan to monitor overall space use of juvenile Atlantic salmon, brown trout, and smallmouth bass, which can show us where in the thermal refugia species are occupying and how much space within the cold-water refugia they occupy. This is in contrast to occupancy and residency which is limited in fully characterizing the habitat use.

Camera arrays were also tested to determine the most effective deployment of cameras for capturing species behaviors within cold-water refugia, maximizing coverage of the area (Fig. 7A). Additionally, lights were evaluated to identify optimal placement for increasing visibility of nighttime observations, for observing predator-prey interactions. Feedback from the workshop

highlighted that lights should be anchored from above using rebar (Fig. 7B) and oriented downward. This configuration provided clearer imagery compared to deploying lights on the substrate alongside cameras (Fig. 7C).

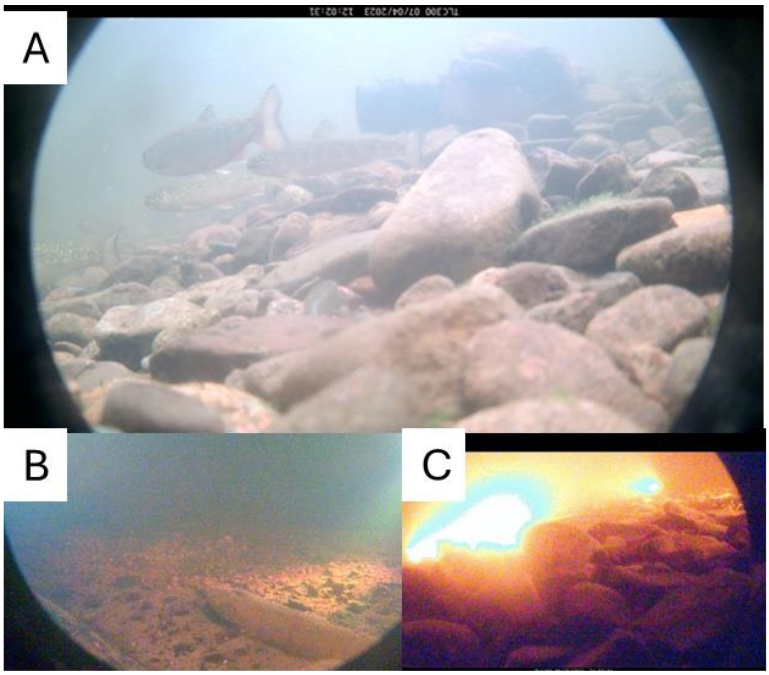

Figure 7 Imagery taken from Brinno timelapse cameras deployed in the Margaree river to show A) species occupying cold-water refugia and additional cameras deployed; B) visibility of lights when anchored on rebar, and facing down; C) visibility of lights when level with cameras on the substrate.

Problems and Concerns

1) Identified thermal refugium site is characterized by high flow, potentially causing increased energy expenditure for juvenile Atlantic salmon, in addition to thermal and predation stress. To account for this, we intend to characterize the flow dynamics across the length of the refugium throughout the summer, adding an extra layer of consideration to our analysis.
2) During previous summer, the Margaree watershed experienced several high-water events, resulting in decreased temperatures for a significant portion of the season. Consequently, it was challenging to comprehensively characterize the behaviours and usage patterns of individuals within the cold-water refugium due to the limited requirement and consequent use of such refugia.

3) The Southwest mainstem is characterized by high-flow waters, unsuitable for smallmouth bass habitat, potentially hindering our ability to observe or tag them near our site. However, we have hired a Masters student to track smallmouth bass as they move out of the lake down the mainstem. Additionally, discussions are underway regarding the potential monitoring of merganser predation on juvenile Atlantic salmon, as suggested by John MacMillan and local rightsholders and stakeholders.
4) The field season for summer 2023 ended early due to health-related issues, resulting in the absence of data collection for August and September, which are critical months for anticipated higher temperature events. Despite this setback, the substantial troubleshooting and testing conducted throughout the summer of 2023, as well as during the following fall and winter semesters, have positioned this project for success. With these preparations, we anticipate a more efficient data collection process during the upcoming summer of 2024.

Photos Captured with Cameras

Figure 8 Beaver

Figure 9 Merganser feet

Figure 10 Single trout and camera array

Figure 11 grouping of trout, confirmation