WINTER RIVER - TRACADIE BAY
WATERSHED ASSOCIATION

Work Report for 2020-21

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1 Executive Summary

This was certainly a different year for the staff and board of the Winter River-Tracadie Bay Watershed Association. COVID-19 presented new challenges, but these were faced head-on with creative ways to accomplish tasks. This year the office was restricted to access by the field supervisor and minimal access by others as required. Social distancing was practiced any time more than 1 individual was in the office, and sanitization measures were in place for touched surfaces. While completing field work, the crew was dedicated to following the public health guidelines, keeping the recommended 2 m distance and sanitizing hands and equipment after use. Where possible, each member of the crew had their own designated equipment that was not shared, e.g. hand saws, pruners, first aid supplies. Board meetings were accomplished through Zoom this year, including the public Annual General Meeting.

Despite these challenges, we are pleased with the work we were able to accomplish this year. In total, 12 brush mats were built/enhanced, 13.65 km of stream was cleared with handsaws, and 374 waypoints were taken for general stream assessments. Through cleanup activities 1,070 kg of waste was removed from 34.13 km of shoreline around the Tracadie Bay, 23.66 km of roadside was cleaned up, and 1,300 kg of garbage was removed from old dump sites bordering streams. The crew continued trail work at the donated woodlot, laying down wood chips and establishing a more well-defined trail.

Water monitoring activities included the use of depth loggers, temperature loggers, dissolved oxygen loggers, weirs, and headwater surveys throughout the watershed. Redd surveys and crop mapping surveys also took place this year. Further culvert assessments took place at 7 sites this year to prioritize a list for replacement or removal. A problematic culvert on an unused farm road was also removed this summer, which should improve fish passage along a branch with high quality habitat connecting to the Winter River.

The following link leads to an interactive map with photos, showing a number of our field activities this season.
https://www.google.com/maps/d/u/0/edit?mid=1c7VdmodU7jyiI5xPFybZJFVNEqK7IGsv&usp=sharing

2 Staff

Due to COVID-19 restrictions and lack of funding we were unable to hire any chainsaw operators this field season.

We were lucky to find 2 sets of siblings interested in working with our group. The sibling teams were helpful for completing tasks that did not allow for physical distancing, which was a key protocol during the pandemic for other workers.

Table 1. Staff employed for the 2020 field season.

Name	Position	Years with WRTBWA	Term of Employment
Sarah Wheatley	Watershed Coordinator	6	Year round
Brittany Steele	Field Supervisor/Natural Resource Technician	2	Spring-Winter
Raena Parent	Water Monitoring & Restoration Intern	1	Summer-Winter
Sarah McBride	Field Crew	4	Spring-Fall
Samantha MacSwain	Field Crew	3	Spring-Fall
Evan Cahill	Field Crew	2	Spring-Summer
Katherine Abrey	Field Crew	1	Summer-Winter
Cydney MacSwain	Field Crew	1	Summer only
Jessica McBride	Field Crew	1	Summer only

3 Project Activities 2020

3.1 Tree Planting and Forest Enhancement at Glenaladale Estate

With all of the uncertainty due to the COVID-19 pandemic, including public health measures and grant funding, no trees were ordered in time for the 2020 field season. However, a number of Red Oak trees were donated by a volunteer. WRTBWA crew planted additional trees at the Glenaladale estate, which were purchased by that group. The fall crew helped plant trees to enhance the forest stands on their property.

Table 2. Trees planted at Glenaladale. All Eastern Hemlock, Aronia, and 25 Red Oak were in 1 gallon pots. The rest were smaller plants in plug trays.

Species	# Trees Planted
Yellow Birch	135
Sugar Maple	135
Red Oak	115
Aronia	24
Eastern Hemlock	42
TOTAL	**451**

Tree planting activities were undertaken by our crew at 2 sites at Glenaladale this year; the North Trail and the Black Brook Trail. Trail creation is underway at both of these sites. There are also forest enhancement activities taking place such as patch cuts, thinning, and adding coarse woody debris to the forest floor. The fall crew, with the help of a couple volunteers, worked to diversify the existing forest along these trails by planting Acadian Forest species. Trees and shrubs were planted within multiple distinct habitat types, based on their light, moisture, and space requirements. Next season, additional trees and shrubs will be planted at these sites.

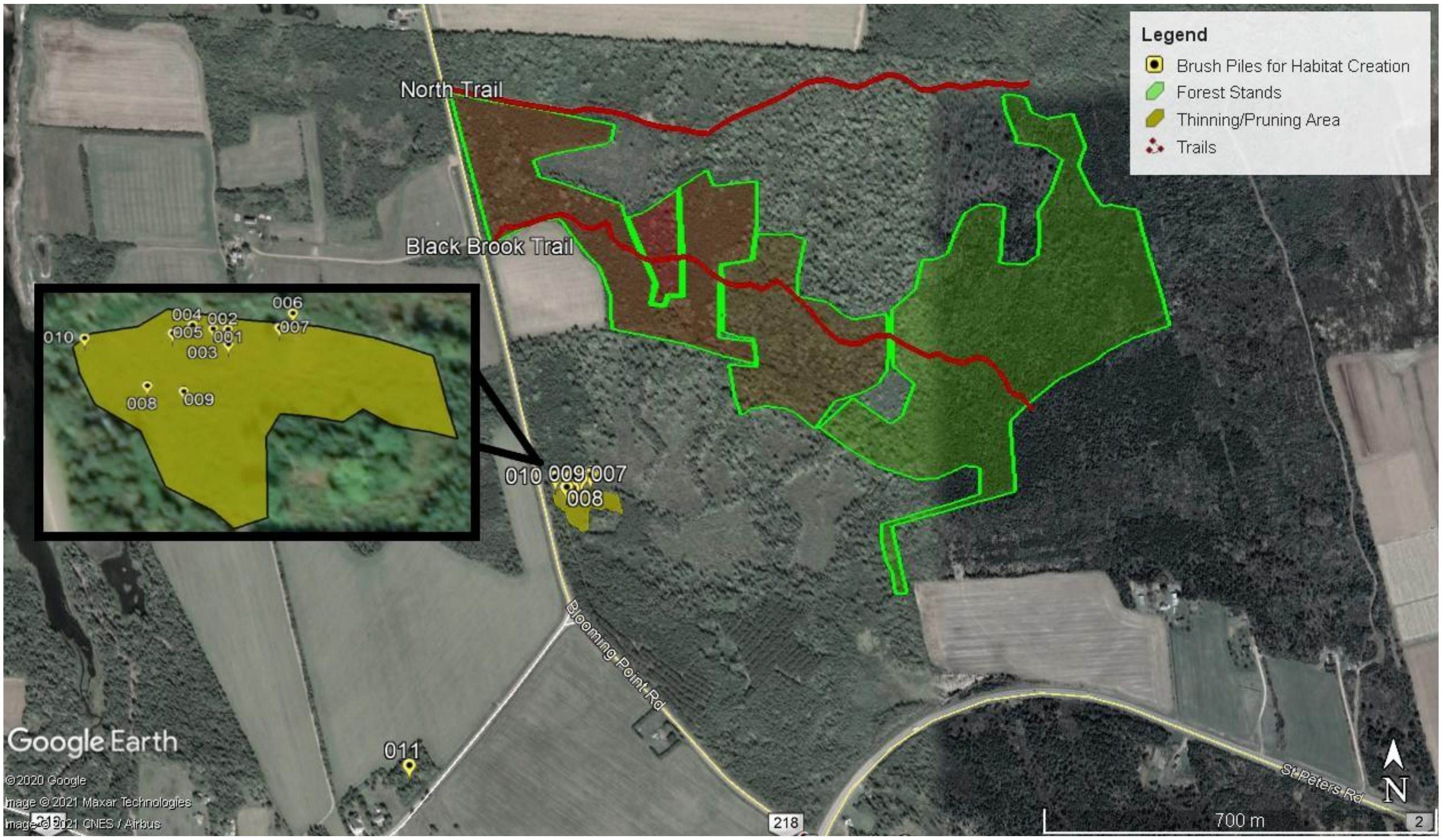


Figure 1. Glenaladale forest enhancement area. The fall crew planted trees along the 2 trails, which stretch across multiple forest stand types. The WRTBWA crew continued work this summer in the Thinning/Pruning Area, creating wildlife habitat with any brush cut from the site.

The property at Glenaladale consists of many different stand types with various levels of diversity. Much of the forest has been cut over the last 40 years, and about half has been converted into plantations of only 1 or 2 coniferous species (e.g. monoculture White Spruce). There is little natural forest left, however some areas have large individual White Pines, Red Oaks, and Red Maples present (Macphail Woods Ecological Forestry Project, 2019). The Glenaladale Heritage Trust has been working with the MacPhail Woods Ecological Forestry Project to enhance the area and create nature trails, with the goal of creating a large block of healthy woodland.

Tree clearing and pruning occurred at a couple sites on the Glenaladale property this season. At the Glenaladale woodlot, trees were thinned out in areas dominated by pioneer species such as Pin Cherry, White Spruce, and Gray Birch to create space for other species to thrive. Pruning efforts focused on pruning multiple leaders and removing dead branches, or those that would break and cause problems for the tree in the future. This was a continuation of work started on the woodlot last year, and some tree planting has already been completed in this area with Eastern Larch, Red Maple, Yellow Birch, White Birch, and White Pine. Brush piles were constructed with the cut trees and branches, creating habitat for wildlife in the area. This summer, the crew also removed chicken wire, buckets, and other garbage from the woods.

Figure 2. Before and after pruning to release trees at Glenaladale woodlot.

3.2 Stream Clearing

Due to the effects of hurricane Dorian in the fall of 2019, there were a large number of bigger trees that had fallen in or around streams. Unfortunately, due to COVID restrictions and funding, we were unable to hire any chainsaw operators this year to take care of the bigger blockages. However, each member of the crew was equipped with a Silky Gomboy folding hand saw and we were able to minimize or remove blockages along 13.65 km of stream this field season.

Stream clearing is needed to keep fish passage open, but the crew is careful not to remove too much, as woody debris acts as important habitat and cover for aquatic organisms. Where possible, trees that have fallen across the stream are just limbed, leaving the trunk as a stream crossing for animals. The link below leads to an interactive map showing locations and before-and-after photos of stream clearing completed this season.
https://www.google.com/maps/d/u/0/edit?mid=1c7VdmodU7jyiI5xPFybZJFVNEqK7IGsv&usp=sharing

Figure 3. Before and after work was completed to minimize stream blockage for fish passage from fallen trees. Chainsaw crews will eliminate these trees in future years.

Figure 4. The crew getting ready to stream clear along the main branch of the Winter River (left) and Friston South (right).

3.3 Wildlife Habitat

This year, 17 brush piles were created for wildlife habitat enhancement throughout the Watershed. Brush piles are used by wildlife such as snowshoe hare, snakes, shrub-nesting birds, and amphibians as they decay, providing valuable habitat (Harris et al., 2012).

The link below leads to an interactive map with brush pile locations and photos.
https://www.google.com/maps/d/u/0/edit?mid=1c7VdmodU7jyiI5xPFybZJFVNEqK7IGsv&usp=sharing

3.4 Brush Mats

The crew worked on 12 brush mats along 3 different stream branches this season; Tim's Creek, Friston North, and MacLauchlan branch. We were fortunate to have a landowner allow us to cut down and use the limbs from trees on their property to build brush mats, because there weren't enough suitable trees near the brush mat locations to supply the necessary materials.

Brush mats were enhanced above and below the road crossing at Tim's Creek to reduce sediment in anticipation of the culvert replacement on Suffolk Rd. The replacement was originally scheduled for summer 2020, but with COVID-19 delays, the installation of the purchased culvert has been rescheduled to 2021. On the Friston Branch, 3 brush mats were improved. This is quite a silty branch of stream, and is located near an active shale pit. The brush mats will help collect silt, building up the bank in the process. The brush mats will also work to narrow the stream channel, following the natural meander of the watercourse. Further brush mat construction occurred along the MacLauchlan branch, a continuation of advice given by fish biologist Rosie MacFarlane, who identified a site as being important for young fish. Brush mats were needed on both sides of the stream to narrow the channel, increasing flow and allowing the sediment-covered stream bottom to start scouring itself out.

The link below leads to an interactive map showing brush mat locations and photos from this field season.
https://www.google.com/maps/d/u/0/edit?mid=1c7VdmodU7jyiI5xPFybZJFVNEqK7IGsv&usp=sharing

Figure 5. The crew building brush mats along Tim's Creek.

3.5 Shoreline, Roadside, and Streamside Cleanups

The WRTBWA crew cleaned up a total of 34.13 km of shoreline around the Tracadie Bay this field season. 1,070 kg of shoreline waste was dropped off to Island Waste Management Corporation. The majority of this waste was styrofoam buoys, with lesser amounts of mussel socks, rope, and food/beverage containers. We also found pieces of many shotgun shells. The longer these items are left as garbage in the environment, the greater chance they have of breaking down to become microplastics, creating further issues for wildlife.

Microplastics are pieces of plastic measuring under 5 mm. These can be broken down into several sub-categories, including foam, threads, and fragments, among others. Microplastics can accumulate in wildlife and humans alike (Barboza et al, 2018). Sarah, Brittany, Raena, and Katherine attended a microplastics workshop with Coastal Action in the fall, learning methods for sampling both surface water and onshore sites. Next season, we will begin sampling for microplastics in the Tracadie Bay area.

We cleaned 23.66 km of roadside this field season as well. This garbage mostly consisted of coffee cups, beverage cans and bottles, chip bags, and cigarette butts, all items which could travel from the ditches to nearby streams and also become microplastics. During the early days of the work season, this was an important activity which allowed for physical distancing while crews implemented other pandemic protocols and completed trouble-shooting of these systems before more complicated activities began. It also increased our public visibility, so community members would know that our organization was still completing work despite the pandemic. The waste from these areas was combined with that from other cleanups, as it generally consisted of a small volume of easily compacted materials. A volunteer helped clean a section of the East Suffolk Road.

The link below leads to an interactive map showing locations and photos of some of the garbage collected this field season through shoreline and roadside cleanups.
https://www.google.com/maps/d/u/0/edit?mid=1c7VdmodU7jyiI5xPFybZJFVNEqK7IGsv&usp=sharing

The crew also took on the cleanup of several old dump sites near streams. The garbage here included old vehicles, tractor parts, glass and metal food containers, oil cans, cleaning products, shotgun shells, paint cans, barbed wire, old appliances, many tires, and even old pesticide containers. Due to the very large volume of materials that were found, staff prioritized items that would pose greater risks to the environment, and secondly those which were a risk to people who would be completing stream work in these areas in future. 1,300 kg of garbage was cleaned up from these sites, and more work is planned for next year.


Figure 6. The crew cleaned up garbage at many dump sites adjacent to streams this fall. The photo on the right is 1 of many piles that were taken to Island Waste Management Corporation for disposal.

3.6 Donated Woodlot (Watershed Trail)

This field season, a great deal of time was allotted to continuing to build a trail on the property that was gifted to the WRTBWA in the past. Crews spent time clearing back growth that was covering the trail path and flattened out sloped areas, building it up level with a rake and shovel. To cut large areas of plant growth, crew members used a scythe that was borrowed from John Hughes, a board member. To widen some areas of the path, small trees and branches were cut down or pruned.

We received wood chips from trees that were cut along the Suffolk Road by Maritime Electric maintenance crews. There was 1 load dropped off at the Watershed property, but due to space limitations, further material was put at the farm of a volunteer about 1 km away. Material can be transported from this site to the Watershed property as needed. The field crew spent time carrying wood chips from the pile at the centre of the property, and placing them on the trail to inhibit future plant growth on the path. Wood chips also help to define the path more clearly for visitors. Figure 7 shows an example of before and after crew members cleared vegetation and covered a section of the trail with wood chips. In preparation for future work on the trail, brainstorming was done towards ways to make the trail safer and easier to navigate. For example, making notes of areas that require handrails and steps.

Figure 7. Before and after vegetation was cut and wood chips were laid on the trail at the donated woodlot trail.

3.7 Culvert Removal

There were 2 potential culvert removal sites for this season. A previously assessed culvert on the Suffolk Road, which is in an important location for fish, was scheduled for replacement by the PEI Department of Transportation this year, in partnership with WRTBWA. However, due to COVID-19 related delays in getting the culvert from the supplier, it has been purchased but is being held in storage until next field season when it will be installed. In anticipation of this planned work, brush mats were added to the stream above and below the culvert in hopes of catching sediment entering the steam.

Culvert PR-039 was removed this summer. The culvert was part of an old stream crossing, no longer in use, between agricultural fields. Before its removal, it was assessed and found to have a large outflow drop, shallow water, and insufficient backwatering. It was also quite deteriorated and bent, where 2 sections of pipe were no longer well connected and each had a different slope. Brook Trout have been spotted during stream assessment surveys in this area on multiple occasions, and the removal of this culvert should help to improve their passage through the area.

Prior to removal, the surrounding trees were pruned or limbed to allow easier access for the contractor. A couple trees growing on top of the culvert had to be cut down with a chainsaw. Heavy equipment was used to haul out the old culvert and grade the slope of the banks on either side of the stream afterward. After removal, the crew raked the banks and planted grass seed. Geojute was pegged down on top using live willow cuttings to help control erosion, holding everything in place as the vegetation on the banks became established. The area was periodically watered and checked after rain events for signs of erosion. Shortly after removal, the streambed began scouring itself out, and in the coming years the stream should carve out a more natural, meandering path where the culvert once impeded this. The culvert site was last checked in late November, and the grass had become well established, with no signs of bank erosion.

Figure 8. Left: culvert PR-039 from the downstream end on 2020-07-14, before removal in August. Right: crew clearing a path for equipment to come in to remove the culvert.

Figure 9. Before and after the culvert removal at site PR-039. The left photo was taken in July, the culvert was removed in August, and the right photo was taken at the end of November.

An interactive map, including photos of progress at the culvert removal site, can be found at the following link. https://www.google.com/maps/d/u/0/edit?mid=1c7VdmodU7jyiI5xPFybZJFVNEqK7IGsv&usp=sharing

3.8 Community Outreach

With COVID-19 restrictions, we were unable to host our usual events such as the Lady Slipper Hike, volunteer events for tree planting, or shoreline cleanups. Our last event was the 2020 winter hike/snowshoe event in February 2020, just before the lockdown. The 2021 event was cancelled due to logistical hurdles of the pandemic restrictions and liability concerns.

4 Habitat Monitoring and Restoration Activities

4.1 Stream Assessments

Each year, the crew completes general stream assessment surveys to monitor stream health, detect issues, and plan for future work. During these assessments issues are marked on a GPS, including stream blockages, beaver activity, erosion, buffer violations, cattle in streams, and dump sites. GPS points are also taken to mark tree planting and brush mat zones for the next season. This year a total of 374 waypoints were taken.

4.2 Redd Surveys

Introduction

Redd surveys are completed around the end of October to late November, when Brook Trout are spawning (there are no longer Atlantic Salmon in our Watershed). Brook Trout typically choose sites near springs to spawn, where the temperature is fairly consistent, near 7-8°C, and there is coarse substrate, e.g. cobble and gravel (Franssen, 2011). The fish make a nest in the stream bed by using their tail to move rocks around and dig away fine sediment. This is where they deposit their eggs. When looking into the stream, the redd appears as a lighter patch (often reddish in colour on PEI) in the stream bed, and there are overturned rocks. After 2 years of the stream waters being too murky to see redds, we were finally able to conduct redd surveys this year.

Methods

Staff walked the length of streams where it was probable to find Brook Trout redds; areas with good habitat or previous years' evidence. When a redd was located, a GPS waypoint was marked, a photo taken, and notes made regarding its size, available cover, the presence of fish, etc. Polarized sunglasses were used to cut the glare and allow easier viewing of the stream bed. Redd data is entered into an Excel sheet and uploaded to Google Earth every year to compare changes in timing, abundance, and location choices over time. Though useful, these surveys can prove to be very subjective since, depending on experience level, it's easy to overestimate or underestimate the actual number of redds. This year, redd surveys were conducted along the Winter River, Black River, MacAulay's Creek, Pipers Creek, Beatons Creek, Friston Main branch, Friston South branch, Afton branch, part of Anderson branch, MacLauchlan branch, and below Hardy Mill Pond.

Results & Discussion

We found 43 potential redds in total, along 9 of the branches surveyed throughout the Watershed. For the past few years, we have been unable to conduct redd surveys due to the siltation that can occur after the heavy rain events typical of the fall months. Streambeds with high levels of fine sediment in the areas where spawning or incubation occur can have a negative impact on fish reproductive success. It can lead to silt infiltration in the nest over the winter months, collecting around the eggs and limiting the amount of oxygen available to the developing embryos (Franssen, 2011). As such, we are looking into ways to correct this issue, but we were happy to see redds and Brook Trout of reproductive size in our streams this year.

Figure 10. A redd found along 1 of the branches surveyed in the Winter River--Tracadie Bay Watershed.

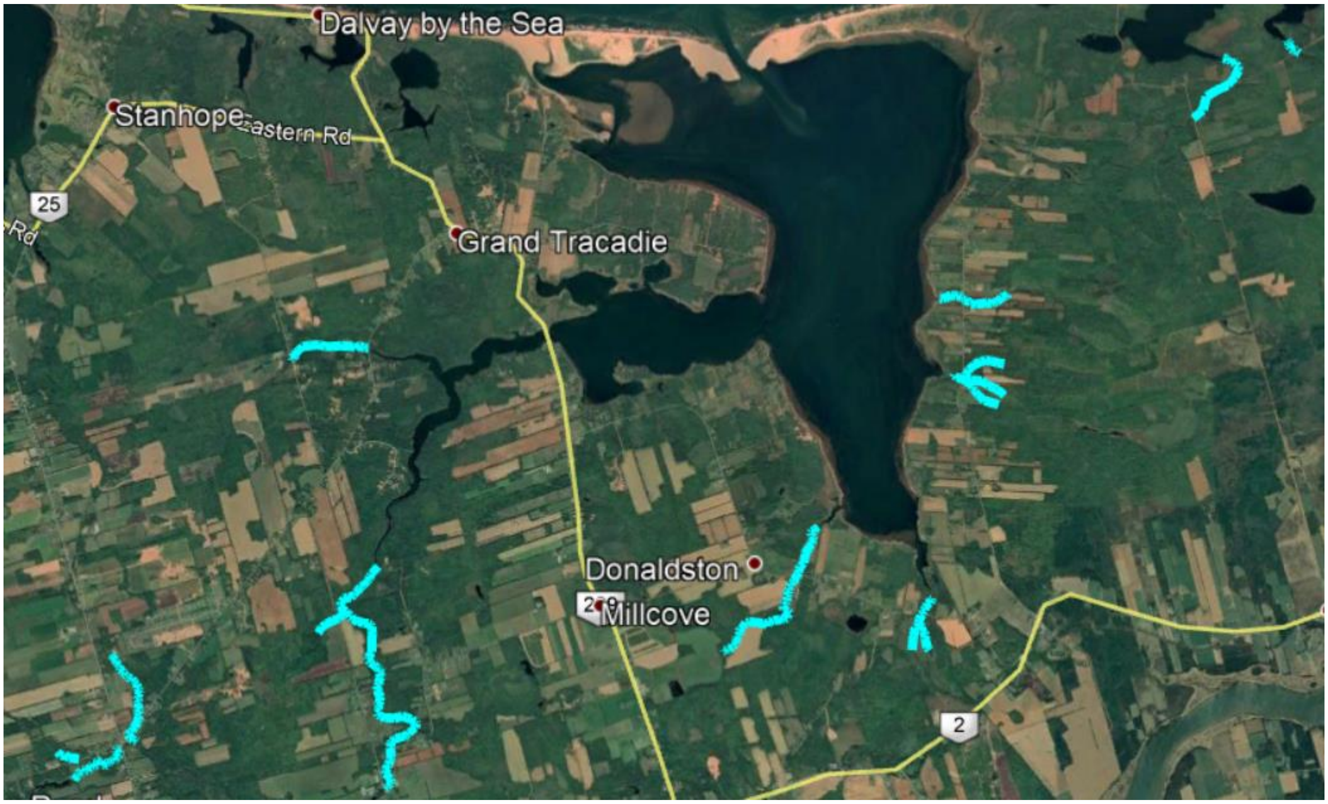


Figure 11. Streams where redd surveys were performed in late October and November 2020.

4.3 Beaver Management

Introduction

WRTBWA has a beaver management plan which identifies the main branch of the Winter River as a beaver-free zone. This plan was put in place to prevent beavers from blocking important fish passage and reducing water quality and quantity. While the main branch is a beaver-free zone, beavers are permitted on the side branches from the river and in other subwatersheds besides the Winter River. Every spring and fall, staff perform beaver assessments of the main branch, walking along the streams and checking for any beaver signs. This could include beaver trails, chew marks on trees, or the presence of a lodge or dam. Any beavers located in the beaver-free zone are to be trapped by local trappers. We try to have this completed within the trapping season, so the beaver pelt is of value and not wasted. However, if the beaver is creating a problem in the off season, it will be removed, after obtaining a nuisance beaver permit.

Methods & Results

During the stream assessment in the spring, there were signs of beaver activity observed along a few areas within the beaver-free zone. In the fall, a trapper was hired to remove beavers from 2 locations along the main branch of the Winter River. The beavers built dams in York and below Hardy Mill Pond that were impeding the flow of water and greatly affecting fish passage (Figure 13).

After the trapper had been out to the York site, a notch was made in the dam to allow water to flow. If there were any beavers in the area they would be attracted to the sound of the flowing water and come to patch up the hole. While the trapper did not catch any beavers, the dam had not been repaired when checked a few days later, so it was assumed that the beaver was no longer present in the area. Raena and Brittany then went back out to the site and breached the dam, removing the intertwined sticks and muddy debris with beaver hacks and handsaws. This area seems to be a reoccurring problem; in 2018 8 beavers were trapped from this location.

The beaver dam below Hardy Mill Pond was in the same location as last year. In December 2019 a trapper was sent out and caught 4 beavers, and we breached the dam once all were removed. During a stream assessment survey in the fall of 2020, it was found that beavers came back and repaired the dam, making it even more robust than before. The area is still being actively trapped at the time of writing, with 1 beaver trapped so far.

Figure 12. The beaver dams observed in 2020 within the Beaver Management Zone of the Winter River-Tracadie Bay Watershed.


Figure 13. Beaver sign (left) and dam (right) downstream from Hardy Mill Pond.

Figure 14. York beaver dam before and after clearing by fall crew.

Discussion

Beavers can have a number of impacts on fish and stream health, both positive and negative. They can greatly alter habitat in a short period of time, influence stream discharge, and affect water temperature (Pollock et al., 2003). The ponds created by dams provide habitat for wetland species, but can impede fish migration upstream and downstream. Dams also flood out forested riparian zones and act as a holding place for shallow water, allowing it to warm.

Balance is important, which is why our Watershed Management Plan includes a beaver-free zone only for areas where dams would impede fish passage along important spawning routes. American Eel, Rainbow Smelt, Gaspereau, and sea-run Brook Trout spend part of their life at sea, and the other part in freshwater systems, relying on open passage to migrate between them. Beaver dams can also block fish from seeking out cooler water at springs during warm summer conditions. Brook Trout, for example, cannot survive temperatures at or above 23°C, and higher temperatures have been recorded in the ponds in the Watershed. The Winter River has high water temperature issues caused by the large shallow areas of Officer's Pond and Hardy Mill pond, along with groundwater extraction by the City of Charlottetown, so limiting beaver dams and allowing access to cooler areas is particularly important for fish in the Winter River.

4.4 Culvert Assessments

Introduction

Culverts are assessed to determine which are problematic for fish passage, the extent of their issues, and possible options to address these issues. Since there are many more problematic culverts than our organization or the provincial government can afford to replace, it is important to prioritize which culverts must be replaced, which can be repaired or modified to improve fish passage, and which culverts are in locations that are lower priority fish habitat. This year 7 culvert surveys were undertaken throughout the Watershed, at both public and private road crossings. This is a continuation of previous efforts to assess culverts and their ability to allow fish passage. This year, they were performed by Evan, Katherine, and Sam. Culverts PU-014, PU-034, PU-036, PR-030, PR-032, PR-038, and PR-039 were assessed.

An interactive map with photos at each culvert site can be found at the following link.
https://www.google.com/maps/d/u/0/edit?mid=1c7VdmodU7jyiI5xPFybZJFVNEqK7IGsv&usp=sharing

Methods

The same survey methods were used this year as in 2019 and can be found in Appendix A: Culvert Assessments. Both visual observations and measurements were taken to assess each culvert and its associated stream channel. The crew used surveyor equipment to take elevation readings at each site.

Results & Discussion

Culverts can create passage barriers, limiting the level of aquatic connectivity throughout the Watershed. Aquatic connectivity refers to how much movement can occur within the aquatic ecosystem, including nutrients, organic matter, sediment, water, and organisms. Systems with little connectivity are limited in their levels of biodiversity. Aquatic connectivity is important to both residential and migrating fish species, as it dictates their access to seasonal and spawning habitat, cold water refugia, food sources, and opportunities to evade predators (NSLC Adopt a Stream Program of the Nova Scotia Salmon Association, 2018).

This round of culvert assessments was used to determine candidates for replacement or removal. All culverts surveyed this year were of the corrugated metal pipe (CMP) style. CMPs have unnatural, slippery bottoms lacking rest points for fish. Low water level and high velocity both pose significant barriers for fish passage, and without baffles or a more natural style bottom with rocks to create deeper water and rest points, fish have trouble navigating through the culvert. All of the sites also had a noticeable change in stream width above and below the culvert. None of the culverts surveyed were sufficiently backwatered. Table 3 includes a brief summary of the 2020 culvert assessments.

Table 3. Summary of culvert assessment results 2020. CMP=corrugated metal pipe. PR=private road crossing, PU=public road crossing.

	Observations					Calculations	
Culvert ID	**Type**	**Culvert Deformed?**	**Extent of Deterioration**	**Water Depth <15 cm in Culvert?**	**Visible Outflow Drop**	**Outflow Drop (cm)**	**Culvert Slope**
PR-030	CMP	yes	none	yes	present	20	0.21%
PR-032	CMP	yes	moderate	yes	absent	0.04	0.84%
PR-038	CMP	yes	none	yes	present	-0.07	3.18%
PR-039	CMP	yes	moderate	yes	present	issues due to deterioration	issues due to deterioration
PU-014	CMP	yes	none	yes	present	20	1.69%
PU-034	CMP	no	moderate	yes	present	0.01	0.69%
PU-036	CMP	yes	severe	yes	present	16	4.86%

4.5 Crop Data

Introduction and Methods

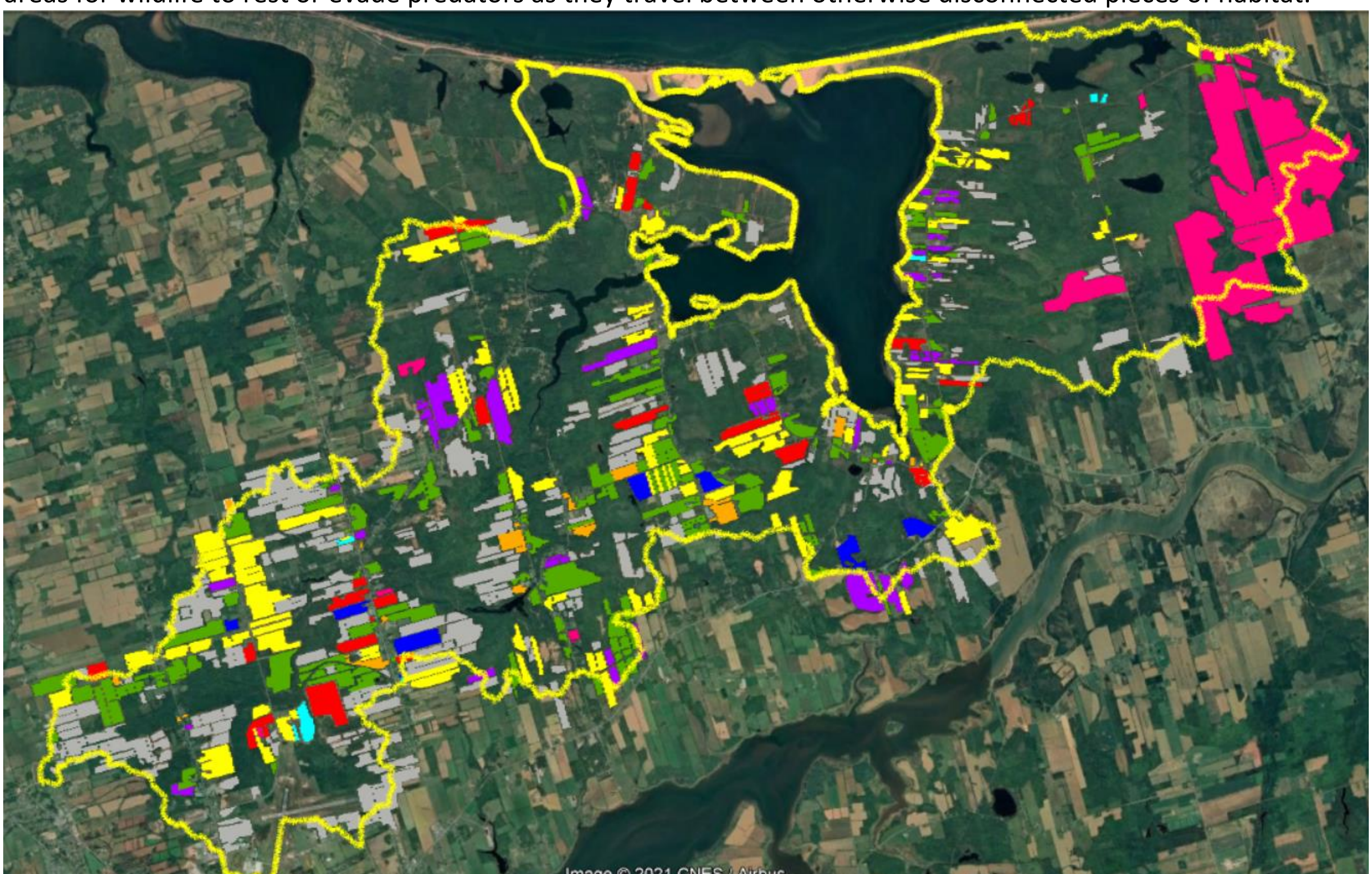
Crop data is collected as part of an ongoing project to track trends in which crops are grown in the Watershed, crop rotation cycles, and as part of a risk assessment for different streams. For example, streams where there are large areas upland in potato rotation tend to experience more sedimentation than streams where agricultural activity focuses more on perennial crops such as blueberries or pasture for livestock. This information also helps interpret water quality data, based on possible sources of contaminants.

During the 2020 growing season, Sam and Cyd travelled throughout the Watershed to record what was growing in the agricultural fields visible from public roads and trails. These 2 had the most experience in agriculture from helping on a family farm. Their brother, and our former staff member, Trent previously completed this task for us, and he volunteered to assist them with some additional training on plant identification. The 2 sisters were in the same family “bubble” (a term used frequently during the pandemic to describe small closed groups such as families, where individuals do not need to follow the public health restrictions that are used for limiting disease transmission between individuals), so could travel together and complete this task without having to distance from each other or wear masks within the vehicle. Once all fields had been marked, the GPS data was transferred to Google Earth for mapping.

During the winter these GPS data points were converted to polygons, which were labelled and colour coded by crop type. This information was also entered into a spreadsheet with crop data on some fields going back to 2013. The project started in 2013 as part of a nutrient management program within the Winter River subwatershed only. Since 2016 fields throughout the WRTBWA management area have been added. The information in a spreadsheet format can be used to calculate which crops occupy the most land within the Watershed, how land use changes over time, and provides foresight for areas that may pose problems in the future.

Results & Discussion

Below is a map of the agricultural lands with crops recorded within our Watershed area (Figure 15). Over the years, data can be compared to see changes in crop rotations, field usage and size. In recent years, a lot of fields have been joined to make larger fields, and a number of hedgerows have been removed. Hedgerows are important from both wildlife habitat and soil stability perspectives. They catch soil that is moved by wind and water, keeping it on the field and out of our waterways. Hedgerows also provide wind breaks, shade, and refuge areas for wildlife to rest or evade predators as they travel between otherwise disconnected pieces of habitat.



Legend	HAY	GRAIN	POTATO	CORN	SOY	PASTURE	PERENNIALS (ex.Blueberry)	OTHER	NO DATA

Figure 15. Map of 2020 crops growing in the Winter River - Tracadie Bay watershed, as recorded by staff.

A total of 470 fields, consisting of 3,177 hectares, were surveyed this year. It should be noted that not all fields within the WRTBWA management area were mapped, only those that could be seen from public roads, trails, or from the stream. As such, this provides an estimate rather than a complete representation of the agricultural land use in the Watershed. Blueberry and other perennial crops such as apples and raspberries accounted for 17% of crop land recorded. Blueberries make up the vast majority of this category (the others make up less than 1%). Hay (18%) and grain (15%) were the most abundantly grown annual crops this year. The “Other” category represents the less common crops such as buckwheat, cabbage, peas, and sunflower, and only accounted for 1% of crop land that was mapped.

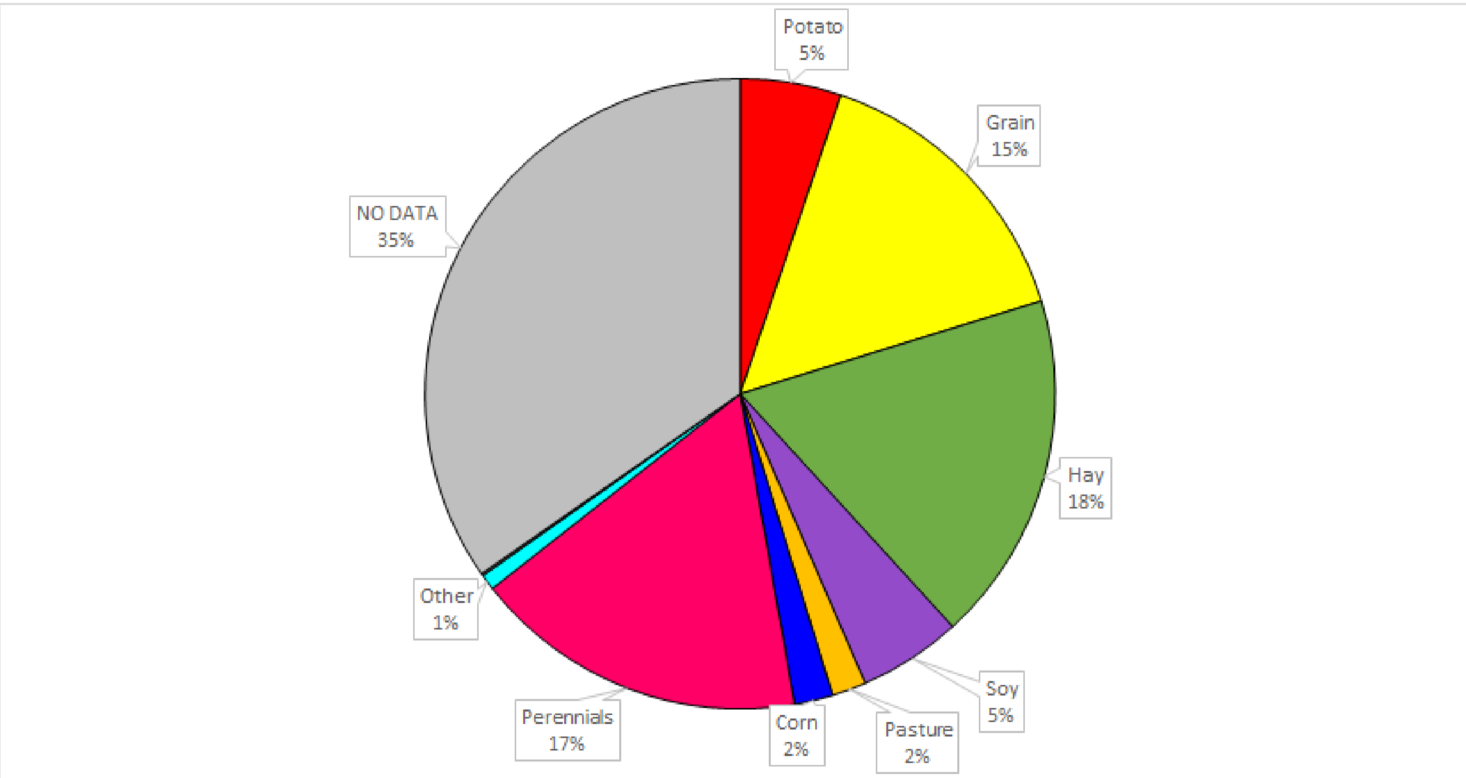


Figure 16. Crop data collected by staff during the 2020 growing season. The “Perennial” category is mostly blueberry land. “No data'' encompasses all fields that are not monitored due to their inaccessibility from public lands.

In addition to the proportion of land occupied by each crop type, proximity to watercourses is important. It is safer to have crops like hay grown near streams than large fields of row crops, especially potatoes. When livestock are pastured along stream banks, sediment is added to streams through erosion, and nutrients and organic matter are able to enter the surface water (University of Minnesota, 2018). However, buffer zone rules in PEI have largely eliminated this issue, with only a few exceptions. Perennial pasture for animals, or perennial forage crops such as alfalfa that are only tilled once every several years create minimal soil erosion into streams.

During rainfall and snowmelt events, the following major agricultural pollutants can run off of farmland: nutrients, sediment, pesticides, bacteria, and oxygen-demanding substances. Nutrients from fertilizer or animal waste can cause excessive algae growth and lead to low-oxygen or anoxic events. Sediment runoff creates turbid water, damaging fish and plant habitat, and may also carry nutrients to the stream. Pesticides entering waterways can be toxic to fish and other aquatic life. Coliform bacteria can make its way into surface and groundwater, and oxygen-demanding substances, such as manure, sewage, crop residues, and other decaying organic matter can use up the oxygen needed for fish survival (University of Minnesota, 2018).

4.6 Freshwater Mussel Collection

In late August, members of the crew went out to Officer's Pond to look for freshwater mussels with Rosemary Curley. She has been working on a project looking for more sites for a specific species, the Alewife Floater (*Utterbackiana implicata*), which has only recently been discovered on PEI. We used buckets with clear bottoms to see the bottom substrate more easily, and pulled out promising shells for closer inspection. Most of the mussels we came across were only shells, but a few were live mussels. Rosemary taught us which identifying characteristics to look for, and because they can sometimes be a tricky species to ID for certain, samples were sent to the New Brunswick Museum for analysis. While we did not end up finding any Alewife Floater, we did find some Eastern Floater (*Pyganodon cataracta*) individuals and it was a great learning opportunity for the crew.

Figure 17. The crew searching for Alewife Floater (*Utterbackiana implicata*) with Rosemary Curley at Officer's Pond in August. Mussel on the bottom left is an Eastern Floater (*Pyganodon cataracta*) that was found here. Photo credit for top right & bottom left: Rosemary Curley.

5 Water Quality Monitoring

5.1 Groundwater Monitoring

This spring, we could not do our usual groundwater sampling blitz with the YSI due to COVID-19 delays to the start of the field season. In the fall, the groundwater levels were too low to obtain much usable data after the summer drought. See Figure 35 in Section 6.3 for a map of drought conditions this summer.

5.2 Suspended Sediments in Water

Introduction & Methods

We did some surface water sampling for total suspended solids (TSS) in late September. TSS are particles in the water column larger than 2 microns and can include sediment, silt, sand, and decaying organic matter (Fondriest Environmental, Inc., 2014). In addition to indicating erosion, TSS levels can directly impact the health of streams. The amount of TSS in a water body affects water clarity, and high levels of total suspended solids can increase water temperatures, as more solar heat is captured by the particles than by water alone. Because warm water can hold less oxygen than cold water, this leads to decreased levels of dissolved oxygen. Usually the majority of suspended sediment in a water body comes from erosion or runoff (Fondriest Environmental, Inc., 2014). Areas with more robust riparian zones can trap this sediment, preventing it from entering the watercourse.

Samples were taken at 27 sites throughout the Watershed after a heavy rainfall to detect signs of erosion in various streams. The water was collected in 1 L plastic bottles supplied by the PEI Analytical Lab, after being rinsed 3 times in the stream water at each sample site. These samples were then processed by the PEI Analytical lab.

Results & Discussion

Water with a TSS concentration below 20 mg/L typically appears clear, while water over 40 mg/L may appear cloudy (Fondriest Environmental, Inc., 2014). The sample with the greatest amount of total suspended solids (39 mg/L) was downstream from an area that had been disturbed through land clearing activities, was near agricultural fields, and included a drainage ditch with minimal vegetation. There were 2 sites with the lowest TSS reading (1 mg/L), and upstream of these sites was mostly tree-covered or residential. The median reading was 3 mg/L, and 93% of the samples had a concentration of 20 mg/L or less. The samples were taken after a heavy rainfall because more water passes over the land and enters waterways during heavy rain events, and the increased flow rates keep sediment suspended in the water rather than allowing it to settle out to the bottom. This allows us to catch the areas with higher erodibility.

Table 4. Total suspended solids (TSS) sampling results from 2020-09-24, from lowest to highest TSS per site. See Figure 18 below for a map of locations where these samples were taken.

Location	TSS (mg/L)		Location	TSS (mg/L)
Main at York	1		Wheatley	4
Afton @ Pt Deroche Rd	1		Vanco Stream	6
MacLauchlan	2		Tim’s	6
Apple Orchard	2		Friston South	6
Mazer	2		Anderson	6
Friston North	2		Brackley @ Union	7
Beaton	2		Affleck	10
Lowe	2		Pater - Bales	11
Main at Hardy	3		Main at Union	12
Main at Officer’s	3		Pipers	15

Main at Tim's	3		VanWesterneng	20
Friston Main	3		Cudmore	25
Black River	3		Vanco Ditch	39
MacAulay	3			

Figure 18. Map of total suspended solids (TSS) sampling sites in 2020.

5.3 Dissolved Oxygen Loggers

Introduction

Indicators of anoxic events can be observed both visually and through collecting water chemistry data. Dissolved oxygen (DO) loggers were deployed in 2 locations in the Winter River estuary. These loggers collected dissolved oxygen and temperature data hourly, 24 hours a day, to help monitor when and where hypoxic/anoxic conditions were occurring, and the fluctuating conditions aquatic organisms must face. The DO loggers and Estuary Monitoring Surveys (Section 5.4) were both used to monitor for hypoxic (oxygen poor) or anoxic (depleted of oxygen) conditions. Anoxia can often be brought on by excess nutrients entering the waterway from upland sources. It is important to monitor for anoxic events because of their negative effects on aquatic life; anoxic events can lead to fish kills. This information is valuable for determining severity and potential sources of the problem so appropriate actions can be taken to try to mitigate harm.

The link below leads to an interactive map with dissolved oxygen logger locations and photos from the 2020 field season. https://www.google.com/maps/d/u/0/edit?mid=1c7VdmodU7jyiI5xPFybZJFVNEqK7IGsv&usp=sharing

Methods

As with other routine monitoring activities, this year our methods were modified as a result of COVID-19 safety protocols. During the peak of the outbreak, the crew used 2 kayaks, rather than 1 canoe, to access the DO loggers to allow for greater distancing. Later on in the season, a canoe that permitted 2 m physical distancing between 2 individuals was used. In previous years, 3 individuals would work from this same canoe. None of the equipment was passed between hands, so there were distinct duties for each worker. For example, a crew member would use the YSI and take pictures. While another would write in the notebook and handle the DO loggers and GPS.

In total, 3 HOBO U26-001 Dissolved Oxygen Loggers were deployed from 2020-07-09 to 2020-09-21 at 2 locations in the Winter River estuary; near the Pleasant Grove boat launch and near the Corran Ban Bridge. At the Corran Ban Bridge site, 2 loggers were set up, 1 close to the surface and another near the bottom, due to the greater depth of the water at this site. At the Pleasant Grove site a single dissolved oxygen logger and a HOBO U24-002-C Conductivity Data Logger were deployed together near the surface, because the water was only 1-2 m deep. Due to the rapidly changing conditions with the tide, the conductivity logger was needed to calibrate the dissolved oxygen logger to provide accurate readings at this location. At each site, the loggers were attached to a rope with zip ties and duct tape, with buoys tied at the top and a concrete anchor to prevent the loggers from drifting.

The loggers were accessed by canoe/kayak, and were retrieved, cleaned, and had their data downloaded every couple of weeks. During each deployment and retrieval, a YSI reading was taken at the logger and recorded with the time, to make sure the DO loggers were still reading with accuracy, and providing reference points for data analysis later on. Each time a logger was removed from its site, it was cut free from the duct tape and zip ties and taken back to the office for downloading. The body of the logger was cleaned with a brush and fresh water to remove any buildup of algae, and the anti-fouling guard was gently brushed off, briefly soaked in vinegar, and wiped off with a J-cloth. The sensor itself was rinsed off with water and wiped with lens paper. The loggers were then taken back out to the field and were taped and zip tied on securely for redeployment. At the end of the season the Pleasant Grove anchor was hauled in to land by hand, and the anchor in Corran Ban was left over winter, as there was gear set up in the water by other parties which we did not want to disturb.

Results

It should be noted that there were some data quality issues with the loggers, with extremely high and low values recorded sporadically. The bottom logger at Corran Ban was especially problematic. The sensor repeatedly became covered in muck from the bottom of the estuary with the changing tides, despite efforts to keep it clean. As a result, a large section of data had to be removed from the dataset. Some data also had to be removed from the Pleasant Grove dataset due to poor quality readings. As such, results should be interpreted with caution. According to the logger manual, the reading range for dissolved oxygen is 0-30 mg/L and the calibrated range is 0-20 mg/L. As such, all values under zero and all values over 20 were removed during data analysis. There are short breaks in data approximately every 2 weeks where data was downloaded from the loggers back at the office. The loggers were usually redeployed the same day they were retrieved, but from 08-17 to 08-20 they were all out of the water for a stretch before redeployment.

The temperature across all 3 logger sites were fairly consistent with each other. However, the dissolved oxygen at Pleasant Grove fluctuated more per day than the Corran Ban sites (Figure 19). Readings were taken at the beginning, end, and mid-deployment with a YSI to ensure the DO loggers were still recording accurately (Figures 20, 21, 22). At Pleasant Grove, a conductivity logger was also deployed in conjunction with the DO logger to provide accurately calibrated readings with the greater fluctuations in tide at this site. In Figure 20, the conductivity and tide level tend to peak at the same time of day, with drops in conductivity occurring at low tide. The temperature increased during low tide at all logger sites. The dissolved oxygen was highest when the tide was going up, usually around midway to high tide, at both Pleasant Grove and Corran Ban Surface (Figures 20 & 21). The inverse relationship between temperature and DO could sometimes be seen at those sites, but at other times the high peaks in both temperature and DO appeared to line up. The Corran Ban bottom logger did not have enough usable DO data to see if it followed the same patterns.

For insight into the degree of variability aquatic species are subject to in the Winter River estuary, we can look at how great the changes in temperature and dissolved oxygen are over a period of 24 hours (Figures 23 & 24). The temperature, dissolved oxygen, and conductivity fluctuated most at the Pleasant Grove site. This site also had the greatest tidal fluctuations, being furthest upstream. The dramatic change in water level was visible between visits to the site. The Corran Ban bottom logger was generally the least variable for both temperature and dissolved oxygen within a 24-hour period. Although the 3 sites had different degrees of variability in temperature (Figure 24), their minimum, maximum, and mean temperatures were quite similar between all sites (Table 5). On average, the difference between the daily high and daily low temperature at Pleasant grove was 3.07℃. The average difference between the daily high and daily low dissolved oxygen at this site was 9.12 mg/L. The Corran Ban surface site had an average daily temperature difference of 2.51℃ and DO difference of 4.45 mg/L. The Corran Ban bottom logger had the least variable conditions, with average daily differences of 1.04℃ and 1.46 mg/L. Figures 23 & 24 show the daily variation of temperature and DO for the whole logging period.

All of the sites monitored experienced hypoxic or anoxic conditions. Hypoxia is defined as having a dissolved oxygen concentration under 2 mg/L, and anoxia as 0 mg/L (Coffin et al., 2017). For our purposes, we included all values within 0.2 mg/L of zero as anoxic, since our logger is accurate to within 0.2 mg/L. The logger at the surface in Corran Ban recorded dissolved oxygen levels under 2 mg/L only once over the entire logging period, with no readings under 0.2 mg/L. The Corran Ban bottom logger read 4 instances of hypoxia, and 1 of anoxia, but that dataset was greatly reduced due to quality issues. The Pleasant Grove site had hypoxic values 37 times, and anoxic values 4 times (Table 5). Pleasant Grove also had the longest consecutive period of hypoxia, with 6 hours. Again, it should be noted that some data had been removed from the dataset due to quality issues, so there may have been longer periods of hypoxia that were not captured by our data. The longest periods at Corran Ban were 1 hour at the surface and 2 hours at the bottom, however there was limited data for the bottom logger.

Table 5. Summary of HOBO U26-001 Dissolved Oxygen Logger results at the 3 sites for the period of 2020-07-10 to 2020-09-21. Readings were taken hourly. Corran Ban Bottom values are based off of a very limited dataset. *The logger used provides accuracy to 0.2 mg/L, so any values less than or equal to 0.2 mg/L were counted as anoxic.

Site	**Duration Low Oxygen** (<5 mg/L)	**Duration Hypoxic** (<2 mg/L)	**Duration Anoxic** (≤0.2 mg/L)*	**Minimum DO (mg/L)**	**Maximum DO (mg/L)**	**Minimum Temperature (℃)**	**Maximum Temperature (℃)**	**Mean Temperature (℃)**
Corran Ban Surface	6.9%	0.1%	0.0%	1.94 (2020-08-16)	19.45 (2020-07-11)	12.02 (2020-09-21)	27.42 (2020-08-11)	21.46
Corran Ban Bottom	48.8%	1.6%	0.4%	0.18 (2020-09-21)	10.74 (2020-09-19)	13.68 (2020-09-21)	26.20 (2020-08-11)	20.88
Pleasant Grove	13.3%	2.5%	0.3%	0.02 (2020-09-21)	19.97 (2020-08-14)	12.16 (2020-09-19)	29.42 (2020-08-16)	22.21

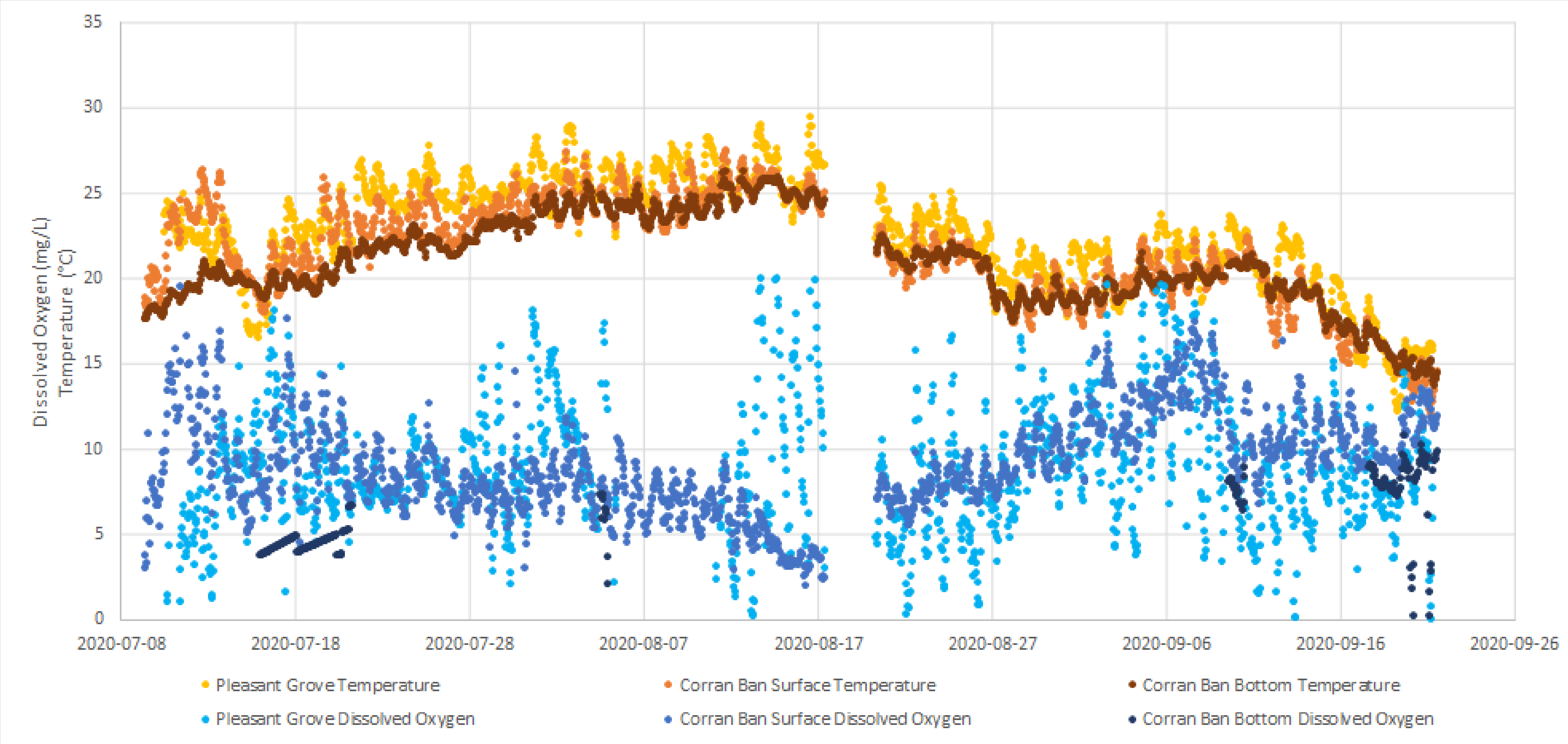


Figure 19. The temperature and dissolved oxygen values recorded every hour by 3 HOBO U26-001 Dissolved Oxygen Loggers deployed at sites in the Winter River estuary from 2020-07-09 to 2020-09-21. The Corran Ban Bottom site dataset is significantly reduced due to data quality issues.

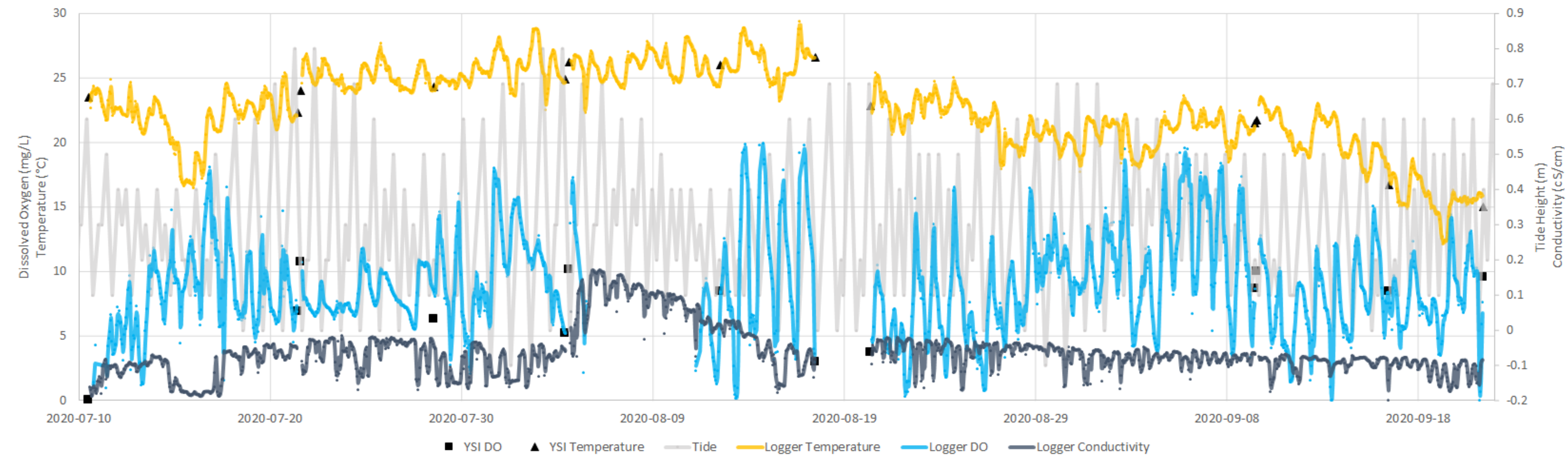


Figure 20. Temperature, dissolved oxygen, and conductivity readings taken by a HOBO U26-001 Dissolved Oxygen Logger and HOBO U24-002-C Conductivity Logger at the Pleasant Grove site from 2020-07-09 to 2020-09-21. The loggers took readings every hour, and the YSI readings were taken during logger deployment and retrieval, as well as during estuary monitoring surveys. DO data from 2020-08-05 to 2020-08-11 was removed due to faulty readings. The tide data was obtained from a tide table (Fisheries and Oceans Canada, 2020).

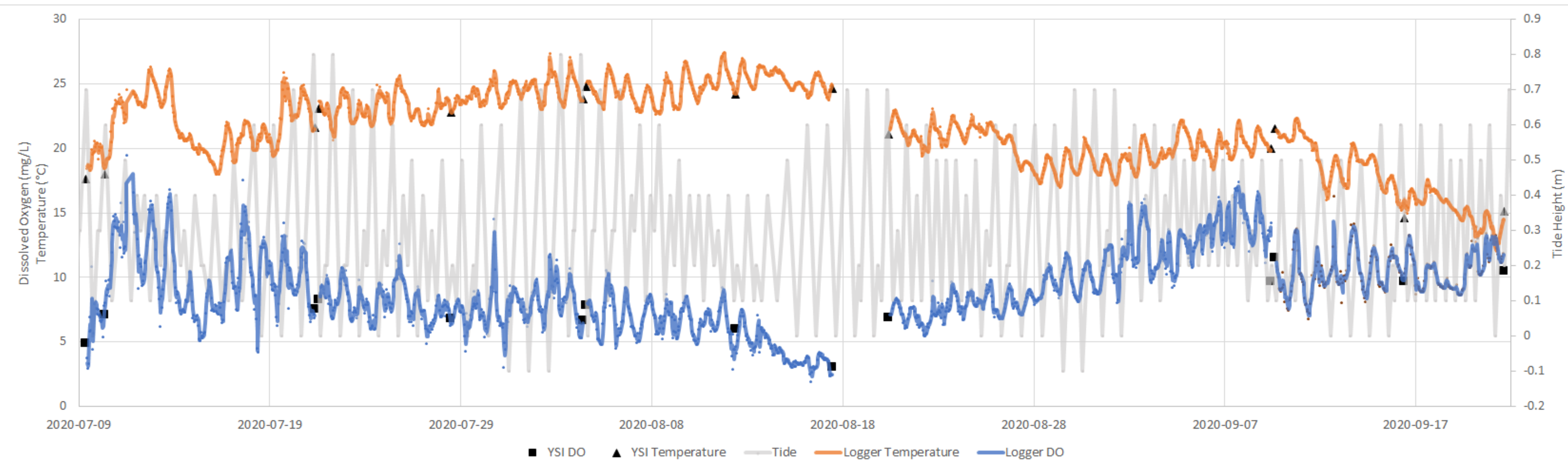


Figure 21. Temperature and dissolved oxygen readings taken by a HOBO U26-001 Dissolved Oxygen Logger at the Corran Ban Surface site from 2020-07-09 to 2020-09-21. The loggers took readings every hour, and the YSI readings were taken during logger deployment and retrieval, as well as during estuary monitoring surveys. The tide data was obtained from a tide table (Fisheries and Oceans Canada, 2020).

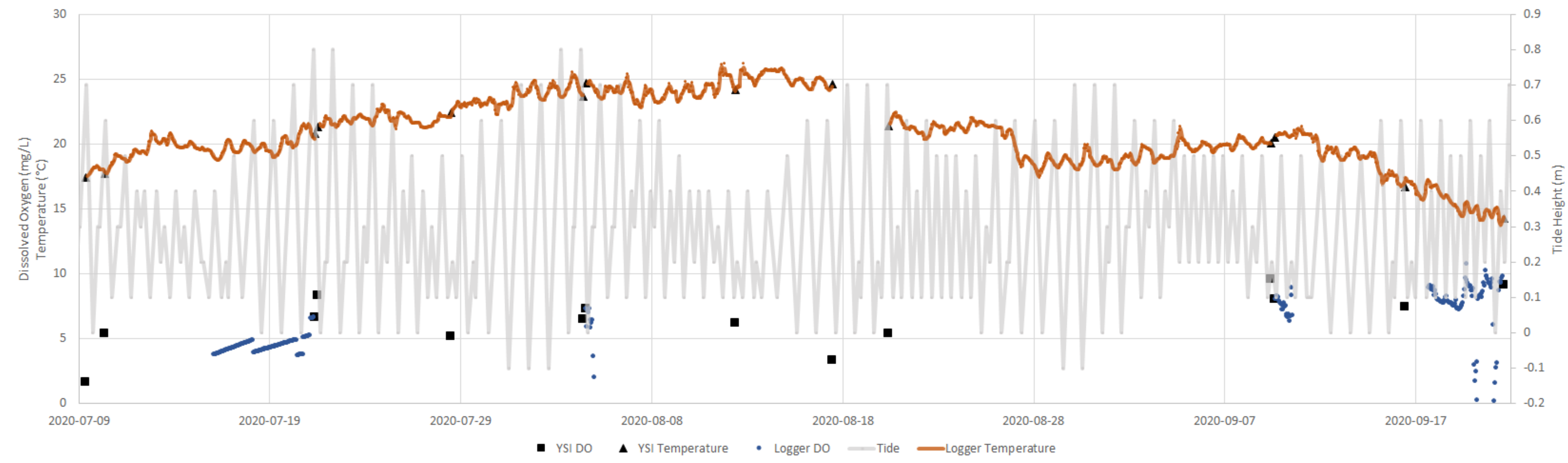


Figure 22. Temperature and dissolved oxygen readings taken by a HOBO U26-001 Dissolved Oxygen Logger at the Corran Ban Bottom site from 2020-07-09 to 2020-09-21. The loggers took readings every hour, and the YSI readings were taken during logger deployment and retrieval, as well as during estuary monitoring surveys. The tide data was obtained from a tide table (Fisheries and Oceans Canada, 2020).

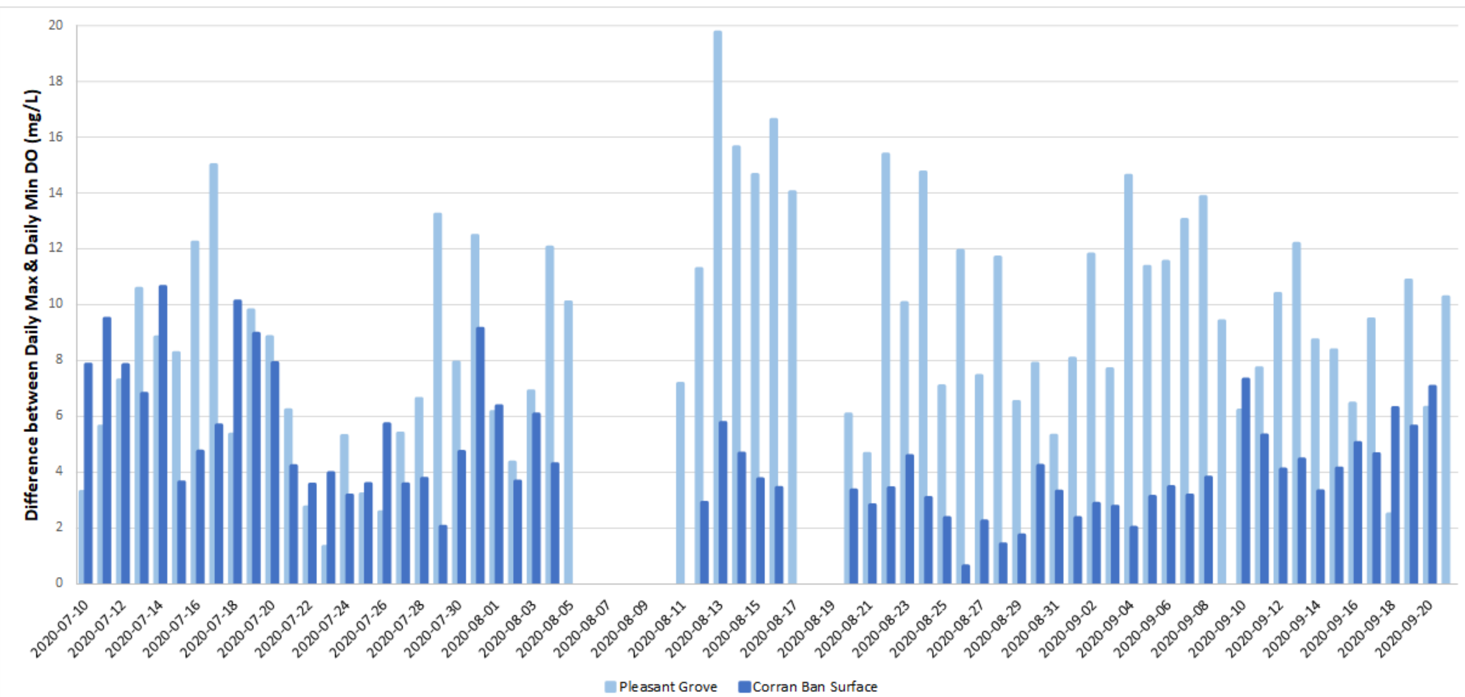


Figure 23. Variation in dissolved oxygen over 24-hour periods across 2 of the 3 logging sites, Corran Ban Surface and Pleasant Grove. Each bar represents the difference between the daily maximum and daily minimum dissolved oxygen recording for each day of the logging period. Gaps in data represent time when the loggers were out of the water. The Corran Ban Bottom logger has been omitted due to lack of usable data.

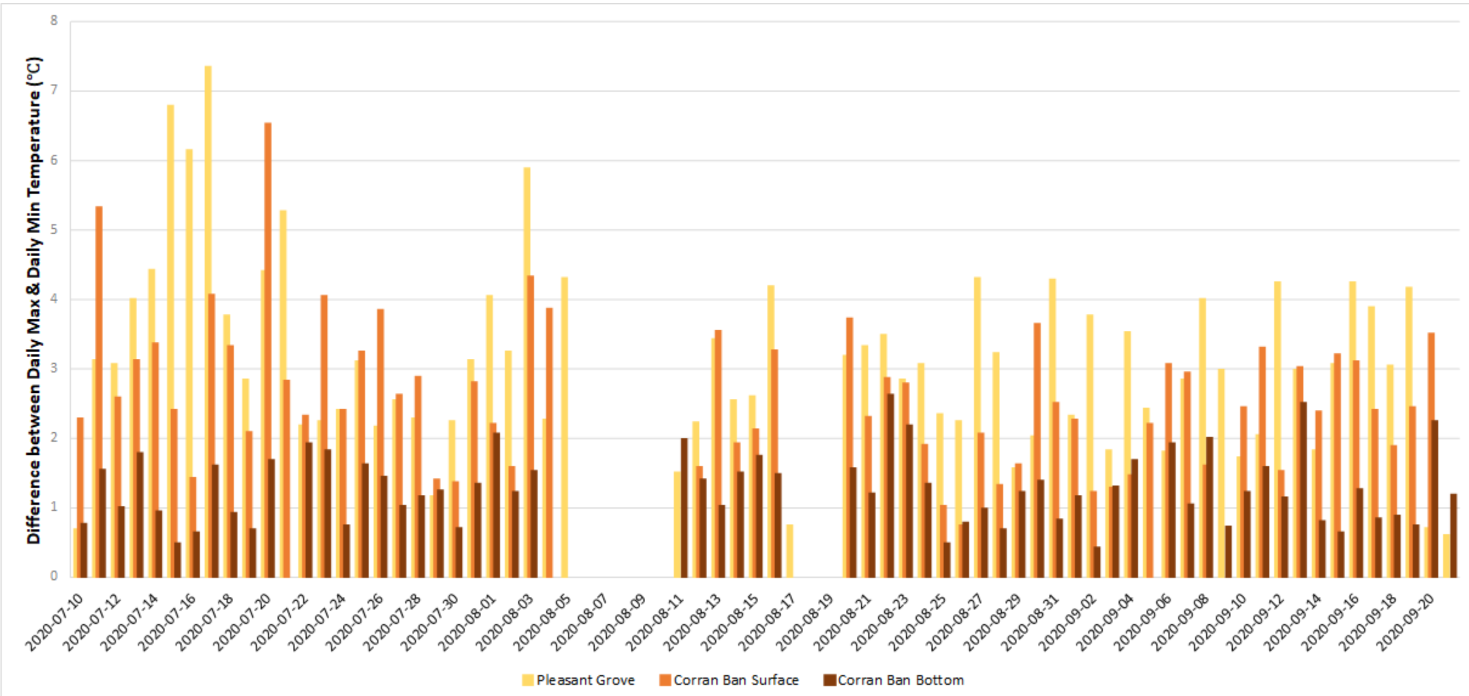


Figure 24. Variation in temperature over 24-hour periods across all 3 logging sites, Corran Ban Surface, Corran Ban Bottom, and Pleasant Grove. Each bar represents the difference between the daily maximum and daily minimum temperature recording for each day of the logging period. Gaps in data represent time when the loggers were out of the water.

Discussion

Oxygen can enter water through diffusion, natural aeration from waves, photosynthesis, and human routes of entry such as runoff. When there is a lot of photosynthetic activity, the concentration of dissolved oxygen can even reach over 100% saturation (University of Florida, n.d.). The main ways oxygen losses occur are through increasing water temperature, plant and animal respiration, and aerobic decomposition of organic matter by microbes (Northeastern Regional Association of Coastal Ocean Observing Systems, n.d.). Naturally, DO levels vary depending on the time of day, season, temperature, and salinity (University of Florida, n.d.). The concentration of dissolved oxygen is inversely related to water temperature and salt concentration, so cold water can hold more oxygen than warm water, and freshwater can hold about 20% more oxygen than seawater at the same temperature and pressure (Xylem, 2019). At all sites, the DO concentration was generally highest when the temperature was lowest (Figures 20, 21, 22). Aquatic vegetation and algae release oxygen into the water during photosynthesis, and use oxygen for their metabolism at night (Utah State University, 2019), so a normal oxygen cycle has a maximum concentration late in the day and a minimum concentration early in the morning (Government of British Columbia, n.d.). Dissolved oxygen is at a seasonal low in the summer and entering the fall (USGS, n.d.-a).

At low tide there is less saltwater influence in the estuary, measured as drops in conductivity (Figure 20), which allows the water to hold more dissolved oxygen. However, the water is also shallower, heating up more from the sun, and not getting mixed with incoming water. Dissolved oxygen has been found to be higher at high tide in systems where saltwater is joining freshwater, due to the incoming water mixing the water mass, allowing diffusion to occur (Leidonald et al., 2018). This could be seen at the Pleasant Grove logger where DO was more variable, changing with the tides (Figure 20). “Hypoxia/anoxia is typically most severe closer to the substrate and dampened by air-water exchange near the water’s surface” (Coffin et al., 2017). In addition, photosynthesis by phytoplankton and algae boosts dissolved oxygen near the surface (Leidonald et al., 2018). At the Corran Ban site, there was a greater distance between the surface and bottom, and the data showed this contrast; the DO at the Corran Ban surface logger was higher than at the bottom logger (Figure 19). The bottom had less variable conditions than at the surface, but the values were lower. However, there was limited data from the bottom logger to work with.

In addition to the natural processes that influence dissolved oxygen levels, excess nutrient inputs (that are often from land sources) can also affect the waterbody and the community it supports. When large inputs of bioavailable nitrogen enter the water it can stimulate rapid and dense algae growth, leading to eutrophication. When these algal blooms die, their decomposition process depletes oxygen in the subsurface water (USDS, n.d.). Even a small change in DO concentration can affect the composition of aquatic communities (Utah State University, 2019). When conditions are hypoxic, under 2 mg/L, many species will move from the area, and those that are immobile may die. Anoxic conditions, defined as 0 mg/L, may lead to total mortality for organisms that require oxygen for survival (University of Florida, n.d.).

Most aquatic animals and plants require dissolved oxygen levels greater than 5 mg/L for normal growth and reproduction (University of Florida, n.d.). Species such as crabs and oysters only need levels around 1- 6 mg/L, but fish living in shallow waters require levels closer to 4-15 mg/L for respiration (Fondriest Environmental, Inc., 2013). Fish become distressed at levels around 2-4 mg/L, and fish kills typically occur when the concentration of dissolved oxygen is under 2 mg/L (Stantec Consulting Ltd., 2013). Some fish may sense and avoid low-oxygen environments, which can affect migrations and cause additional issues if space or food resources are limited (Government of British Columbia, n.d.). Due to the effects on aquatic organisms, zones of hypoxia are an important economic and environmental issue to commercial and recreational fisheries (USDS, n.d.). In our results, the Corran Ban bottom site was under the 5 mg/L threshold for almost half of its deployment, making it less suitable for organisms requiring oxygen. The other 2 logger sites were under this threshold for much less time (6.9% at Corran Ban surface, 13.3% at Pleasant Grove, see Table 5). This difference likely came from the increased opportunities for oxygen uptake at the water's surface. Despite the lower values at CB bottom, the area around the Pleasant Grove logger looked and smelled far worse and for a longer period of time.

Potential sources of error in our data may include a dirty sensor at the Corran Ban bottom site. The rope connecting the logger to the buoys was not short enough to avoid the base of the logger dipping into the bottom muck when there were very low tides. The rope was shortened on multiple occasions, but the problem did not seem to be resolved until the end of the deployment period. Additionally, when taking readings during the deployment and retrieval of the DO loggers, the YSI probe may have stirred up the bottom waters enough to give slightly higher DO readings for that moment in time, especially at the Corran Ban Bottom site.

At both the Pleasant Grove and Corran Ban logging sites, algae would build up on the ropes holding the loggers. A sudden increase in photosynthetic activity can lead to supersaturation (DO concentration >120%), and supersaturation can occur at lower concentrations as water temperature increases (Fondriest Environmental Inc., 2013). This may have been the cause for some of the extremely high and extremely low negative recordings. The preferred method for calibrating the DO loggers requires taking a jar of water from the site at retrieval and deployment, however, we used the alternate method in the manual for calibrating, and this may have given less accurate results. DO logger data processing was a trying task to figure out appropriate settings and ranges, but the steps we used can be found in Appendix B: DO Data Formatting Steps.

5.4 Estuary Monitoring

Introduction

Estuary monitoring surveys were performed in addition to using the dissolved oxygen loggers (Section 5.3) to monitor health. These surveys provided data throughout the estuary, from the head of tide to the opening of Tracadie Bay. Visual observations of water conditions and water chemistry measurements were taken to monitor for hypoxic or anoxic events, which can create uninhabitable environments for aquatic organisms. Using the Estuary Watch Index developed by the province (Appendix C: Estuary Watch Index Scoring; Crane, 2016), visual observations can be categorized. They determine healthy water to be clear, with little to no colour, no odour, and less than 25% sea lettuce (*Ulva* spp.) coverage. The dissolved oxygen level would be within 10% of its normal value and the sea lettuce would look mostly healthy. Water with impaired health is described as being clear to slightly cloudy, with some light greenish colour, no odour or a very faint odour, and sea lettuce coverage over 25%. Hypoxic water is slightly- to very cloudy, may be olive, lime green, or gray in colour, and has a mild to medium odour. Sea lettuce coverage is more than 25%, appears to be dying or unhealthy, and DO levels are under 50% of the normal value. When water is anoxic it is very cloudy, with a white or gray colour and medium to strong odour. Sea lettuce coverage may have quickly decreased as other conditions worsened, and most sea lettuce present is dead. Dissolved oxygen levels are zero or nearly zero, especially at the bottom (Crane, 2016).

The link below leads to an interactive map with the estuary survey points and photos from the 2020 field season.
https://www.google.com/maps/d/u/0/edit?mid=1c7VdmodU7jyiI5xPFybZJFVNEqK7IGsv&usp=sharing

Methods

To monitor the conditions throughout the estuary (besides the 2 locations with continuous data loggers) staff paddled from the Corran Ban Bridge, near Tracadie Bay, upstream to the head of tide (end of tidal influence). Using the YSI, readings were taken for DO, conductivity, pH, and temperature at 12 waypoints set approximately 250 m apart. Note that the nitrate probe must be removed before use in saltwater, so no nitrate measurements were recorded. In addition, notes were made of visual indicators of anoxic events where applicable. Visual indicators include the extent of sea lettuce coverage, water colour, and water clarity. There is also a rotten-egg-like smell associated with anoxia from the decay of the sea lettuce by bacteria. The estuary surveys were first performed 2020-07-10, then almost every week from 2020-07-21 to 2020-09-16.

Results & Discussion

Hypoxia is defined as having a dissolved oxygen reading under 2 mg/L and anoxia as reading 0 mg/L (Coffin et al. 2017). Low oxygen conditions were observed on 2 survey dates, 2020-07-10 and 2020-08-12. On the first occasion, hypoxic conditions were recorded at 75% of the sites, with only the 3 points nearest the bay over 2 mg/L (Figure 25 shows map of sites). On the second occasion, only 1 site was hypoxic (Table 6). The lowest DO recorded was 0.15 mg/L, and highest was 13.16 mg/L, these were at sites EWS-03 and EWS-08, respectively. Temperature and dissolved oxygen have an inverse relationship, where cold water can hold more oxygen than warm water (Xylem, 2019). The overall highest temperature was 26.2℃, recorded at site EWS-07 on 2020-08-12. This was the warmest day for 83% of the sites. EWS-08 stands out for having a temperature several degrees lower than the rest of the survey sites on this day. The tide was low and this site is close to a freshwater input, which may account for the difference. The lowest overall temperature was 15.0℃, recorded at site EWS-01 on 2020-09-16. This was also the coolest day for all of the sites. More temperature data can be seen in Table 7.

Observations from the estuary surveys can be found in Table 8, including water discolouration, smell, and presence of algae. The dominant macroalgae found in PEI estuaries is *Ulva* spp., which is present year-round, but typically reaches its maximum density in June-July. It normally exists as submerged mats, but at times they will rise near the surface (Coffin et al., 2017). During the estuary surveys, there were occasions where mats of algae could be seen on the bottom, but this was not always possible unless the water was clear. Floating algae was not observed until the 2020-07-10 survey, but was then present in various locations until the 2020-09-16 survey. In July, there were instances where the water ranged from a milky aqua to gray/green. The water colour seemed to return to a clear, normal colour at most sites by the final survey in September. The smell of decomposing algae was strongest on the 2020-07-08 survey, and began to fade out as time went on. Signs of hypoxia were most often observed in the area near the Pleasant Grove logger; the smell and milky colour lingered there the longest, and in the triangle of area between there, EWS-06 and EWS-09 floating algae was most often seen. On 2020-07-10, there were a few dead sticklebacks found at survey point EWS-08. Anoxic events have been recorded by the province in this estuary every year from 2011 to 2020 (Department of Environment, Water and Climate Change PEI, 2019; Department of Environment, Energy and Climate Action PEI, 2021).

Table 6. Dissolved oxygen (mg/L) measured with the YSI for the 12 Estuary Survey monitoring sites in the Winter River estuary. Red values are hypoxic, grey are without data. EWS-02 and EWS-03 were the only points with YSI readings taken on 2020-07-21, due to extra time available after checking the DO loggers that day. The missing points from 2020-07-28 are due to time constraints on that survey day. On 2020-09-16 survey point EWS-08 could not be measured due to an extremely low tide.

	EWS-01	EWS-02	EWS-03	EWS-04	EWS-05	EWS-06	EWS-07	EWS-08	EWS-09	EWS-10	EWS-11	EWS-12
2020-07-10	0.19	1.15	0.15	0.78	0.67	0.74	0.16	0.29	1.43	6.7	6.96	7.3
2020-07-21		12.66	12.85									
2020-07-28				5.03	5.72	5.46	5.65	9.75	3.83	5.65	4.98	4.34
2020-08-12	10.08	11.25	7.6	8.62	8.11	6.21	1.64	13.16	7.05	8.07	7.94	6.3
2020-09-16	10.82	7.15	8.49	8.93	8.35	12.23	9.64		9.33	10.22	9.37	9.02
Minimum DO by Site	**0.19**	**1.15**	**0.15**	**0.78**	**0.67**	**0.74**	**0.16**	**0.29**	**1.43**	**5.65**	**4.98**	**4.34**

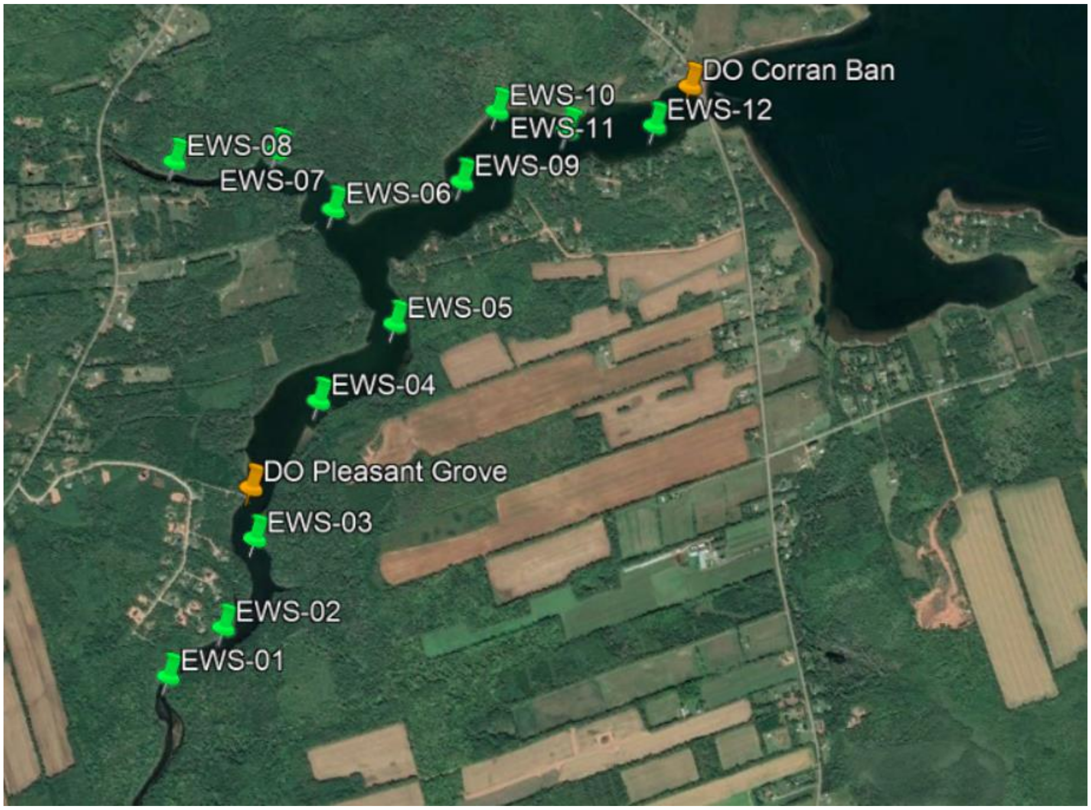


Figure 25. Map of points sampled during each Estuary Survey in the Winter River estuary. Shows proximity of each point to the bay and head of tide (end of tidal influence).

Table 7. Temperature (°C) data collected with the YSI during Estuary Surveys in the Winter River estuary for the 2020 field season. EWS-02 and EWS-03 were the only points with YSI readings taken on 2020-07-21, due to extra time available after checking the DO loggers that day. The missing points from 2020-07-28 are due to time constraints on that survey day.

	EWS-01	EWS-02	EWS-03	EWS-04	EWS-05	EWS-06	EWS-07	EWS-08	EWS-09	EWS-10	EWS-11	EWS-12
2020-07-10	21.4	22.5	21.8	20.6	18.8	18.6	19.4	20.8	18.4	18.0	18.0	18.6
2020-07-21		22.8	26.0									
2020-07-28				23.9	23.0	23.2	24.7	22.6	22.7	23.1	22.6	22.6
2020-08-12	25.2	25.9	25.4	25.3	26.0	24.8	26.2	19.5	24.6	24.6	25.1	25.3
2020-09-16	15.0	16.9	18.2	17.6	16.7	16.5	17.7	15.6	18.3	16.3	17.4	16.3

Table 8. Observations from Estuary Survey monitoring, where ✓ indicates presence and X indicates absence of visual indicators. Estuary Watch Index Score is based on how our field observations fit into the categories laid out by the province (Crane, 2016). A description of these categories can be found in the Introduction above. (*water appears healthy, but it was low tide, and these points are at the furthest point from tidal influence, so water was very low.)

Date	Location	Water Discoloured	Smell	Floating Algae	Estuary Watch Index Score
2020-07-03	PG	✓	✓	X	hypoxic
2020-07-03	CB	✓	✓	X	hypoxic
2020-07-08	PG	✓	✓	X	anoxic
2020-07-08	CB	✓	✓	X	anoxic
2020-07-09	CB	✓	✓	X	impaired
2020-07-09	PG	✓	✓	X	hypoxic
2020-07-10	EWS-12	✓	X	X	impaired
2020-07-10	EWS-06	✓	-	✓	impaired
2020-07-10	PG	✓	✓	✓	hypoxic

2020-07-10	EWS-03	✓	✓	✓	hypoxic
2020-07-28	PG	✓	-	✓	impaired
2020-08-04	CB	✓	X	-	impaired
2020-08-04	PG	✓	X	✓	impaired
2020-08-12	PG	✓	-	mats on bottom	impaired
2020-08-12	EWS-07	X	-	-	healthy*
2020-08-12	EWS-04	✓	-	X	hypoxic
2020-08-17	PG	✓	-	✓	impaired
2020-08-17	CB	✓	-	-	impaired
2020-08-20	PG	✓	-	✓	impaired
2020-08-20	CB	✓		-	impaired
2020-09-09	PG	✓	X	✓	hypoxic
2020-09-09	CB	X	-	X	healthy
2020-09-16	CB	X	-	mats on bottom	healthy
2020-09-16	EWS-09	X	-	✓	healthy*
2020-09-16	PG	X	-	mats on bottom	impaired
2020-09-16	EWS-02	✓	-	mats on bottom	impaired

5.5 Temperature Loggers

Introduction

Water temperature was recorded using automated data loggers throughout the Watershed to monitor periods of high temperature. Temperature provides an indication of stream health, and whether the conditions are hospitable for fish. Prolonged high temperature conditions can be problematic for fish such as Brook Trout (Millar et al., 2019). To assess the temperatures in our streams, we used the temperature class system used by the Nature Conservancy of Canada (NCC). It is a rating system for freshwater systems based on the mean summer temperature of the water. There are 3 categories: “Cold” for average summer temperatures less than or equal to 18°C, “Cool” for averages between 19 and 21°C, and “Warm” for averages greater than or equal to 22°C. These categories can tell us a lot about the health of our streams and if the conditions are hospitable to fish (Millar et al., 2019).

The link below leads to an interactive map with temperature and depth logger locations for the 2020 field season.
https://www.google.com/maps/d/u/0/edit?mid=1c7VdmodU7jyiI5xPFybZJFVNEqK7IGsv&usp=sharing

Methods

To record temperature there were loggers placed at 10 sites; 4 temperature-only loggers at the surface and bottom of Hardy Mill Pond and Officer’s Pond, and 6 depth loggers used to record temperature at Hardy Mill Pond Outlet, Officer’s Pond Outlet, Winter River at Apple Orchard, Winter River at Union Pumping Station, Winter River at Tim’s Creek, and Beaton’s Creek. HOBO Pendant UA-001-08 Temperature Data Loggers were to measure temperatures at the bottoms and surfaces of Hardy Mill Pond and Officer’s Pond. They were positioned in the middle of the ponds, using GPS points from previous years for accuracy. The surface and bottom temperature loggers were both attached to a rope, with an anchor of bricks at the bottom and buoys at the top. The temperature loggers then took readings hourly from June to September. They had to be accessed by kayak/canoe for deployment and retrieval. The HOBO U20L-01 Water Level Loggers set up at our depth logger sites were also used to measure temperature every hour from June to December. They were attached to rebar that was pounded into the stream bed. For more detailed information on depth logger methods, please refer to Section 6.2: Depth Loggers.

Results

While our temperature loggers only recorded temperature from 2020-06-23 to 2020-09-21, our depth loggers recorded temperature from 2020-06-18 to 2020-12-14. The maximum water temperature throughout the sites ranged from 16.99°C to as high as 29.25°C. The highest temperatures reached were recorded at the pond sites, with the Officer's Pond Surface reaching the highest average summer temperature and the Hardy Mill Pond Surface recording the highest maximum temperature. These areas have historically been warmer than surrounding areas of the river. However, it should be noted that unlike the previous year, both pond surfaces have been classified as "warm" according to the Nature Conservancy of Canada Guidelines. A summary of the 2020 temperature data can be viewed in Table 9.

Table 9. Summary of 2020 temperature data from WRTB watershed. Temperature classes determined according to Nature Conservancy of Canada (NCC) guidelines. Includes temperature data from both temperature loggers (TL) and depth loggers (DL).

Logger	Logging Period (days)	NCC Temperature Class	Average Temperature (°C)	Average Summer Temperature (°C)	Maximum Temperature (°C)	Longest # Hours in Stress Zone
Officer's Pond Surface TL	90	Warm	21.89	22.85	28.16	855
Officer's Pond Bottom TL	90	Cool	20.53	21.18	26	805
Officer's Outlet DL	179	Cool	15.5	21.82	25.51	812
Hardy Mill Pond Surface TL	90	Warm	21.42	22.48	29.25	697
Hardy Mill Pond Bottom TL	90	Cold	14.45	14.11	16.99	0
Hardy Mill Outlet DL	189	Cool	14.45	19.51	25.9	253
Apple Orchard DL	189	Cold	11.31	14.68	20.04	1
Beaton's Creek DL	179	Cold	12.11	16.26	21.38	11
Tim's Creek DL	189	Cold	12.08	15.9	19.85	0
Union Station DL	178	Cold	11.61	15.73	22.05	35

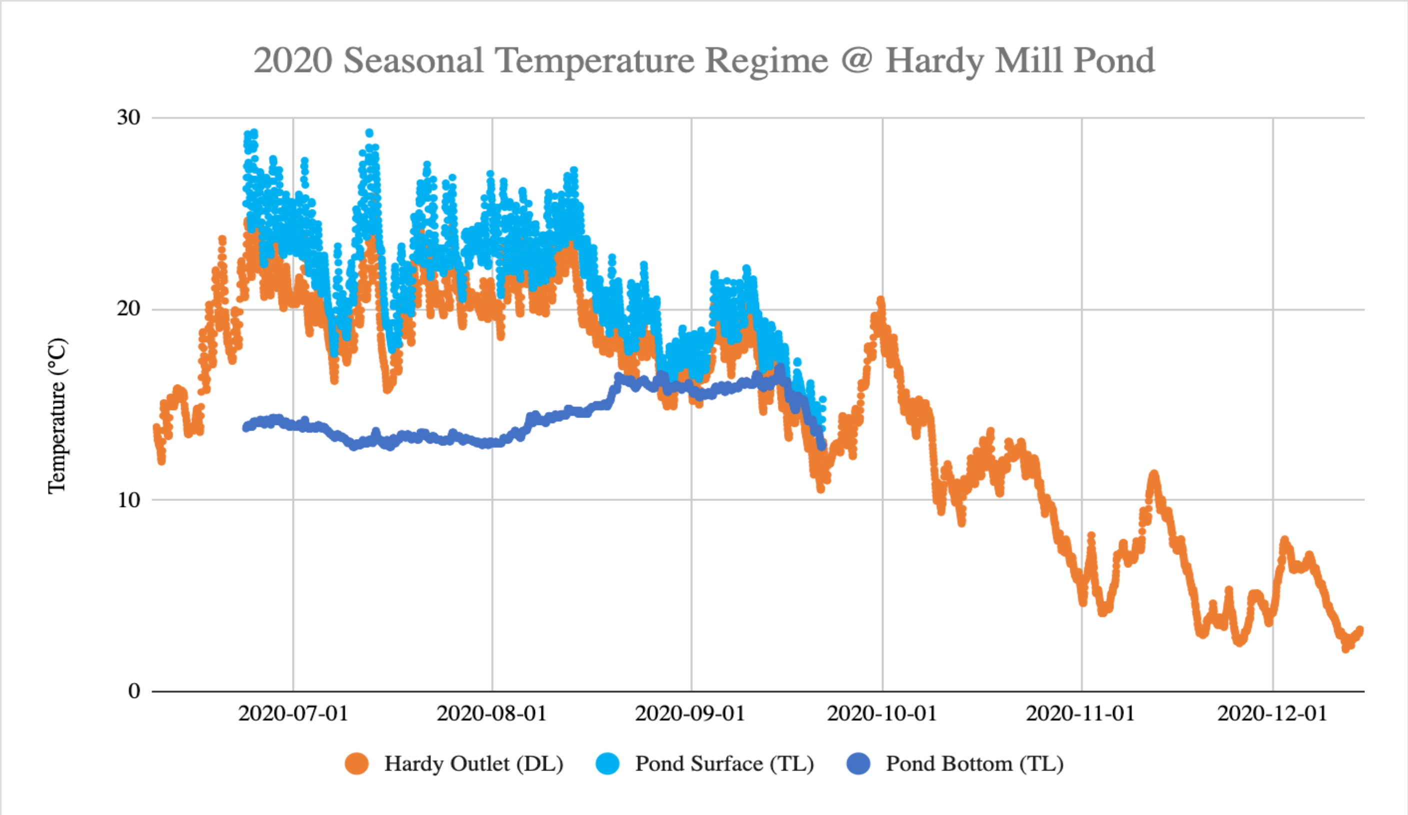


Figure 26. Hardy Mill Pond temperature regime across all loggers deployed for the 2020 field season.

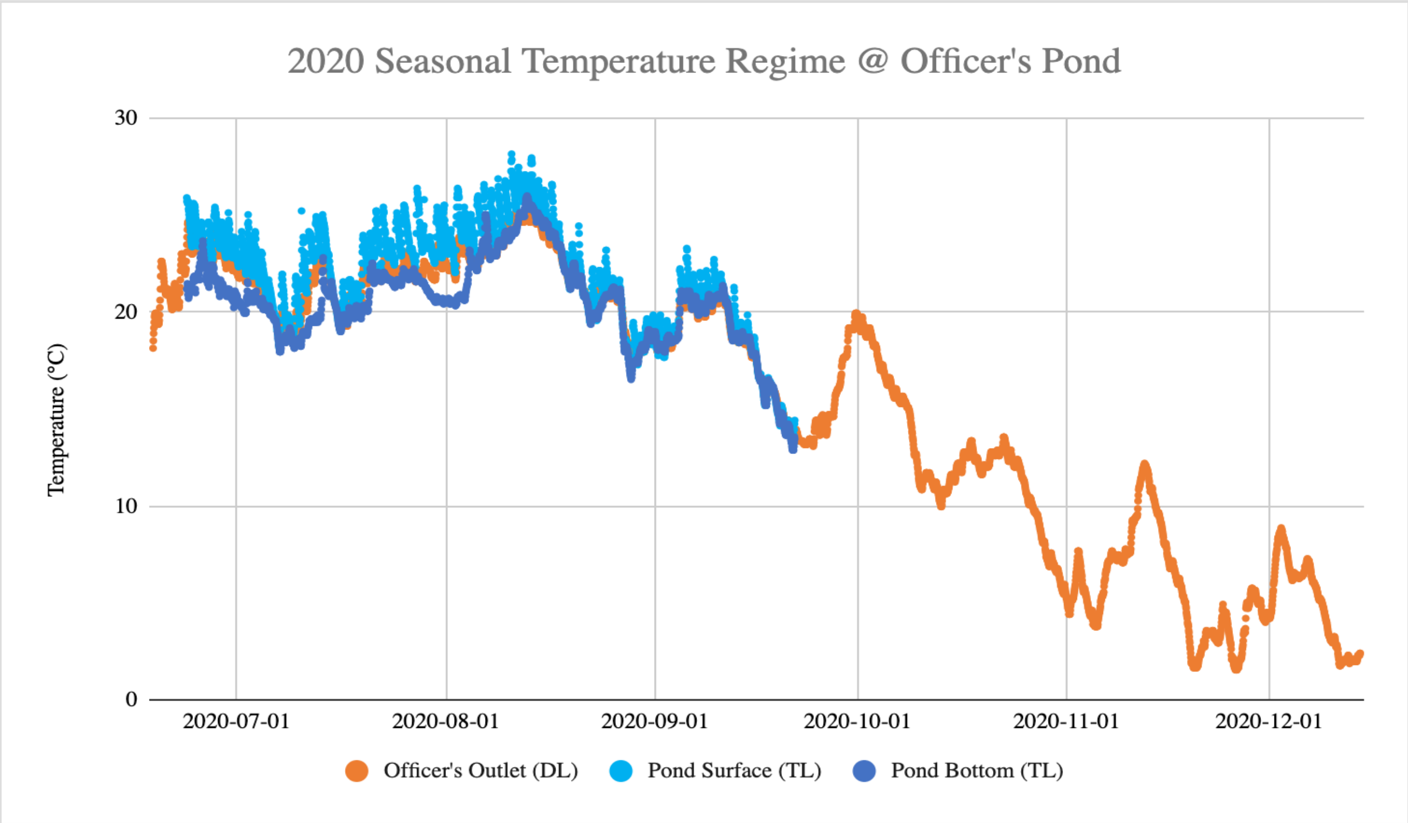


Figure 27. Officer's Pond temperature regime across all loggers deployed for the 2020 field season.

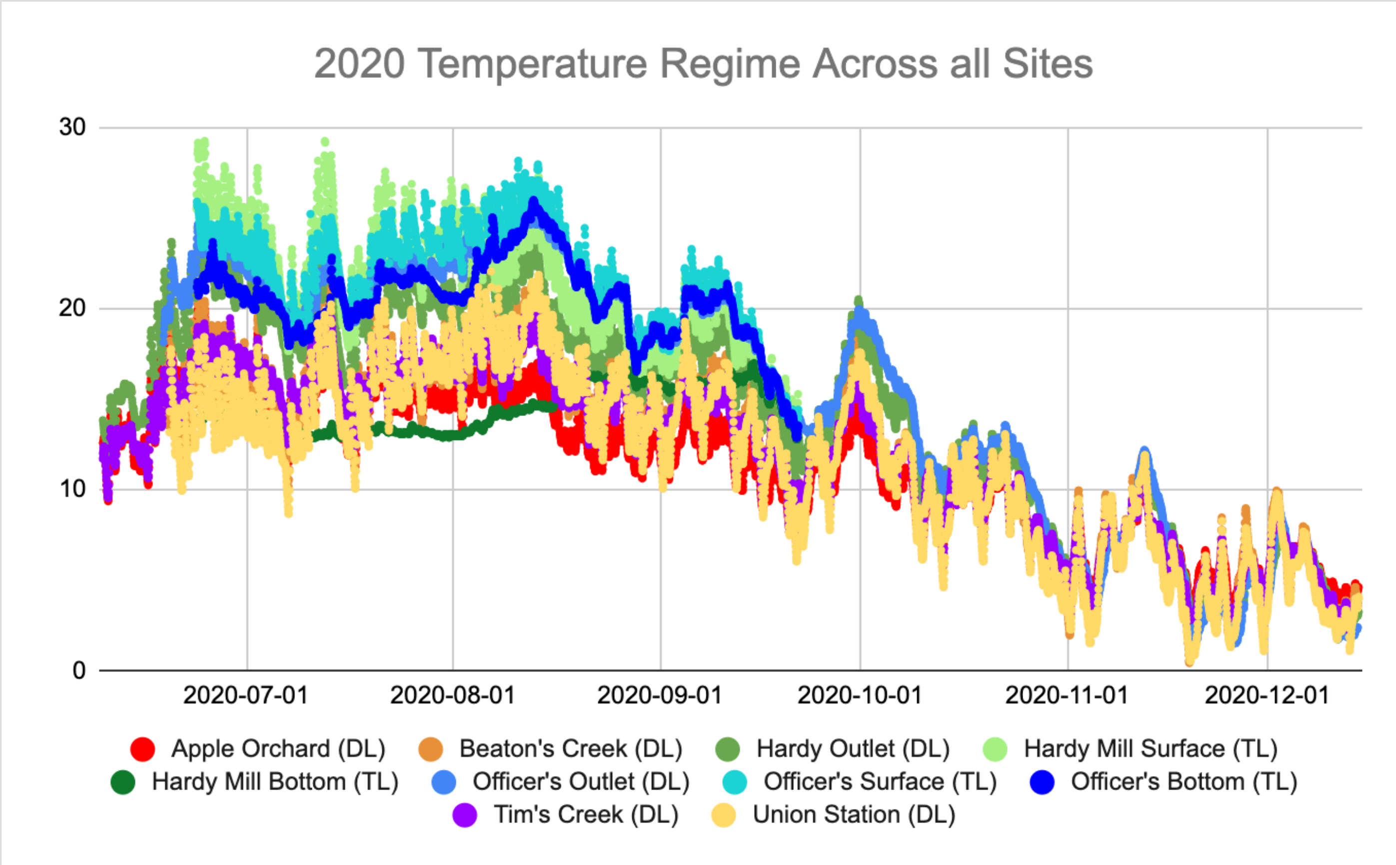


Figure 28. Temperature monitored across the Winter River – Tracadie Bay watershed for the 2020 field season, at both temperature logger (TL) and depth logger (DL) sites.

Discussion

All 10 loggers successfully captured temperature data for their full deployment. In previous years, there have been issues with lost or malfunctioning loggers. Warmer water has many effects on aquatic life, influencing growth rates, changes to community structure, and the amount of available dissolved oxygen in the water (Credit Valley Conservation, 2011). The loggers were generally set up in locations to measure the temperature of water before entering and after exiting pond systems, as well as within the pond itself, to monitor for areas of warm water that may inhibit the movement and survival of aquatic organisms. Brook Trout can tolerate temperatures ranging from 0°C to 20°C, with their optimal growth occurring between 11°C and 18°C (Millar et al., 2019). With such high ranging temperatures this field season, the Tim’s Creek and Hardy Mill Pond Bottom monitoring sites were the only 2 to stay within the tolerated temperature range for 100% of the time, while all 3 sites at Officer’s Pond spent a significantly troubling amount of time in the Stress Zone of over 20°C.

According to the NCC ranking system, only 5 of the 10 monitoring sites were classified as “cold”, 3 were classified as “cool” and 2 were classified as “warm” (Table 9). All loggers that were placed in stream channels as well as the Hardy Mill Pond Bottom logger were ranked as Cold with the longest time spent in the Stress Zone ranging from 0 to 35 consecutive hours. The remaining sites, involving both outlets, both pond surfaces and the Officer’s Pond Bottom monitoring site, all spent drastic amounts of time in the Stress Zone with the largest number of consecutive hours hitting as high as 855 at the Officer’s Pond Surface site. The temperature at the bottom of Officer’s Pond seems unusually high this year. Unfortunately the Officer’s Pond Bottom logger was lost in 2019, so there is no data to compare with that year. In 2018, the maximum summer temperature at this site was 20.2°C and the average was 16.9°C. This year the maximum was 26°C and the average was 21.18°C. The longest period in the Stress Zone was only 40 hours in 2018, whereas it was 805 hours this year. Pond bottoms can be cold water refugia for mobile fish species during summer months (Ebersole et al., 2020), so this is concerning. The warming effect from ponds can be felt downstream as well, as the warm water from the pond surface is fed into the stream, with potential to drastically increase the stream temperature (Credit Valley Conservation, 2011).

This summer the drought experienced in PEI likely impacted the water temperature within the ponds. Without rainfall to flush the pond, and with limited groundwater flow (due to a history of water extraction by the City of Charlottetown), water has a long time to continue warming in the shallow pond before moving on downstream. The amount of algae within Officer's Pond was also noticeably worse this year. This was commented on by our staff members and by the landowner. There were also numerous dead fish found in this area (Figure 30) and while the cause of this is unknown, there is a possibility it was related to high temperatures or oxygen issues related to the algae build up. Our staff members made efforts to clear some of this algae using hand tools as a temporary improvement (see Figure 29). Throughout the summer, large quantities of algae also accumulated near the Officer's Outlet depth logger, which were routinely cleared away by staff during water discharge measurements.

Figure 29. Crew members using rakes to clear away built up algae at Officer's Pond.

Figure 30. An example of the numerous dead Gaspereau found at Officer's Pond during the 2020 field season.

6 Water Quantity Monitoring

6.1 Headwater Surveys

Introduction

Headwater surveys give an indication of where stream flows are most impacted by changes in groundwater. The headwater streams are assessed visually and classified into 1 of 5 categories to document changes in surface water connectivity and water velocity throughout the length of the stream. By obtaining this data year after year, it aids in understanding how water extraction and other conditions affect water levels and flow. We follow the 2015 protocol developed by David Cody, Qing Li, and Shawn Hill which allows for comparison between other watershed groups on PEI to see the impacts of water extraction in our river compared to river systems that are not impacted.

Due to the COVID-19 pandemic, there was a late start to the field season and the crew did not get a chance to complete all branches normally surveyed in May. Some sites were completed in late May and early June, but others were omitted this year due to lack of suitable survey conditions within the recommended time frame. The 2 streams that were surveyed in the spring were again surveyed in September.

Methods

Headwater surveys must be conducted between May 1-15 and September 1-15, without any significant rainfall or snowmelt events occurring in the previous 3 days. If conditions allow, surveying slightly outside of these timeframes is still acceptable. Sections of the stream are classified into 1 of 5 categories based on a visual assessment: 0 – no surface water, 1 – surface water in pools only, 2 – surface water present but no visible flow, 3 – flow only interstitial, 4 – surface flow continuous.

This year the Brackley and MacLauchlan streams were surveyed. Staff walked up these headwater streams until they reached a point that was dry or until the most upstream point was reached. Along the way, GPS points were taken as the streambed shifted between the different categories. Photos were taken at each point, and notes recorded in a field book.

Results and Discussion

Generally, groundwater levels are low and thus streams are drier in the fall, after a season of heat and greater use of groundwater (by plant roots and by human extraction), than in the spring when groundwater levels are highest. This year, PEI experienced an extreme drought, so many streams in the Watershed had low levels of water (see Figure 35 in Section 6.3 for a map of drought conditions this summer). This could be seen in the headwater survey results as well. The Brackley branch had 2.16 km of stream go dry this summer. The survey at the MacLauchlan branch ended at a Category 1, where a wide wetland began (thus no more defined flow channel). The maps below show the results from this field season (Figures 31 & 32).

The Brackley branch historically runs dry most summers. It is located between the wellfields at the Union pumping station and the Brackley pumping station. In 2019 extraction by the City of Charlottetown from the Brackley wellfield was greatly reduced due to additional capacity becoming available at the Miltonvale wellfield, so we expected to see improvements in the Brackley branch. Much less of the stream went dry in 2019, but it was also an unusually wet year. This year with continued low extraction but with a drought, the distance of stream that went dry is comparable to numbers we've seen in the past (Table 10). It will be interesting to see headwater survey results in a future year where precipitation is within normal range and water extraction levels continue at current levels or hopefully even lower levels.

Table 10. Year-over-year headwater survey summary data for the Brackley branch in the WRTB watershed.

	Distance of Dry Stream (m)					# springs mapped on branch	Approximate Distance to Wells (m)
Tributary Name	2016	2017	2018	2019	2020		
Brackley	3,295	2,285	2,369	1,195	2,160	28	1,000

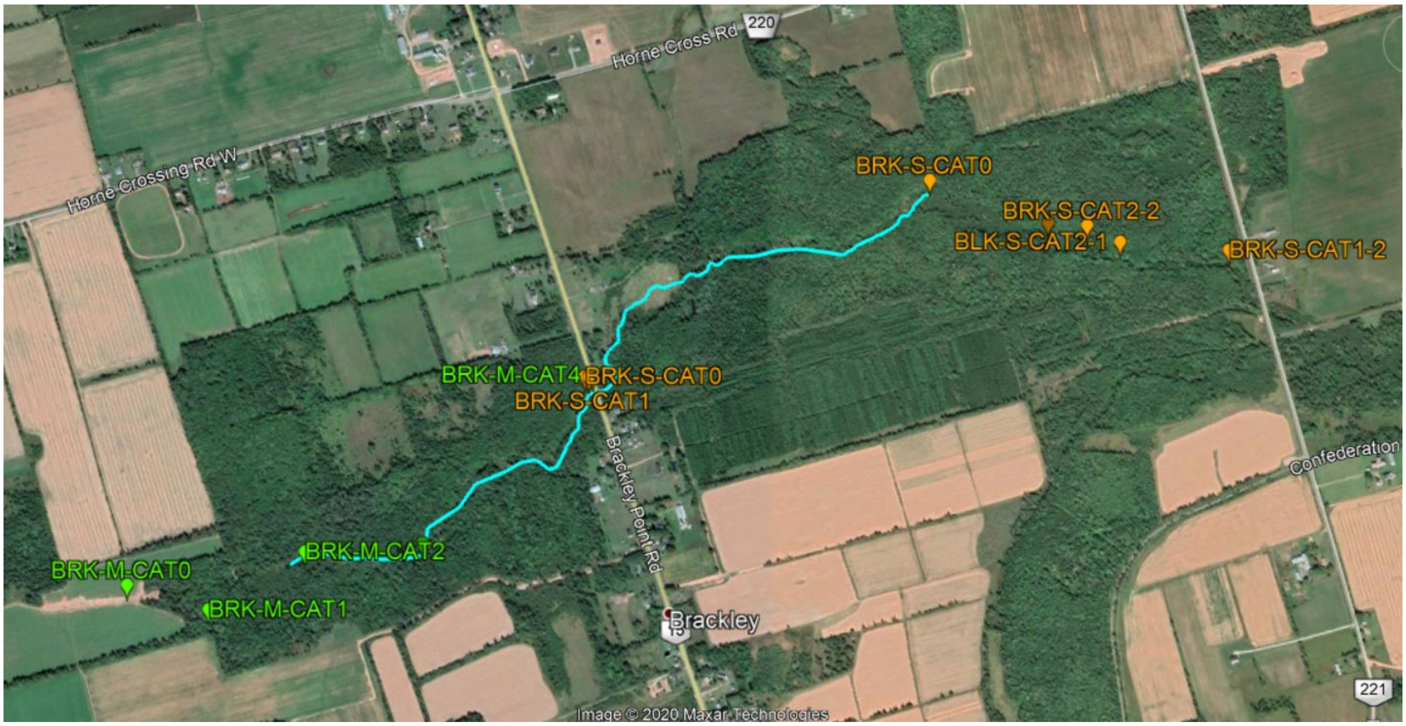


Figure 31. Brackley branch headwater surveys for 2020 field season. Blue line marks the section of the stream that went dry this summer. Green points are from the May survey, orange from September.

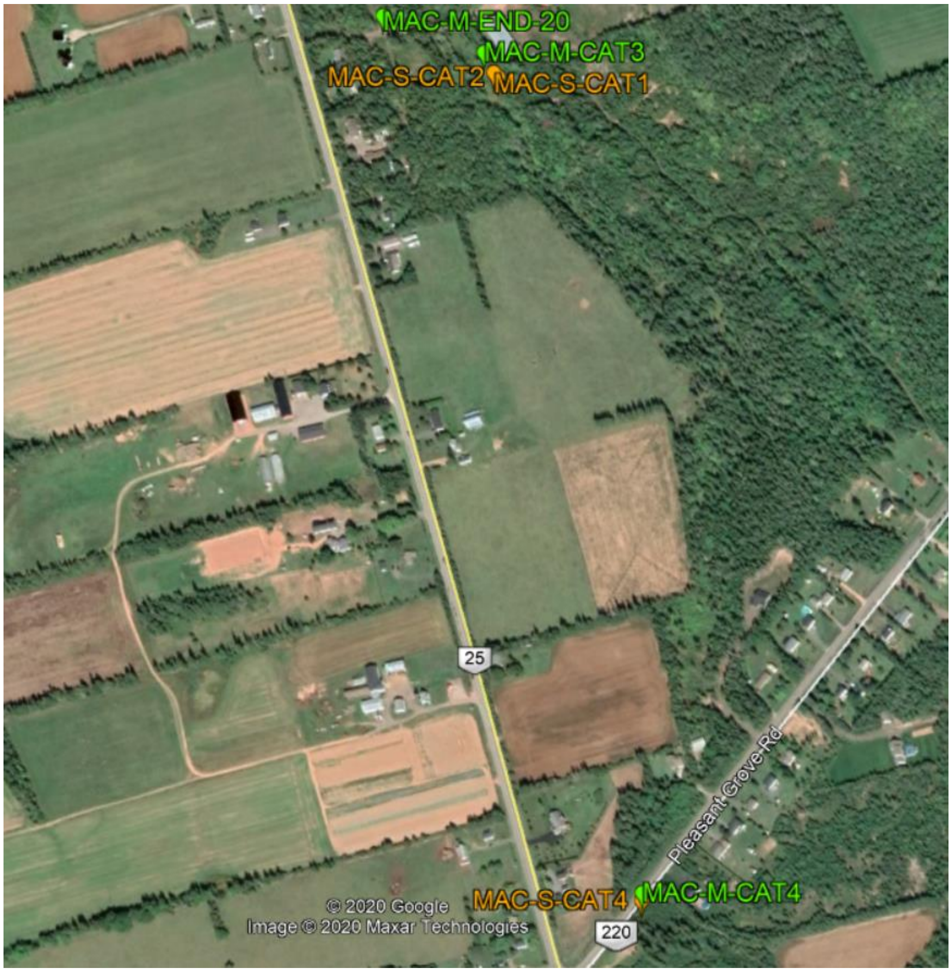


Figure 32. MacLachlan branch headwater surveys for the 2020 field season. Green points are from the May survey, orange from September. Survey stopped at the top edge of the map above, despite not reaching a Category 0, because the stream turned into a wide wetland with no defined channel.

6.2 Depth Loggers

Introduction

Depth loggers were deployed in the same 6 locations throughout the Watershed that were used in the 2019 field season. They were located at Beaton's Creek, the outlets of Hardy Mill Pond and Officer's Pond, and along the main branch of Winter River at the Tim's Creek, Union Pumping Station, and Apple Orchard sites. A logger was also set up outside the Watershed office as a control, about a meter above the ground, to measure changes in atmospheric pressure. With the readings from the depth loggers and stream measurements taken in the field, flow values were determined for each of the sites.

Flow, or discharge, is defined as the volume of water moving past a designated point over a fixed time period (U.S. Environmental Protection Agency, 2012). Stream flow is affected by weather, seasonal changes, and water withdrawals. The depth logger data provides information regarding the flow of streams and how "flashy" they are. The flashiness of a stream is determined from the number of times the discharge reaches 3x that of the median flow in a season (Giroux et al., 2014). In our data, the number of high flow pulses, where the flow was greater than 3x the median, was counted to compare flashiness between stream sites.

With this data, calculations were performed to determine the Richard-Baker Flashiness Index (R-B Index) of the streams as well. "The R-B Index is a measure of flow variability and flashiness. The index measures oscillation in discharge relative to total discharge, and as a result, characterizes the way a catchment processes inputs into its stream flow outputs" (Giroux et al., 2014). For example, when water flows from the land into a stream during heavy rain events, if it causes a large, rapid increase in the stream's discharge each time before settling to normal, it likely has a high R-B Index value and is a flashy stream. This is typically seen in smaller streams, as larger water courses tend to absorb the input without a drastic change from the normal flow rate (Baker et al., 2004).

The link below leads to an interactive map with depth logger locations from the 2020 fields season.
https://www.google.com/maps/d/u/0/edit?mid=1c7VdmodU7jyiI5xPFybZJFVNEqK7IGsv&usp=sharing

Methods

In total, 6 HOBO U20L-01 Water Level Loggers took readings once every hour for temperature and barometric pressure while deployed in the streams from June to December. Each depth logger was affixed to a piece of rebar using either wire or zip ties looped through its cap. The cap was also wrapped in bright coloured duct tape for extra reinforcement and to aid in finding the logger in times when the water was murky. The rebar was then pounded into the streambed with a mallet until the logger sat level with the bottom.

The loggers were monitored weekly from their deployment in mid June to their retrieval the third week of December. During these weekly monitoring activities, staff performed maintenance such as clearing off any sediment or debris to maintain the accuracy of the depth readings being recorded by the logger. The YSI was used to measure the temperature, dissolved oxygen, conductivity, pH, and nitrate levels of the water at every logger location during each flow measurement. This was for a separate project to track long term water quality parameters throughout the Watershed.

We used the same general methodology in the 2020 field season as was used in 2019 for velocity and channel measurements, see APPENDIX D: Depth Logger Methods for details. However, a number of changes had to be made to accommodate the COVID-19 restrictions in place during the field season. For example, staff members did not share or take turns using the same piece of equipment. Instead, tasks and equipment were assigned. For example 1 person would use the YSI and take notes, while the other person would use the measuring tape and meter stick. When doing the velocity measurement with the tennis ball, both individuals wore gloves when handling the ball. The ball was dropped by the first person and thrown back to them once it had drifted down the stream by the second person. The methods for our depth loggers were adopted from the protocol used by Parks Canada for the PEI National Park (Hawkins, 2014).

Results

Data from Officer's Pond will not be used in any analyses because there was an obvious logger malfunction. The minimum flow values for the 6 depth logger sites varied from 0.006m^3/s to 0.216m^3/s while the maximum flows had greater variance, from 0.069m^3/s to 0.726m^3/s. It can also be observed in Figure 33, that Hardy Outlet and Union Station had noticeable differences between their minimum and maximum flow values. These were found to be the flashiest sites, having the highest R-B Index values and they were also the only sites to have pulses above the high flow threshold. The other sites, showing no high flow pulses as well as low R-B Index values, were relatively stable in comparison.

The minimum flow values varied throughout the sites ranging from late summer to late fall. The lowest flow for Union Station happened on 2020-08-22, Hardy Outlet was 2020-09-02, Apple Orchard was 2020-09-06, Beaton's

Creek was 2020-09-12, and Tim's Creek was 2020-09-20. The dates for the maximum flow values at each site went as follows: for Tim's Creek it took place on 2020-06-06 and for Apple Orchard, Beaton's Creek, Hardy Outlet and Union Station the maximum flow took place on 2020-12-06.

Table 11. Depth and flow data collected from the 2020 depth logger sites.

Site	Average Wetted Width (m)	Average Depth at Logger (m)	Median Flow (m3/s)	# High Flow Pulses	R-B Index Value
Apple Orchard	5.59	0.296	0.197	0	0.02
Beaton's Creek	1.88	0.197	0.029	0	0.08
Hardy Outlet	2.58	0.102	0.035	4	0.10
Tim's Creek	10.63	0.119	0.367	0	0.04
Union Station	4.19	0.233	0.014	9	0.26

Table 12. R-B Index values from 2017-2020 field seasons using data collected from the depth loggers. Values closer to 1 indicate flashier sites, values closer to 0 are less flashy. *Beaton's Creek data for 2018 was not for a full season, it spent the first half of the season at the old Friston site.

Site	R-B Index Value			
	2017	2018	2019	2020
Apple Orchard	0.03	0.25	logger lost	0.02
Beaton's Creek	logger used to be at Friston	0.01*	0.09	0.08
Hardy Outlet	0.17	0.68	0.48	0.10
Officer's Outlet	0.02	0.22	0.14	logger malfunction
Tim's Creek	0.05	0.12	0.12	0.04
Union Station	0.33	0.92	0.62	0.26

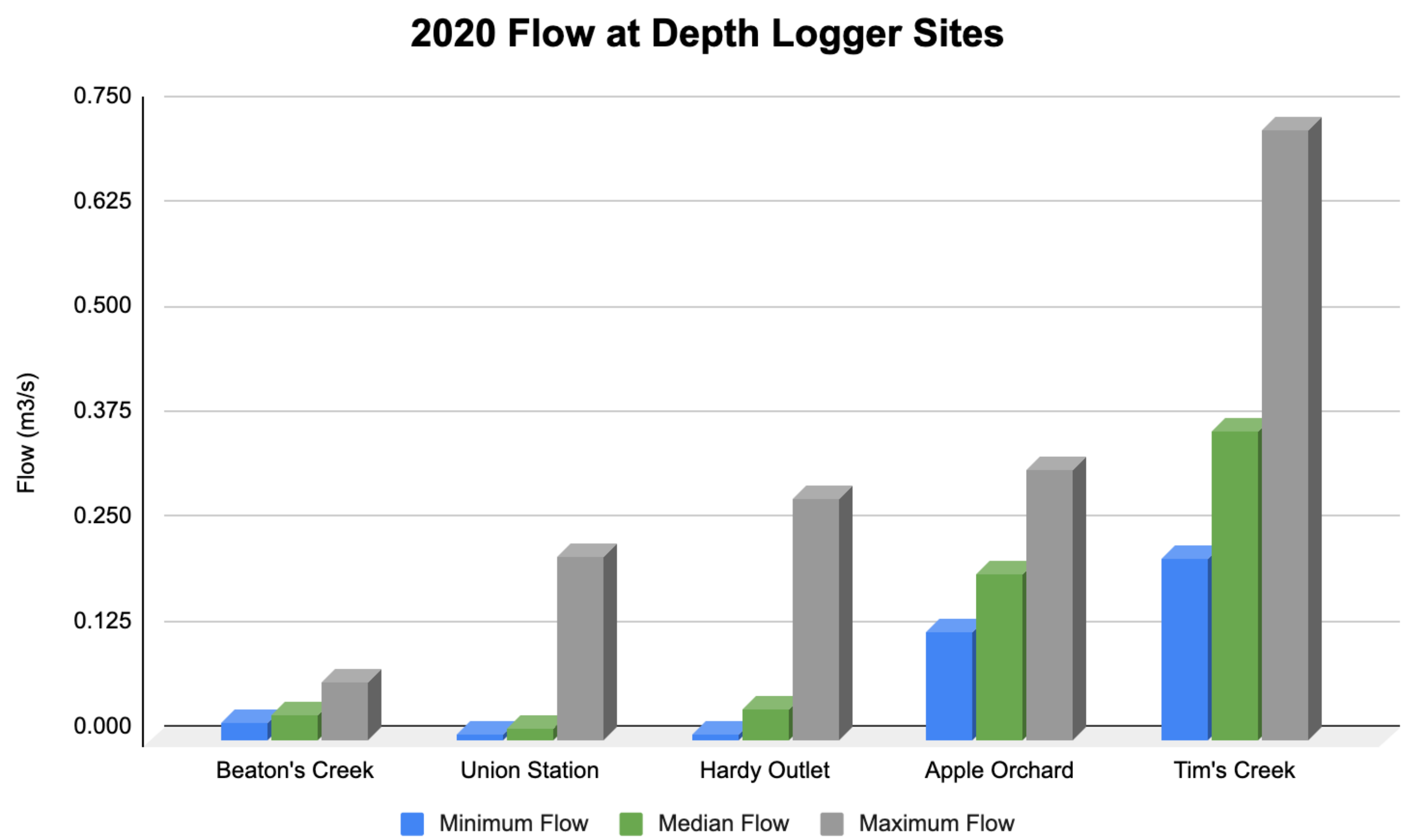


Figure 33. Maximum, minimum, and median flow values for the 2020 field season at each of the depth logger sites (in order of upstream to downstream). Note that the depth logger location for Officer's Outlet has been omitted due to logger error.

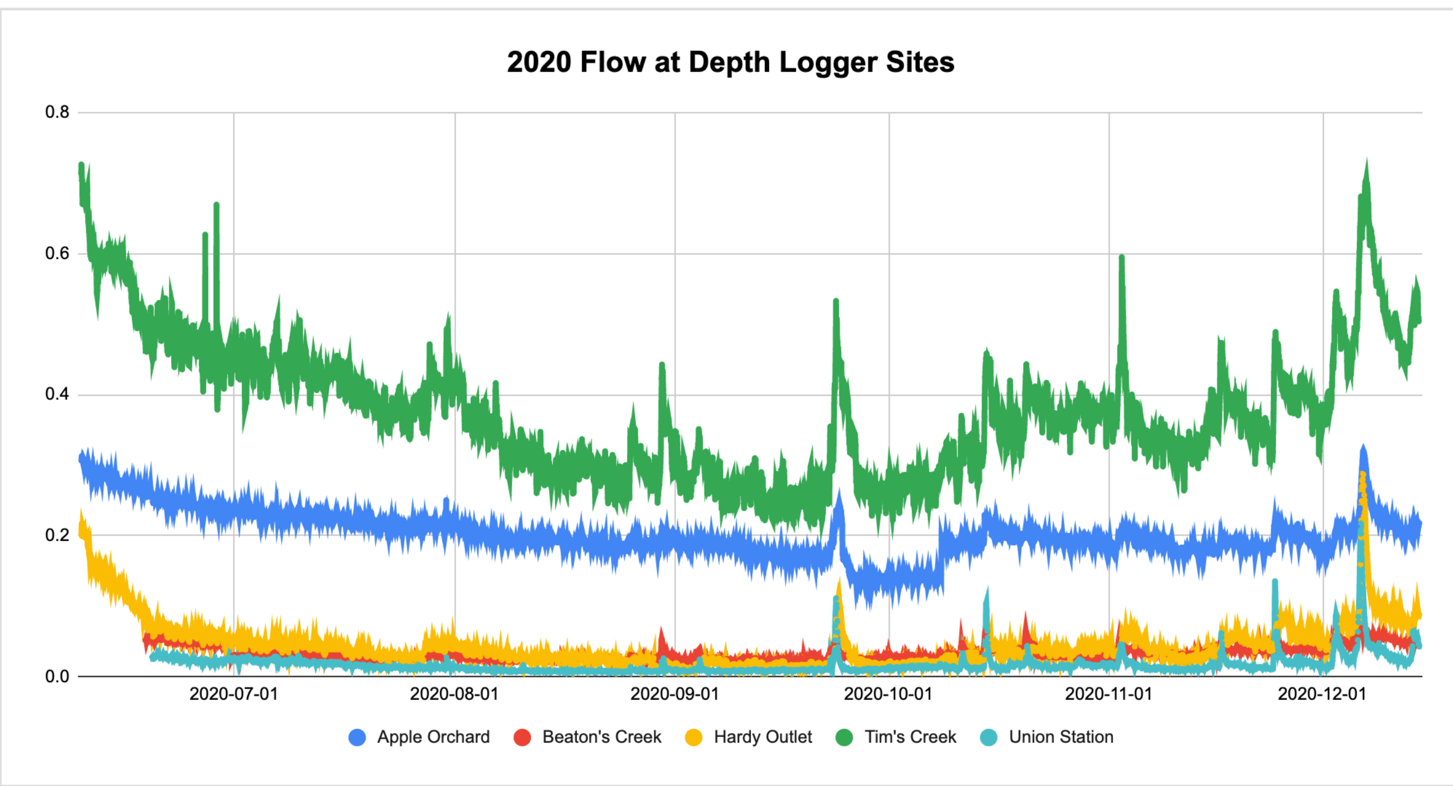


Figure 34. Flow values for the 2020 field season at each of the depth logger sites. Note that the depth logger location for Officer's Outlet has been omitted due to logger error.

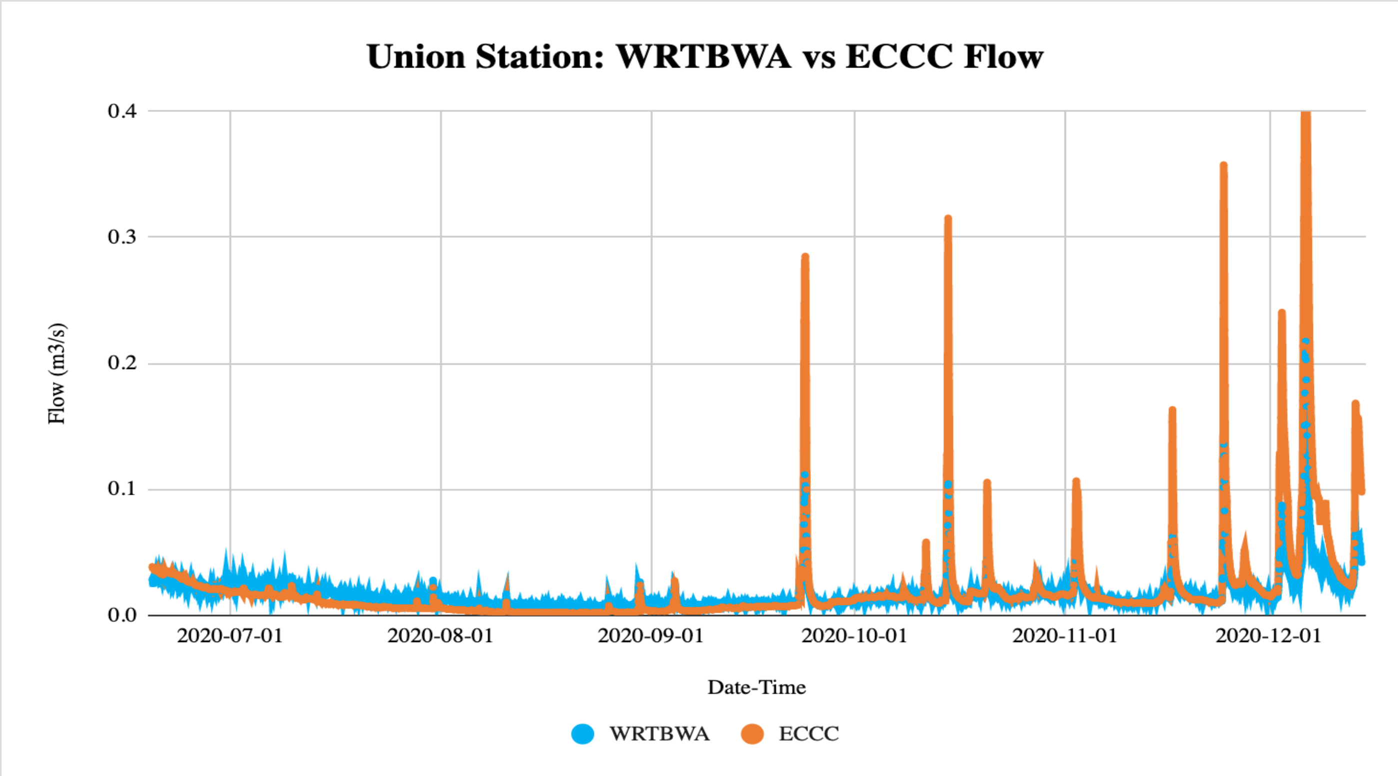


Figure 35. Measured flow at Union Station is compared from the WRTBWA depth logger and data collected by Environment and Climate Change Canada (ECCC).

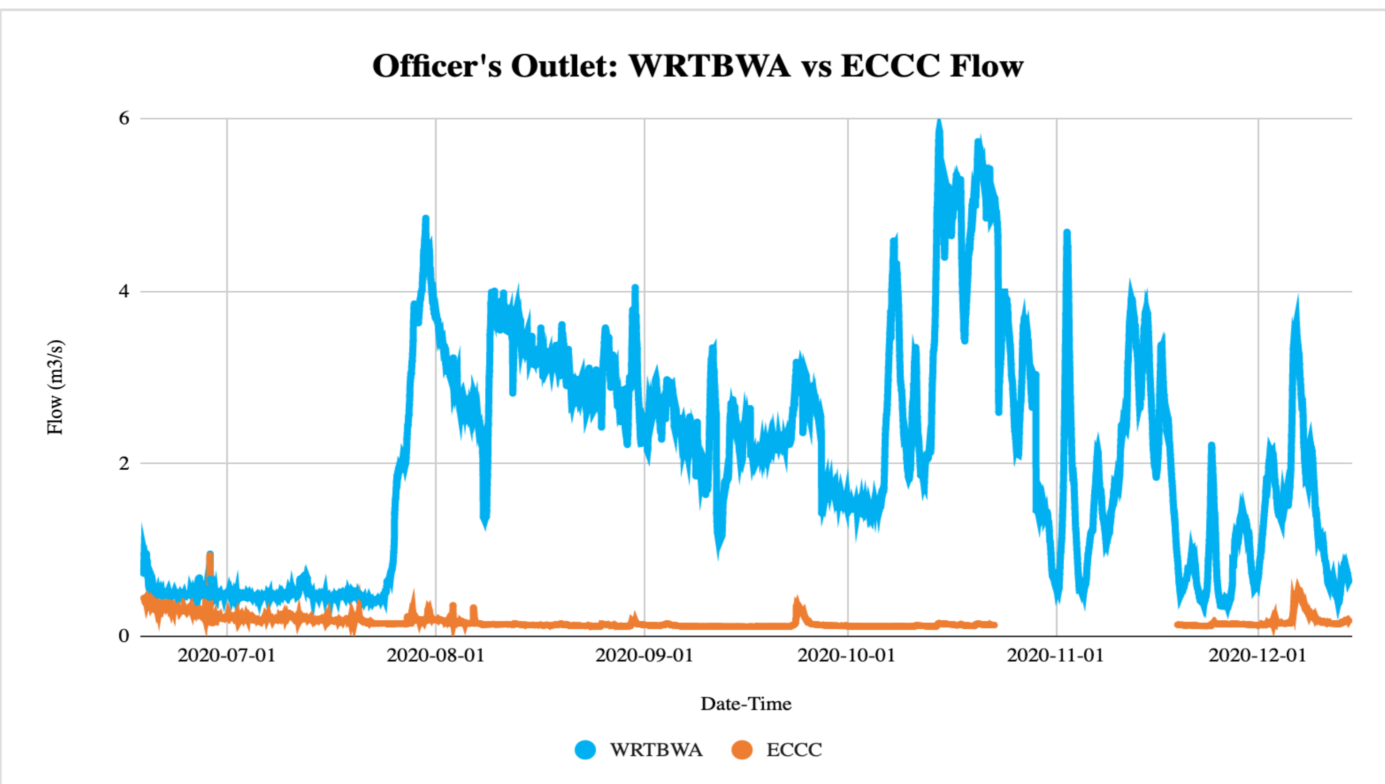


Figure 36. Measured flow at Officer's Outlet is compared from the WRTBWA depth logger and data collected by Environment and Climate Change Canada (ECCC). This logger had an obvious malfunction, starting in late July and persisting for the remainder of the logging period.

Discussion

Data collected from the depth loggers was used to determine which of the streams were most flashy. The term “flashiness” refers to the frequency and rapidity of short-term changes in stream flow, which is especially evident during runoff events (Baker et al., 2004). Monitoring the flashiness of streams provides insight into how dramatic an impact heavy rain events have on particular streams and their inhabitants. Changes in the flashiness of streams can greatly affect the presence and distribution of stream biota (Hawkins, 2014).

To compare streams in a standardized way, the R-B Index can be used. The R-B Index measures oscillations in flow relative to total flow, providing a useful characterization of the way watersheds process hydrologic inputs into their streamflow outputs (Baker et al., 2004). The index has a scale of 0 to 1, where streams with values closer to 1 are most flashy, and those near 0 are more stable. R-B Index values tend to decrease with increasing watershed size, and it has commonly been observed that small streams are flashier than large streams (Baker et al., 2004).

From upstream to downstream, the order of sites along the Winter River were: Union Station, Hardy Outlet, Apple Orchard, Officer’s Pond, then Tim’s Creek. The logger at Beaton’s Creek is on a different system. There was a logger malfunction at Officer’s Pond, so it was omitted from our data. At each site, there is a greater volume of water passing through than at the site immediately before. The larger streams have more opportunity for the effects of the increased volume to be absorbed with little change to the flow rate (Baker et al., 2004). This rings true for the Union Station logger, but the other sites were in a slightly different order for largest to smallest RBI (Table 11).

Every stream is unique in its own rates and processes, but generally seasonal patterns of stream flow depend on precipitation patterns (USGS, n.d.-b). Data between years can be compared to identify dry versus wet years, and to note changes to the typical trends. The depth logger site at Union Station had the highest R-B Index value, as was true in years 2017 through 2019 (Table 12). The only sites with high flow pulses this year were Union Station and Hardy Outlet, with 9 and 4 pulses, respectively. Almost all sites had a lower R-B Index value than last year. This year experienced persistent drought conditions, while last year was particularly wet. The decrease in heavy rain events may have been a factor in this drop.

Areas with greater urban and agricultural land use tend to disrupt the natural flow regimes of streams towards becoming flashier and decreasing their base flow. Much of our Watershed, and PEI for that matter, is made up of residential and agricultural land. These are among the main contributors to increased flashiness through the creation of large impermeable surfaces. The pathway for runoff water to reach the stream is much more direct, not slowed like in forest or wetland ecosystems (Baker et al., 2004). More stable streams are healthier in terms of both biotic and abiotic factors. With sudden high discharge events, banks can be scoured out, heavy erosion can occur, and the normal activity of aquatic species can be disrupted. Reestablishing a more natural streamflow regime is an important factor for stream restoration (Baker et al., 2004).

Environment and Climate Change Canada (ECCC) have a flow station near our Union depth logger site that we use to compare with our collected data. Up until midway through the month of September, the Union depth logger and ECCC data followed similar flow patterns (Figure 35). While data from ECCC shows higher spikes in flow then the WRTBWA depth logger recorded, both experience spikes at similar points of time.

The logger at Officer's Pond recorded exceptionally high flow readings this year. We compared it with data from the nearby ECCC flow station, and discovered there was an obvious logger malfunction (Figure 36). As such this data has been omitted from our results. The abundance of floating algae that collected around the logger may have contributed to the faulty readings by influencing the pressure at the logger site. Each time the crew visited the Officer's Pond logger, the algae was cleared away, but was back by the next site check.

6.3 V-Notch Weirs

Introduction

Weirs are pieces of sheet metal, cut with a v-shaped notch used to control the flow of water coming from a spring so that it can only pass through that standardized shape, allowing calculation of discharge from the spring following a simple measurement with a ruler. The weirs were first installed in 2013 at a large number of sites. Over time the number of sites that can be maintained has been reduced, but the sites that are still in use have 8 seasons of flow data.

There were 12 weirs in place throughout the Watershed this year. There were 5 along the Brackley branch, 2 each at the Pleasant Grove and Tim's Creek branches, and 1 each on the Cudmore, Vanco and Affleck branches. An old weir site (Cudmore #3) was monitored for water depth all season as well, but there was no longer a weir installed here. Weirs at Pleasant Grove, Cudmore, Vanco and Affleck branches were all removed for the winter on 2020-11-18 and weirs at the Tim's Creek branch were removed on 2020-11-30. The 5 weirs at the Brackley branch were monitored later into the winter, and thus became frozen in place.

During the 2020 field season, Prince Edward Island experienced an extreme drought. The lack of precipitation reduced overland water flow into streams, reduced infiltration into groundwater, and created more demand for water by human water users, all of which contributed to lower groundwater levels, and therefore altered the outflow of springs in the Winter River-Tracadie Bay Watershed. Below, Figure 37 shows the worsening of dry conditions from June to August this year, then a slight improvement in September. During August there was an Extreme Drought (D3) throughout the majority of the Island. For more information, visit the Canadian Drought Monitoring website (Agriculture and Agri-food Canada, 2020).

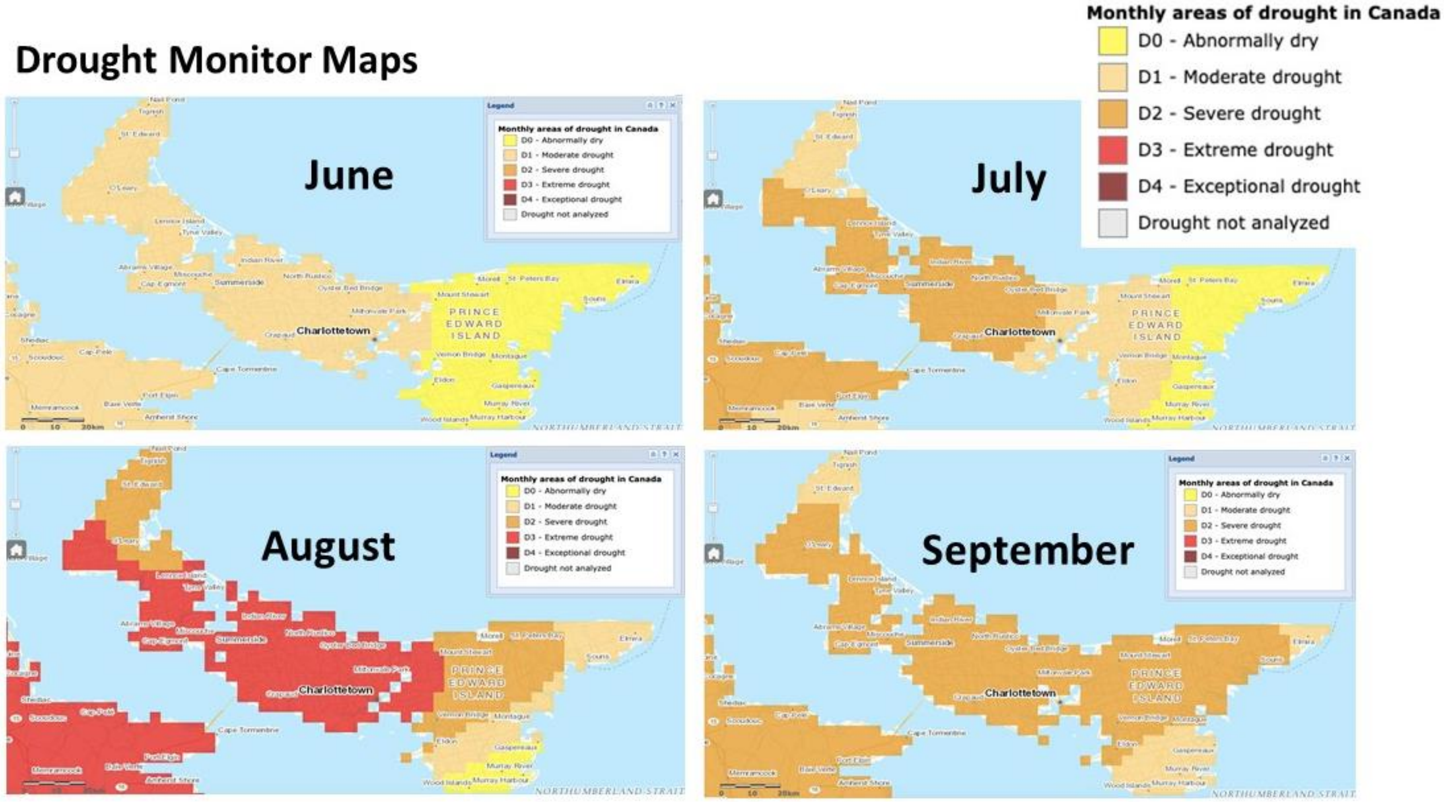


Figure 37. Maps of Prince Edward Island in June to September 2020, showing the occurrence of Moderate Drought (D1) through to Extreme Drought (D3) conditions. Data was collected from the Agriculture Canada Drought Monitor site (Agriculture and Agri-food Canada, 2020).

The link below leads to an interactive map with v-notch weir locations and photos from the 2020 field season.
https://www.google.com/maps/d/u/0/edit?mid=1c7VdmodU7jyiI5xPFybZJFVNEqK7IGsv&usp=sharing

Methods

Approximately every 2 weeks from May to December, the weirs were checked and maintenance performed as required. The weirs were first inspected for any leaks around the sides or bottom of the metal sheet. If there were leaks coming from underneath the weir, a mallet was used with a 4x4 block of wood to pound the weir lower into the ground. Leaks around the sides of the weir were patched with sticks and sod. A YSI measurement would then be taken, placing the probe inside the spring pool. This measured the temperature, dissolved oxygen, conductivity, pH, and nitrate levels of the water for a separate long term study of water quality within the Watershed.

The depth of water flowing through the v-notch of the weir was measured with a ruler, recorded in a notebook, and added to an Excel sheet. Later the flow rate from the spring was determined, converting water height into flow using a conversion chart. If a weir had no water flowing through it, it was marked as dry.

To adhere to COVID-19 restrictions while checking weirs, and still follow our policy of not having staff members working alone, a team of 2 crew members would split roles to avoid close contact and sharing equipment. For example, 1 crew member would fix any leaks and handle the YSI while the other crew member would take pictures of the weir, measure the water height at the v-notch, and take notes.

Results

Both Tim's Creek Lower and Pleasant Grove #5 were unable to be measured for extended periods of time; Tim's Creek Lower had an issue with its placement, causing spring water to flow too far under an undercut of the bank to be fixable, while Pleasant Grove #5 was continuously flooded. The complication at Tim's Creek Lower started 2020-07-14 and continued throughout the rest of the season while Pleasant Grove #5 flooded from 2020-08-24 to 2020-09-09 and again from 2020-10-05 to the end of the field season. This made the data from these monitoring sites inaccurate, and thus will not be used for further analyses.

With such significantly dry conditions this field season, 7 of the 12 monitored springs went dry for various periods of time (see Figure 38). Brackley #3 and Brackley #8 were reported dry 2020-07-22 and Brackley #4 and Brackley #6 were reported dry 2020-07-27. All 4 sites were dry until 2020-12-11, although water levels were still very low at this point. Brackley #7 was reported dry from 2020-08-17 until 2020-12-11. The Vanco spring was observed as dry 2020-08-10 to 2020-12-11, with very low water levels. Lastly, Cudmore #6 went dry 2020-09-22 and no water was reported to be present at this site for the rest of the field season.

The highest measurements for all weir sites in the 2020 field season took place in late June (when measurements started to be recorded) and early July. Only 2 weir sites reached their highest measurement a second time; for Affleck weir it reached it's high again in November and for Pleasant Grove #2, this happened in mid-December. Table 13 shows the highest average flows were reported at Pleasant Grove #2, Pleasant Grove #5 and Vanco weir monitoring sites with Pleasant Grove #2 having the highest discharge of all sites at 0.0035m^3/s. The lowest average flows were reported at Brackley #3, Brackley #8 and Brackley #6 monitoring sites, all of which were dry for the majority of the 2020 field season.

Groundwater Spring Monitoring 2020

Spring Location	Wellfield Distance (m)	2020-06-30	2020-07-07	2020-07-13	2020-07-14	2020-07-22	2020-07-27	2020-07-28	2020-08-04	2020-08-10	2020-08-12	2020-08-17	2020-08-24	2020-09-07	2020-09-10	2020-09-21	2020-09-22	2020-10-05	2020-10-21	2020-11-06	2020-11-09	2020-11-10	2020-11-18	2020-12-01	2020-12-11	2021-01-22	Days Monitored
Brackley #3	698	W	W	W	X	D	D	X	D	D	X	D	D	X	D	X	D	D	D	X	X	D	D	X	L	W	17
Brackley #4	736	W	W	W	X	W	D	X	D	D	X	D	D	X	D	X	D	D	D	X	X	D	D	X	L	W	17
Brackley #6	764	W	W	W	X	W	D	X	D	D	X	D	D	X	D	X	D	D	D	X	X	D	D	X	L	W	17
Brackley #7	871	W	W	W	X	W	W	X	W	W	X	D	D	X	D	X	D	D	D	X	X	D	D	X	W	F	17
Brackley #8	932	W	W	W	X	D	D	X	D	D	X	D	D	X	D	X	D	D	D	X	X	D	D	X	L	W	17
Vanco	1386	W	X	W	X	X	W	X	X	D	X	X	X	X	D	X	D	D	X	X	X	X	D	X	L	X	9
Cudmore #6	1572	W	X	W	X	X	W	X	X	W	X	X	W	X	W	X	D	D	D	X	X	D	D	D	X	X	12
Cudmore #3 (rebar)	1710	W	X	W	X	X	W	X	X	W	X	X	W	X	W	X	W	W	W	X	X	X	W	W	X	X	11
Affleck's Upper	2472	W	X	W	X	X	W	X	X	W	X	X	W	X	W	X	W	W	W	X	W	X	W	X	X	X	11
Tim's Creek Upper	2692	W	X	X	W	X	X	W	X	X	W	X	W	W	X	W	X	W	W	W	X	X	W	X	X	X	11
Tim's Creek Lower	2696	W	X	X	W	X	X	W	X	X	W	X	W	W	X	W	X	W	W	W	X	X	W	X	X	X	11
Pleasant Grove #2	2926	W	X	W	X	X	X	W	X	W	X	X	W	W	X	W	X	W	W	X	W	X	W	X	X	X	11
Pleasant Grove #5	2927	W	X	W	X	X	X	W	X	W	X	X	F	F	X	W	X	F	F	X	F	X	F	X	X	X	11

W	Water
D	Dry
L	Very low
F	Flooded
X	Not monitored

Figure 38. Monitoring summary of 2020 weir sites, showing dry spells that occurred this season. Cudmore #3 is no longer an active weir, but is marked with a piece of rebar where depth measurements are taken.

Table 13. Average discharge at 2020 weir sites. Note Tim's Creek Lower weir was not included due to lack of reliable data.

Site	Average Discharge (m3/s)
Brackley #3	0.000032
Brackley #8	0.000033
Brackley #6	0.00009
Tim's Creek Upper	0.00010
Brackley #4	0.00011
Brackley #7	0.00023
Affleck Upper	0.00030
Cudmore #6	0.00039
Vanco	0.00054
Pleasant Grove #5	0.00061
Pleasant Grove #2	0.00289

Figure 39. All 2020 weir sites, with position shown in relation to water pumping stations in the WRTB watershed.

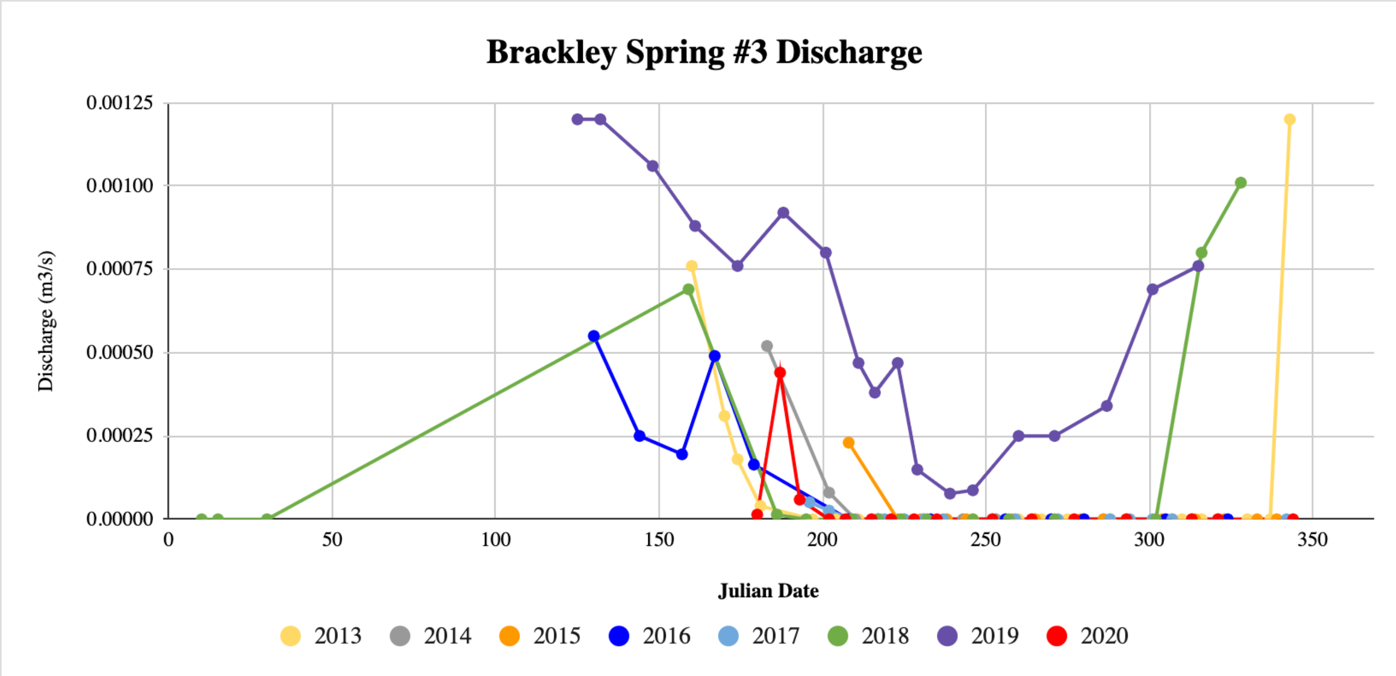


Figure 40. Discharge calculated at the Brackley #3 weir; note the difference between the 2019 field season which was quite a wet year compared to the 2020 field season that suffered through a drought.

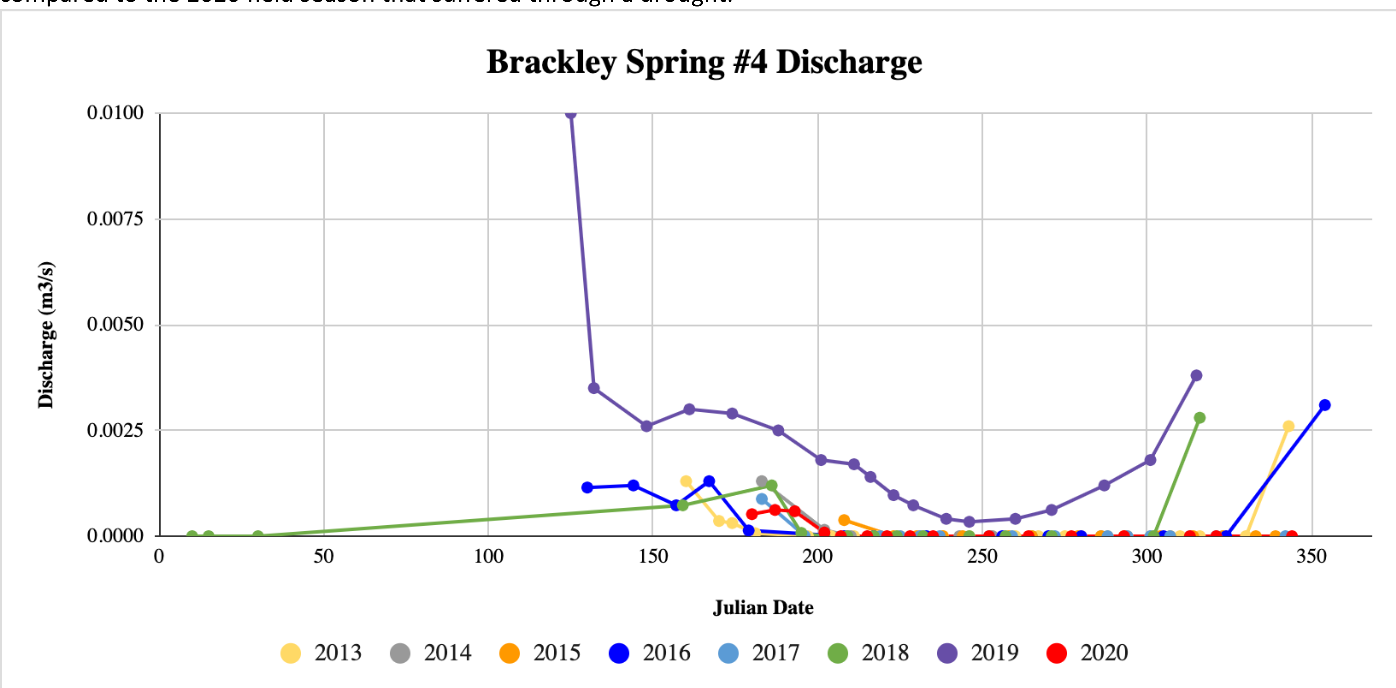


Figure 41. Discharge calculated at the Brackley #4 weir; note the difference between the 2019 field season which was quite a wet year compared to the 2020 field season that suffered through a drought.

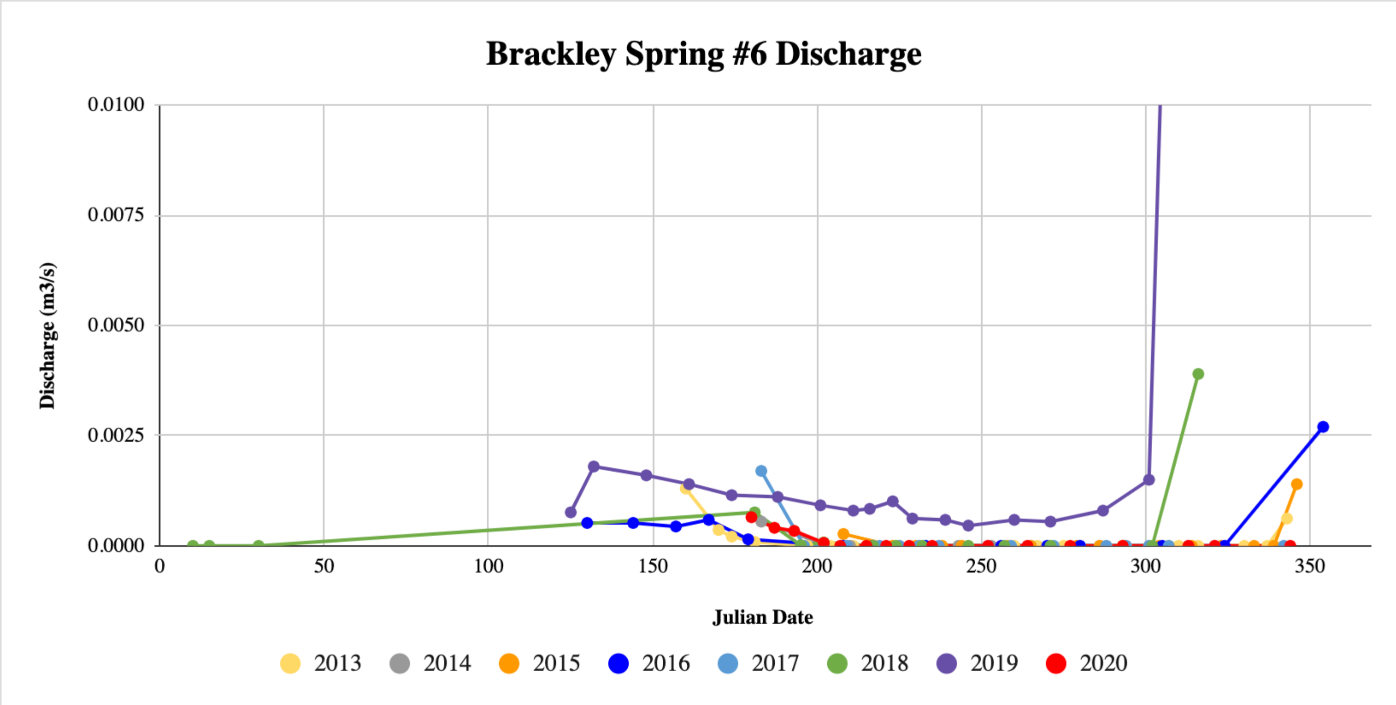


Figure 42. Discharge calculated at the Brackley #6 weir; note the difference between the 2019 field season which was quite a wet year compared to the 2020 field season that suffered through a drought. Values higher than 0.01 are not characteristic and were omitted from the graph for easier viewing. The value extending beyond the chart for 2019 was 0.037m^3/s.

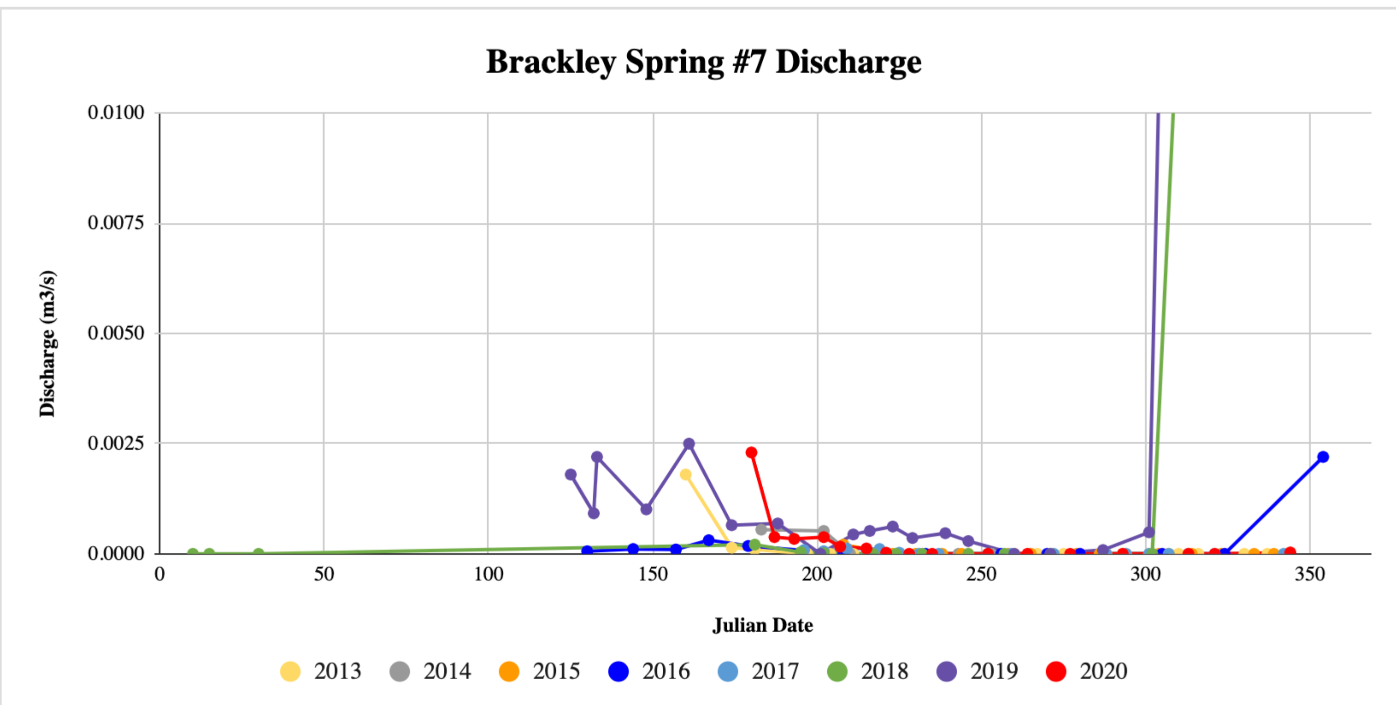


Figure 43. Discharge calculated at the Brackley #7 weir; note the difference between the 2019 field season which was quite a wet year compared to the 2020 field season that suffered through a drought. Values higher than 0.01 are not characteristic and were omitted from the graph for easier viewing. The value extending beyond the chart for 2019 was.0.0476m^3/s. and for 2018 was 0.022 m^3/s.

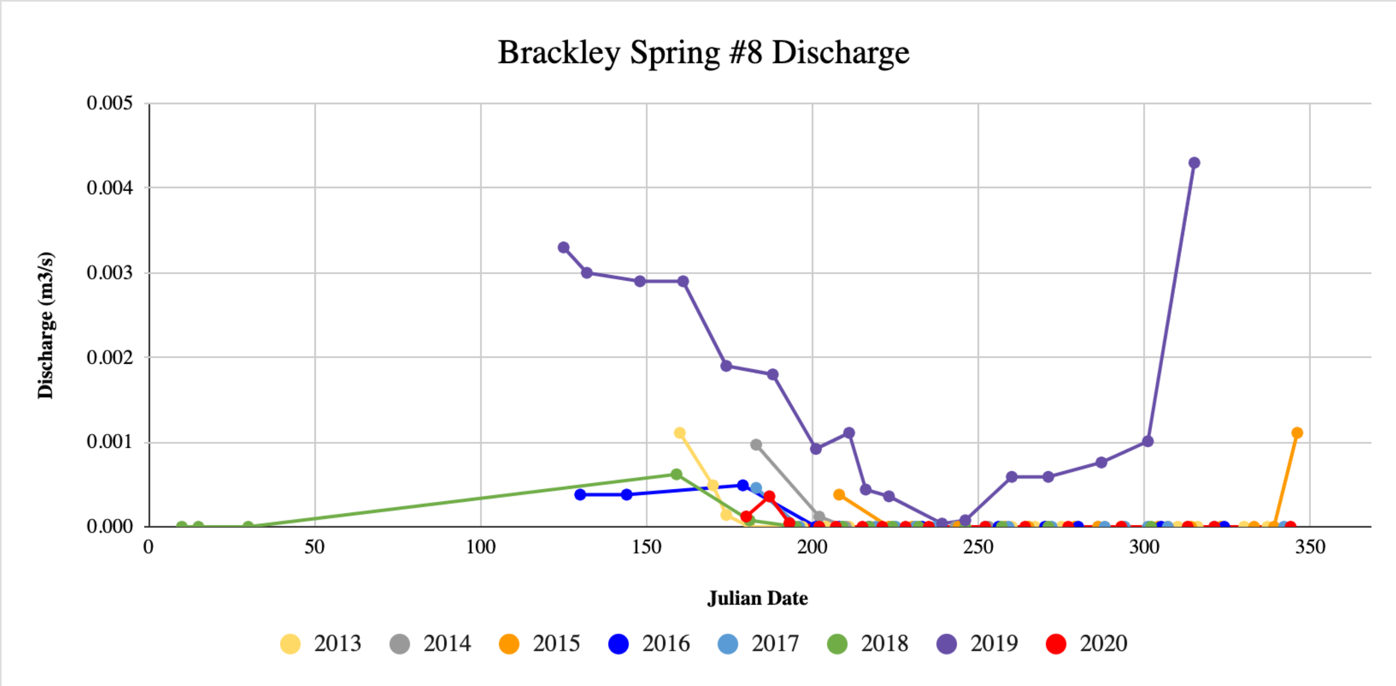


Figure 44. Discharge calculated at the Brackley #8 weir; note the difference between the 2019 field season which was quite a wet year compared to the 2020 field season that suffered through a drought.

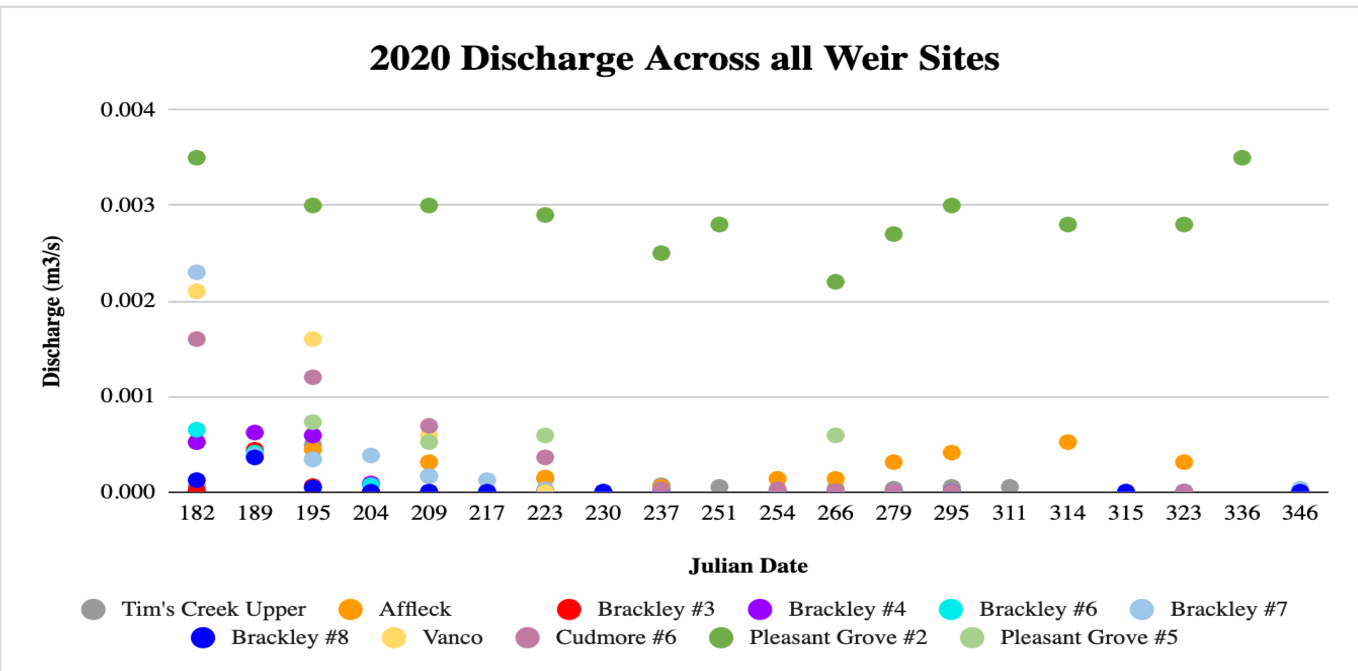


Figure 45. Discharge values across all weir sites for the 2020 field season. Note Tim's Creek Lower weir was not included due to lack of reliable data.

Discussion

The summer of 2020 was very hot and dry with the highest temperatures hitting 31.2°C and the overall average temperature in the hottest month (August) was 19.4°C (Government of Canada, 2020). This caused the majority of our springs to run dry at some point during the field season. "Stream drying with drought is a particularly important disturbance to headwater communities … it is clear that stream drying has a dramatic effect on macroinvertebrate communities that can persist for many years" (Snyder et al., 2013).

Headwater springs tend to go dry in drought conditions earlier than those downstream (Snyder et al., 2013). Our headwater springs are those located along the Brackley, Vanco and Cudmore branches, and have been the only branches to go dry in our data from 2013 to 2020. The Brackley weirs historically have run dry for long periods in the summer and fall. These springs are located between municipal wellfields.

Groundwater extraction from City of Charlottetown wellfields in Brackley and Union decreased in 2019 due to the opening of the Miltonvale wellfield. The combination of decreased extraction and it being a particularly wet year caused more water flow in headwaters than in previous years. While the groundwater extraction decreases were sustained in 2020, this was offset by the extreme drought. We will continue monitoring in 2021 and hope to see an average precipitation year to see how streams respond.

This year Weir #2 at Pleasant Grove flooded repeatedly. The metal weir looked like there were equal depths of water on each side instead of a distinct source of water flow. After close inspection, there appeared to be another spring on the downstream side of the weir, this may have led to the flooding issue. Next field season, the crew will have to inspect the site before weir installation, and may need to change the weir's placement if it really is another spring.

At the end of this 2020 field season, both Tim's Creek Upper and Tim's Creek Lower weirs were retired in an attempt to be more strategic with data collection activities in the future.

7 Recommendations for Future

- Make recommendations for data collection committee of the board of directors
    - Ex. Probably going to retire some of the v-notch weir sites
- Depth loggers: set up rebar at each site 3m apart along the length of the river like at Hardy and Tims. It makes the process of timing the flow with an orange or tennis ball much smoother.
- Depth loggers: attach the loggers with the UV-protected zip ties instead of wire. The wire is easy to maneuver in spring when they are deployed, but harder to remove in the winter. The loggers were attached with both this season and the zip ties seemed to hold up fine over that period of time.
- DO loggers: check the data/do a mini data analysis (for the CB bottom logger especially) in between deployments to check for errors that can be improved for next deployment--CB bottom was consistently mucky, even with shortening the rope every time we went out, but it was hard to tell how long it had been like that. There are some wildly inaccurate DO values in the dataset
- DO loggers: use the jar method for calibrating loggers--take sample both before and after; measure depth of water at CB at very low tide early in the season to ensure proper length of rope, data was low quality for CB bottom this season even after many rope length adjustments due to mucky sensor
- Set up YSI data in the similar format as DataStream upload template for more fluid transfer
- A "FieldSupervisor.WRTBWA@gmail" and "Intern.WRTBWA@gmail." -type account might make for smoother transitions and would ensure any correspondence or files created by the account would stay with the organization
- If estuary monitoring surveys are done again, have a check-box/circle options style datasheet to fill out for more consistent terms to compare sites. The field notes this year described the conditions but are hard to compare to see which days were worse than others (example categories: colour/clarity, smell, presence of algae (and floating or bottom?), fish/aquatic sightings), the form from the province might be a good template?
- Produce a watershed report card for a quick overview of health --from Atlantic Water Network workshop
- A workplace credit card for picking up field supplies

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9 APPENDICES

APPENDIX A: Culvert Assessment Field Methods

Preliminary assessments were completed in 2015-2018, and these forms were adapted from Clean Annapolis River Project forms used in their project “Broken Brooks” (2008-2013). CARP reports are available from https://www.annapolisriver.ca/publications.

Detailed assessment methodology and forms are adopted from those provided by NSLC Adopt-A-Stream, which provided training to PEI Watershed groups in 2019. http://adoptastream.ca/training/culvert-assessment-for-fish-passage

The equipment used for culvert assessments included data sheets, clipboard, pencil, calculator, GPS, camera, spare batteries, tripod, surveyor level and rod, 30 m tape measure, meter stick, thermometer, YSI, flashlight, and tennis balls. First, a “Rapid Assessment” checklist was completed to determine whether to continue with a full assessment. This included questions regarding the depth of water in the culvert, how backwatered the culvert was, and if there was a visible outflow drop. Every culvert surveyed this year needed a full assessment. For the full assessment, both visual qualities and measurements are recorded.

Visual qualities included the culvert material, shape, entrance type, bottom material, the presence/absence of baffles, and any signs of deformation or deterioration. The upstream substrate composition (fines, gravel, cobble, etc.), percent of culvert backwatered, degree of embedment, evidence of beaver damming, and presence of fish were also recorded. Photos were taken from multiple angles to keep with our records.

Culvert dimension measurements were taken at every site, including the width and height at the opening, the width and height of the corrugations, culvert length, and the depth of water in the culvert. Upstream, the wetted and bankfull widths were measured at the nearest pool, riffle, and run to obtain a stream width ratio. Other measurements taken included the distance from the upstream riffle to inflow invert, plunge pool bankfull width, outflow to tailwater control, and tailwater control to second riffle downstream. YSI readings were taken for temperature, pH, dissolved oxygen, and conductivity, and the velocity was measured using the tennis ball method.

For elevation readings, the level was set up in a location where as many elevation measurements as possible could be read without moving to a new sighting location (called turning points); the fewer turning points, the less chance of error when taking readings throughout the site. Upstream of the culvert, elevation measurements were taken at the culvert inflow and crest of the first riffle upstream. Downstream was a little more complex, with measurements at the culvert outflow, plunge pool surface and bottom, first riffle after the outflow (called the tailwater control), and crest of the second riffle. On the downstream side, at the tailwater control, a cross section of 6 equally spaced elevation readings were taken from left to right along the bankfull width.

An example of the datasheet used in the field follows.

Detailed Culvert and Stream Assessment Form

Culvert ID	

Complete IN FIELD	Optional	To calculate	Instructions	May not apply

U/S = Upstream D/S = Downstream

Date	YYYY-MM-DD	Time	
Technicians			
Crossing ID	PU = PUBLIC, PR= PRIVATE		
Stream Name		Road Name	
Coordinates	*Not needed if prior assessment done*		
Crossing Type	☐ Single Culvert ☐ Multiple Culverts ☐Bridge* ☐ Dam ☐ Ford ☐ Other ________		
Debris present?	If yes, describe		
Fish habitat?			

Rapid Assessment

Is there a visible outflow drop?	☐Yes ☐ No
Is the water depth less than 15cm anywhere in the culvert?	☐Yes ☐ No
Is the culvert backwatered only part of the way or not at all?	☐Yes ☐ No
Is the stream width noticeably different above and below the culvert?	☐Yes ☐ No
If the response to any of these questions is YES, then continue with the full assessment.	

Culvert Information

Culvert Material SEE FIG 11 *Check ALL that apply*	☐ Concrete ☐ Corrugated Metal Pipe (Spiral) ☐ Corrugated Metal Pipe (Annular) ☐ Corrugated Plastic ☐ Wood ☐ Other	Culvert Shape	☐ Circular ☐ Box ☐ Pipe Arch ☐ Open Arch ☐ Arch w/Wood Floor ☐ Other	Entrance Type	☐ Projecting ☐ Headwall ☐ Mitered ☐ Wingwall ☐ Other
Is Culvert Deformed?	☐ Yes ☐ No	Deterioration	☐ None ☐ Moderate ☐ Severe	Baffles	☐ Present ☐ Absent
Culvert Bottom	☐ Unnatural ☐ Natural *If Natural, Dominant Substrate:* ___________		Variable Slope in Culvert? SEE FIG. 15	☐Yes ☐ No	

If Baffles are present, fill in Baffle Information on pg.5

Photo Files					
Upstream		File Names/Notes	Downstream		File Names/Notes
Toward Inflow	☐Yes ☐No		Toward Outflow	☐Yes ☐No	
Through Culvert	☐Yes ☐No		Through Culvert	☐Yes ☐No	
Looking Upstream	☐Yes ☐No		Looking Downstream	☐Yes ☐No	
Other(s)	☐Yes ☐No		Other(s)	☐Yes ☐No	

Culvert Dimensions

Culvert Measurements (m)	WIDTH - *A*	HEIGHT	Corrugation (cm) SEE FIG. 17	WIDTH	HEIGHT

Detailed Culvert and Stream Assessment Form

Culvert ID	

Additional Information

Inflow Habitat Type	☐ Pool ☐ Riffle ☐ Run ☐ Drop	Beaver Dam Present	☐ Yes ☐ No
Backwatered SEE FIG. 19	☐ 0% ☐ 25% ☐ 50% ☐ 75% ☐ 100%	Fish Observed	☐ Upstream ☐ Downstream
Embedment	☐ Embedded from Upstream ☐ Embedded from Downstream	Degree of Embedment SEE FIG. 20	☐ 0% ☐ <20% ☐ >20%
Length of Culvert with Embedment		☐ 0% ☐ 25% ☐ 50% ☐ 75% ☐ 100%	

Upstream Substrate composition

(particle diameter) – must add to 100%

Fines (<0.2cm)		%
Gravel (0.2-6.4cm)		%
Cobble (6.4-25.6cm)		%
Boulder (>25.6cm)		%
Bedrock		%

YSI readings	Upstream	Downstream	
Water Temp			°C
pH			n/a
DO			mg/L
Conductivity			µS/cm
Air Temp *(with second thermometer)*			°C

Y	Velocity calculation – *using tennis ball method*	Upstream	Downstream	
Y1	Distance			m
Y2	Time			s
Y3	Velocity *(Y1/Y2)*			m/s

		Upstream/Inlet		Downstream/Outlet	
G	Water Depth: *meter stick parallel to flow*		*R*		cm
H	Stagnation Depth: *meter stick perpendicular to flow*		*S*		cm

Upstream Channel Measurements

	Pool	Riffle	Run	Average (Pool, Riffle, Run)	
Wetted Width (m)					*B*
Bankfull Width (m)					*C*
Stream Width Ratio: *C (avg bankful width) / A (width of culvert)*					*D*

I	Upstream Riffle to Inflow Invert (m)	

J	Culvert Length (m)	

Detailed Culvert and Stream Assessment Form

Culvert ID	

Elevation Measurements

1 DECIMETER = 0.1 METERS

	Upstream	HI (m) *(tripod height)*	FS (m) *(survey rod value)*	Elevation (m) *(HI - FS)*	NOTES
E	Crest of Riffle Upstream	SET AT 10 TO START			
F	Inflow				

Turning Point calculations: if you can't see everything upstream & downstream without moving the tripod, you need turning point(s)

	Downstream	HI (m)	FS (m)	Elevation (m)	NOTES
M	Outflow				
N	Plunge Pool Bottom				
Q	Pool Surface Elevation				
O	Tailwater Control (1ST riffle)				
P	Crest of 2nd Riffle				

Tailwater Cross Section		*Intervals (m)* *O6/5*	HI (m)	FS (m)	Elevation (m)	Water Depth (m)
O1	Left Bankfull	0				*Should be zero*
O2	20% Bankfull Width					
O3	40% Bankfull Width					
O4	60% Bankfull Width					
O5	80% Bankfull Width					
O6	Right Bankfull					*Should be zero*

Wetted Width		m	Bankfull Width		m	Bankfull Width / 5		m

BAFFLES *if applicable*	HI (m)	FS (m)	Elevation (m)	
Most D/S baffle				*a*
Adjacent Baffle to U/S				*b*
Drop Between Baffles (m)				*a - b*

Detailed Culvert and Stream Assessment Form

Culvert ID	

Downstream Channel Measurements

T	Plunge Pool Bankfull Width		m
U	Outflow to Tailwater Control (m)		m
V	Tailwater Control to 2nd Riffle Downstream (m)		m

Baffle Information (ONLY Complete if culvert is baffled) SEE FIG. 28

Baffle Height (cm)		Baffle Material	☐ Concrete ☐ Metal ☐ Wood ☐ Other
Notch Depth (cm)		Baffle Type	☐ Straight ☐ Diagonal ☐ Right Angled ☐ Other
Notch Width (cm)		Notch Chutes	☐ Yes ☐ No
Number of Baffles		Notch Chute Material	☐ Concrete ☐ Metal ☐ Wood ☐ Other
Distance Between Baffles (m)			

Office Calculations

W	Culvert Slope: *(Inflow elevation – outflow elevation) / Length of culvert*	*(F – M) / J*	%
X	Outflow Drop: *Outflow elevation – Tailwater control elevation*	*M - O*	cm

L	Upstream Channel Slope: *(Crest of riffle upstream – Inflow)/ Upstream riffle to invert x 100*	*(E-F) / I x 100*	%
Z	Downstream Channel Slope: *TC elev – Elev. 2nd riffle/Distance from TWC to 2nd riffle x 100*	*(O-P/V x 100*	%

Notes & Sketch

APPENDIX B: **DO Data Formatting Steps**

(Seems crazy, but it works)

1. Open HOBOware software. Click File, Open Datafile to select the previously saved logger data file.
2. Once it opens, click Plot, and a data table will pop up. Click File, Export Table Data. Save as Excel Comma Separated Values file (.csv).
3. Open .csv file and Save As an Excel Worksheet file (.xlsx).
4. Copy the data into a new tab.
5. Copy the date column and put it into 2 separate columns where the format changes. (e.g. 07-12-2020 23:00 vs 07/13/20 12:00:00 AM).
6. Insert two new columns to the right. Use Text-to-Columns to split apart the date and time in each column, using Fixed Column Width (leaving the AM attached to the time even though it suggests a break there).
    a. When splitting columns, set date column format as Date in the d-m-y order that the columns are currently in
7. Convert the newly made date column to the proper yyyy-mm-dd format. Use Custom for Number Format, and enter "yyyy-mm-dd" in the text box.
8. Convert the newly made time column to the proper hh:mm format. Use the 24 hour clock format.
9. Delete the data from when the logger was not submerged before deployment and after retrieval.
10. Make a new column and copy the date column As Text by typing the formula =TEXT(A3,"yyyy-mm-dd") in the new column (for whichever cell the first date value was in).
11. Do the same for the time column with the formula =TEXT(A3,"hh:mm").
12. In a new column, put the date and time back together by using the formula =CONCATENATE(T3," ",U3).
13. Now change the Number Format for that column to Custom and enter "yyyy-mm-dd hh:mm" in the text box.
14. Paste the column with these values to replace the original date-time column, next to the dissolved oxygen data.
15. Now you can graph the dissolved oxygen and temperature data.

Pleasant Grove DO Logger Steps

Note: Ideally the calibration values from the field should have been taken via the "jar method" (where a water sample is taken at the start and end of each deployment period) because it will give more accurate results for an estuary site. The 2020 data used YSI readings at the start and end of deployments right from the estuary itself.

1) Open the conductivity readout file (raw, downloaded from the logger) for the desired deployment period in Hoboware Pro

2) Uncheck the boxes □**Low Range** and □**High Range**

3) Uncheck boxes for all Internal Logger Events

4) Select **Conductivity Assistant** and click **Process**

5) Select **2) Conductivity High Range** (this setting used when logger deployed in non-freshwater environments)

6) Select ®**Non-linear, sea water compensation based on PSS-78**

7) Check boxes for □**conductance** and □**salinity (PSS-78)**

8) Select ®**Use measured points for calibration** and enter info for **Starting Calibration Point** and **Ending Calibration Point** from field measurements taken with YSI during deployment and retrieval of the logger. Note: the time you choose from the dropdown list may not match perfectly with when the field value was taken, it is more important to use a value where the logger has settled and is recording underwater. Values in the square brackets that are too close to zero often do not work, so must choose the next closest time. If no close times work, uncheck the box and do not use a starting calibration point.

9) Check the box □**only report data between selected points** and click **Create New Series**

10) Click **File ->Export Points as Excel (.txt or .csv) file** and click **Export** to save as a .txt file. Export settings are found under **File->Preferences**.

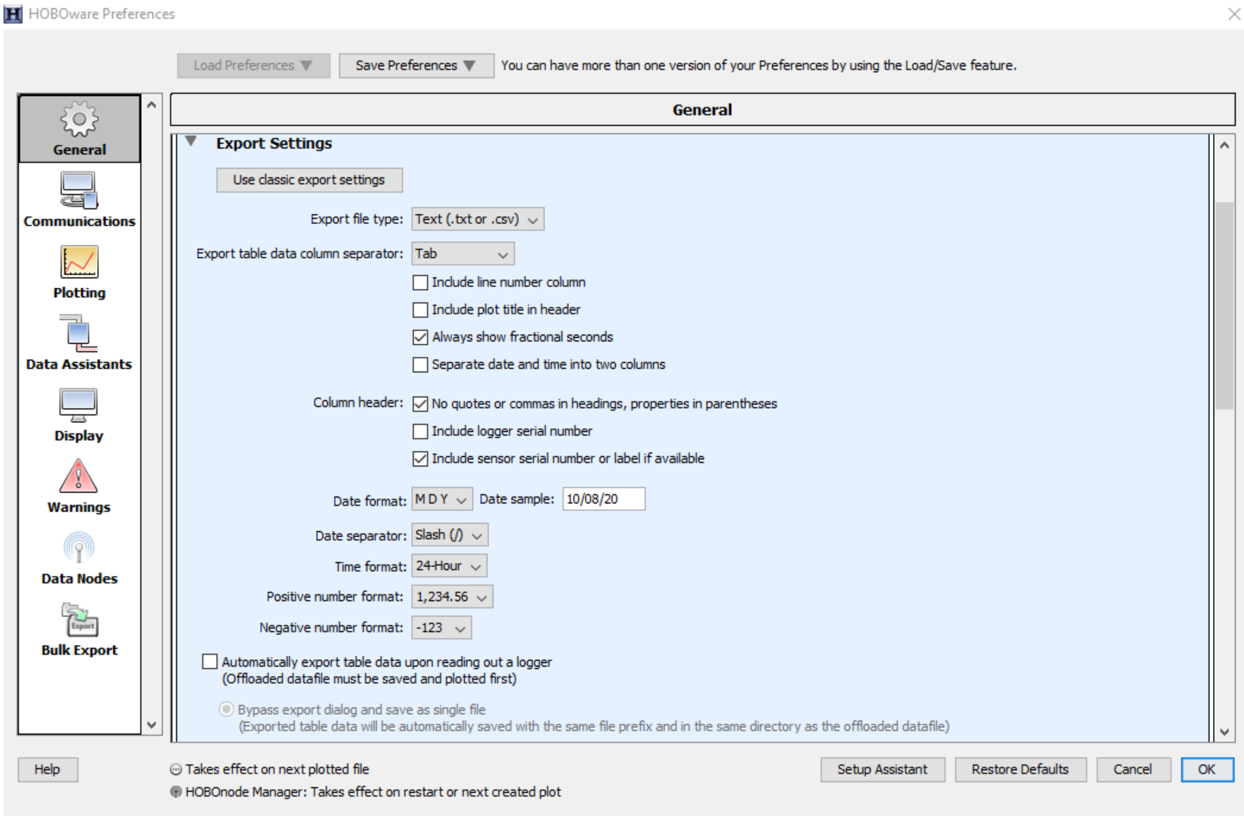


Figure 1. Export settings for Pleasant Grove dissolved oxygen logger. All other boxes in this tab of the window (if you scroll down) are left unchecked.

11) Open the .txt file you just created in Notepad and remove the beginning and end rows where there is no relevant data. Tab over any values that are out of line with the rest of their column and save file.

12) Open the DO readout file (raw, downloaded from the logger) for the corresponding deployment period in Hoboware Pro

13) Uncheck the □**DO conc** box

14) Uncheck boxes for all Internal Logger Events

15) Select **Dissolved Oxygen Assistant** and click **Process**

16) Select ®**Specific Conductance** and ®**Specific Conductance Datafile**

17) **Choose** the conductivity .txt file that you just created in earlier steps (for the same deployment period)

18) ®**Barometric data value** of 760.00 mmHg is the standard. Could get a more accurate reading if there was a depth logger deployed to take atmospheric reading nearby, but just using this value was deemed ok by Hoboware manual

19) Check boxes □**DO adj conc** and □**DO percent sat**

20) Check □**Perform field calibration** and ®**Using dissolved oxygen meter or dissolved oxygen titration** and enter info for **Starting Calibration Point** and **Ending Calibration Point** from field measurements taken with YSI during deployment and retrieval (same note about choosing a dropdown value as with conductivity logger)

21) Check □**Only report data between selected points** and **Create New Series**

22) Make sure delimiter options are as follows and click **OK**

   a. Data Separator: **Tab**
   b. Date/Time Separator: **Space**
   c. Decimal Separator: **Period**
   d. **Edit Date/Time Format**: MM/DD/YY 24 Hour
      i. Separators: Date: **Slash (/)** Time: **Colon (:)**

23) On next window, click **OK**

24) In the window that pops up, "**Salinity/Specific Conductance Datafile Offset**," select **Option 1**

25) In "**Plot Setup**" window, check only □**Temp**, □**DO adj conc**, □**DO percent sat**, and □**Cond**. Make sure all units are correct.

26) Click **Plot** and save as a project file.

27) The project file can be exported as a .csv file now or at a later date. This can be done when the project file is open by going to **File->Preferences->Export Settings**.
Tip: It is easier to do all one type of file (Conductivity), then the other (Dissolved Oxygen) through the Data Assistant rather than having to change any export settings in between types.

DO Logger Date/Time Formatting from 2020

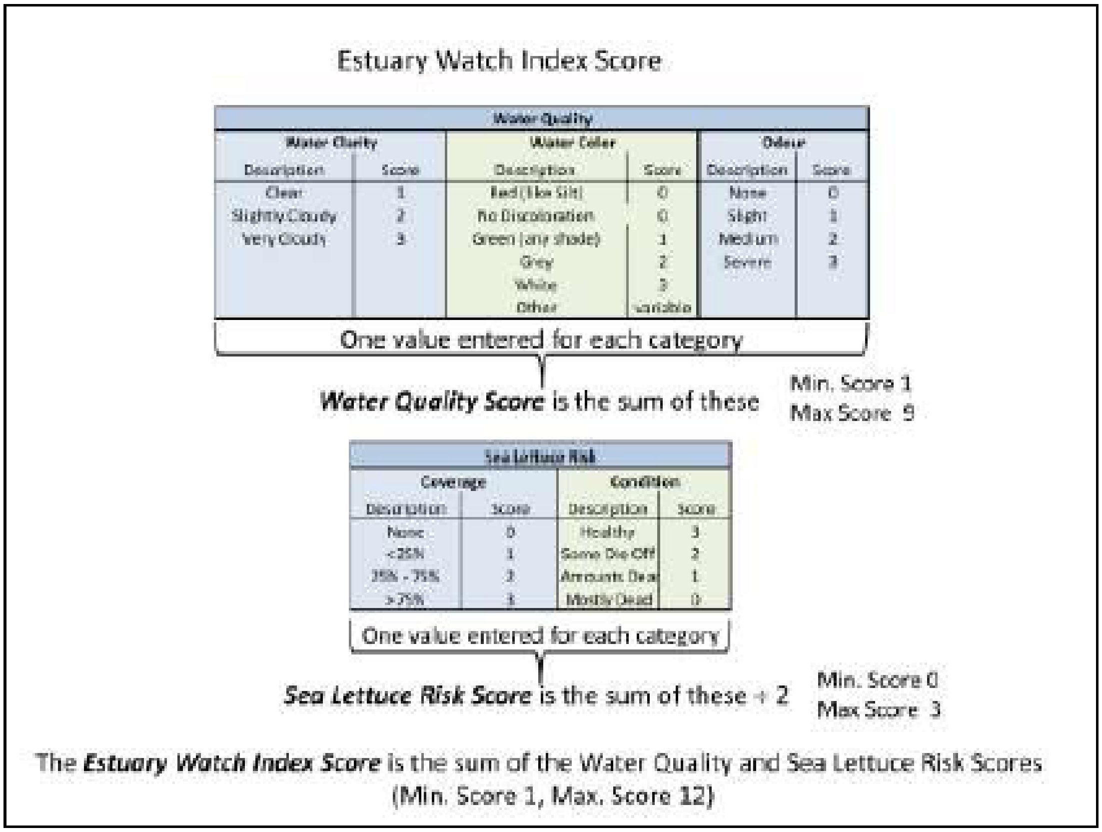
**Each time the spreadsheets have the dates in a slightly different format when exported from HoboWare, you have to play around a bit to make it work. The steps below worked for the DO logger files from all 3 sites in 2020, but PG had 2 different date/time formats in a column, so needed to split before proceeding.

1. "Text to columns" to split date and time
    a. "Fixed width"
    b. Convert both columns to "General", then "Finish"
2. Insert 4 blank columns between the date column and the time column
3. Convert the time column to the 24 hour clock, hh:mm:ss
4. Convert the date column to get rid of the time, mm-dd-yyyy or dd-mm-yyyy, depending on the original format
5. "Text to columns" to split the date into its parts
    a. "Delimited"
    b. Check box "Other" and make it a dash or slash (depending on which was used)
    c. Convert all columns to "Text", then "Finish"
6. Manually change the year to have four digits if it doesn't already (just type 2020 and copy if for the whole column)
7. Manually change the day or month to have two digits if they do not already
8. Combine the 3 date columns into a new column using the formula =CONCAT(A2,"-",B2,"-",C2) to get the day, month, and year into the right order of yyyy-mm-dd
9. Drag the formula down
10. Copy the column and PASTE VALUES into a new column
11. Change the column formatting to "Custom" and "yyyy-mm-dd)
12. If combining the date and time into one column, use formula =A2+B2 and change the format to "yyyy-mm-dd hh:mm"

APPENDIX C: Estuary Watch Index Scoring

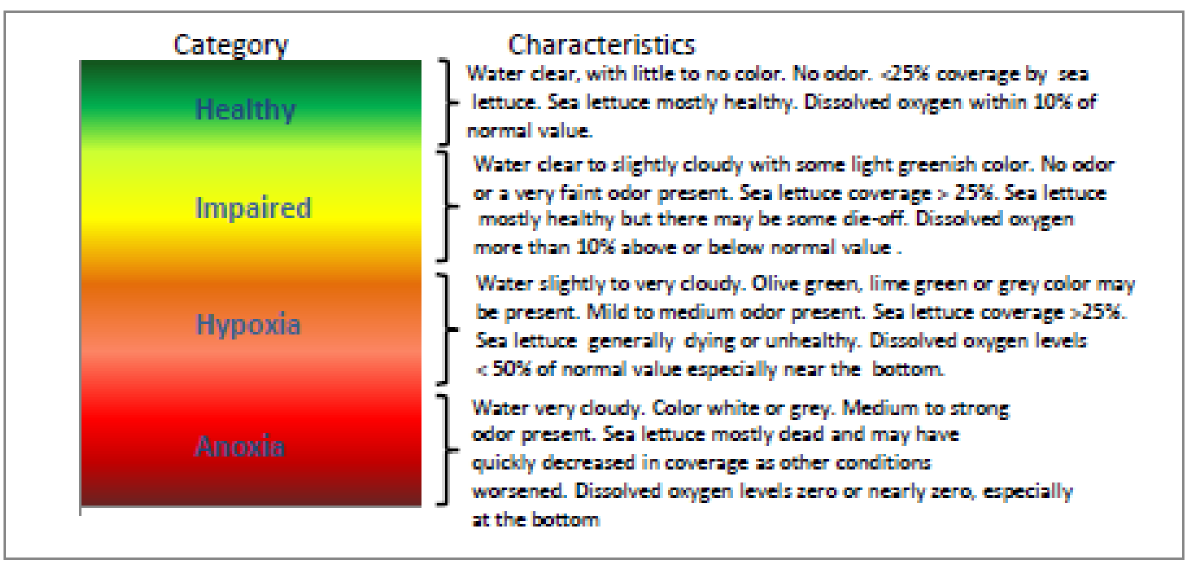
Estuary Watch Index

Volunteer Estuary Watchers record their daily observations in a log by making a check mark in the most appropriate box for each of 5 types or categories of observations. The check marks for each observation are converted to scores and the *Estuary Watch Index Score* is calculated as shown in the diagram below.



Estuary Condition Categories

The Estuary Watch Index Score corresponds to four Estuary Condition Categories; *Healthy* (score 1-2.5), *Impaired* (score 2.6 – 5.5), *Hypoxia* (score 5.6 -8.5) and *Anoxia* (score 8.6 -12). The diagram below, describes the conditions that are typically observed in each of these four water quality categories.



APPENDIX D: Depth Logger Methods

Methods for depth loggers were adopted from the Parks Canada, PEI National Park protocol (Hawkins, 2014). Depth values were calculated by comparing the pressure the loggers were experiencing under water in the streams to the pressure readings from a control logger set up outside the watershed office (titled ATMO). This data was analyzed in the winter and cleaned up of any abnormalities due to logger malfunctions, to provide a running value of the depth of water above the logger.

To calculate the volume of water passing by our data logger point, additional measurements were needed. Repeated measurements of the cross sectional area of the channel at the location where the logger was located, and the average velocity of water at this location were needed to calculate the discharge, or the volume of water flowing through this point in the river in a given time. These discharge values were plotted against the depth of water at the logger during each measuring event, to create a rating curve, and then an associated formula to relate water depth to water discharge. This formula was applied to all hourly depth measurements to create a series with hourly discharge measurements.

The routine measurements included velocity, distance from bank to logger, depth at logger, wetted width, and depth measurements at every 1/6th across the wetted width. A measuring tape was stretched across the wetted width from the left to right bank (when facing downstream), and a meter stick was used to take the depth readings. The velocity of water within the stream was measured using the tennis ball method from previous years. A distance of 3 meters was measured from the depth logger, and a stopwatch recorded how long it took for a dropped ball to travel that distance downstream. Measurements were taken at the left, right, and center of the stream, to get an average velocity value. The velocity and channel measurements were used to calculate the discharge from the stream. The discharge values were then graphed for each site and provided an equation that was used to perform flow statistics for each depth reading. The maximum, minimum, and average flows were calculated, and the number of high flow pulses per site recorded. Through these sets of calculations, the flashiness and R-B Index values were determined for each stream site.

APPENDIX E : DataStream Information Guide

Resources page

- Always review this page (https://atlanticdatastream.ca/en/resources) before adding or modifying data
- This page contains:
  - The most up-to-date Upload Template
  - How-to videos for uploading data
  - PDF documents with step by step instructions for uploading data
  - Access to informative webinars and the DataStream Youtube channel

Upload Template

- *Instructions*: this can be found on the first sheet of the Upload Template and gives a brief explanation of how to fill out each sheet
- *Dataset Metadata*: The metadata can only be changed manually on the DataStream website so the only section that needs to be filled out on this sheet is the Dataset Name as it will be added to the *Export* sheet.
  - Make sure the Dataset Name matches the current Dataset Name (*WRTBWA Quality and Quantity*). Otherwise an error will appear when uploading
- *Monitoring Locations*: Ensure all *Monitoring Location* information is identical to the locations in the existing dataset
  - Any slight difference in name or coordinates will appear as a completely different location
- *Characteristic Metadata*: For the CharacteristicID, include the tool used to find the measurement. This is not necessary but it is useful in differentiating data
  - Example: "YSI nitrate", "TL water temperature"
- *Results*: On this sheet you will fill out the MonitoringLocationID and CharacteristicID using the dropdown boxes. The ActivityStartDate, ActivityStartTime (optional) and ResultValue will be entered in manually. Values can be copied over from other documents but make sure to use the "paste values only" option to keep proper formatting
  - Dates should follow yyyy-mm-dd formatting
  - Times should follow 24-hour formatting (hh:mm:ss)
  - Ensure large numbers are formatted without commas (this will cause an error message when uploading)
- *Export*: You will not have to fill out this form at all. As you fill in the *Dataset Metadata*, *Monitoring Locations*, *Characteristic Metadata* and *Results* sheets, this sheet will automatically fill in. Once all information is filled in, save this sheet as a .CSV file. This is what you will upload to DataStream
- *Tips and Tricks*: this sheet helps with troubleshooting common errors
- *Changelog*: this can be found on the last sheet of the Upload Template. Check any time there is an updated version of the template to be aware of any changes

How to Update Dataset:

1. Log in to DataStream
2. Click on "Upload Data" tab located on top menu bar
3. Click on the existing dataset (*WRTBWA Quality and Quantity*), then click on UPDATE DATASET and follow the steps
4. **Step 1: Terms of Use**
   a. Agree to terms of use
5. **Step 2: Update Type**
   a. Choose from three options depending on what you are looking to do:
      i. **Add new data:** Most common option. Here you can add any additional data to what you have already uploaded in the past. Do NOT reupload data that is already uploaded with this option because it will appear twice in your overall dataset
         1. Version number will change by .1 with each addition. For example, 1.0 to 1.1 since it is an addition to the original

    ii. **Modify existing data:** This option ONLY lets you download the existing dataset, make changes to it and then reupload it, thus replacing the original.
        1. Version number will change by 1.0 with each modification. For example, 1.0 to 2.0 since it is a major change
    iii. **Edit metadata:** This option allows you to change your basic information such as abstract, contact information, etc.

6. **Step 3: Upload Dataset**
    a. Upload dataset in a .CSV file, properly formatted in accordance with the most recent Upload Template
        i. If dataset does not meet all formatting requirements, errors will appear on the bottom of the screen
        ii. Clicking the DOWNLOAD FULL ERROR LIST will give you all the errors needing to be fixed in the file
        iii. After fixing all errors, drag the new version of the file into the box
        iv. Once a successfully formatted file is dragged into the upload box, you will automatically be taken to the next step
7. **Step 4: Metadata**
    a. Fill in metadata information sheet
        i. The Dataset Name is pre-selected based on the dataset you uploaded
        ii. When adding or modifying dataset, most of this section will already be filled out but you are given the opportunity to make any changes
8. **Step 5: Changelog**
    a. You can add in changelog what you have changed in the dataset so that people can follow those changes
9. **Step 6: Preview and Approve**
    a. Uploading is completed and data is combined and added to overall dataset
    b. Dark hourglass symbol: dataset is still uploading
    c. Yellow hourglass symbol: dataset is in preview, meaning you can look at dataset before it is published to make sure it is how you want it to appear
    d. Click on PREVIEW DATASET to look over the uploaded dataset
    e. If you notice a mistake or error in your dataset, click REJECT CHANGES
        i. This will take you back to the previous version and you will have to reupload your new data
    f. Once you are satisfied with your dataset, click APPROVE DATASET and then the dataset becomes published to the public