The Effects of Weather on Young-of-the-Year Brook Trout (*Salvelinus fontinalis*) Survivability

Harriet M. Laver

Ellen's Creek Watershed Group Inc.

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Abstract

Young-of-the-year (YOY) brook trout, *Salvelinus fontinalis*, are an important indicator of stream health in Ellen's Creek. Since 2014, Ellen's Creek Watershed Group Inc. has monitored the population of brook trout in Ellen's Creek through annual electrofishing surveys, taking place sometime between late July and early August. The same area is chosen for the electrofishing survey each year, and a three-pass removal method is implemented. With climate change on the horizon, weather patterns are expected to change which will affect species that rely on specific temperature ranges for survivability, such as brook trout. Weather data from 2013 to 2020 has been analyzed and compared to populations of YOY brook trout from 2014 to 2020. Cold winter temperatures, snow accumulation, and, to some extent, rainfall from March to May, have a positive correlation with an increase of YOY brook trout numbers. With changing weather patterns due to climate change, YOY brook trout numbers are expected to suffer in the future due to less snow accumulation, more cycles of freezing and thawing throughout the winter, and increasing water and air temperatures. This report recommends future monitoring of water temperatures, and stream depth in Ellen's Creek. It also recommends yearly macroinvertebrate studies at this location, and more research to be done to solidify the findings in this report.

Keywords: brook trout, young-of-the-year, electrofishing, climate change, temperature, weather

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Brook trout, *Salvelinus fontinalis*, are an important indicator of a healthy stream since they are highly sensitive to changes in the stream around them (Moyle, 1993). Not only does a thriving population indicate stream health, but it also indicates good management practices regarding recreational fishing. In the midst of a worldwide climate crisis, it is fair to wonder just how the climate crisis could affect local ecosystems; in this case, the YOY brook trout survivability and growth. With climate change, extreme weather events are expected to happen more frequently, along with increased temperatures, and sea levels rising (Duinker, 2002). Many aquatic species will be influenced by these sudden and extreme changes including brook trout. It is hypothesized that climate change could negatively impact brook trout populations with temperatures rising in both the air and water. Ellen's Creek Watershed Group Inc. has monitored the population of brook trout in Ellen's Creek through annual electrofishing surveys, in the same section of the stream, from the years 2014 to 2020. Each survey took place approximately the same time of year in the first week of August. Information collected from these surveys was compared against weather data from 2013-2020.

Food sources and suitable habitat are essential for brook trout to thrive in a stream. As brook trout develop, their needs change too. This involves their required food sources evolving overtime as the brook trout mature. With the changing climate, other species living in the same habitat which brook trout may rely on for food sources could move to cooler locations or could face dwindling populations. Along with species decline or relocation, the habitat where brook trout reside may face some serious changes regarding the loss of suitable habitat and refuge for brook trout seeking shelter from rising temperatures and safe areas for their eggs to hatch successfully over the winter months. Suitable habitat includes a stream sheltered by trees which aid in cooling the water because of the shade they provide (Moyle, 1993) and this also helps to decrease the erosion of banks as well as slow down water runoff.

The purpose of this research is to determine what weather factors have the most impact on YOY brook trout survivability and how those factors may be affected by climate change. With this information, conservation groups can make educated decisions regarding how to proceed in the changing climate to protect the species already residing in the streams on Prince Edward Island.

Materials and Methods

In order to establish the size of the brook trout population in Ellen's Creek year by year, electrofishing surveys took place on a single day between July 31 and August 9 from 2014 to 2020. The surveys took place in a section of the creek, below the Carter's Creek subdivision in East Royalty, which is comprised of neither the best brook trout habitat or the worst, but the habitat which contains a bit of everything in order to get an accurate picture of the state of the brook trout population in Ellen's Creek.

Nets were set up at the start of the capture area upstream and at the bottom of the capture area downstream to prevent any brook trout entering or leaving the area during the electrofishing survey. One person went through the stream with an electrofishing backpack while two other people followed with nets to catch the emerging fish, which were then placed in a bucket containing water from the stream. A three-pass removal method was implemented and diminishing returns ensured accuracy with capture, much like the method implemented in Guignion et al. (2019). Meanwhile, at a station on the bank of the stream, three plastic totes were placed side-by-side. The totes were filled halfway with water from the stream and then ferns were placed for cover in the two larger totes to decrease the stress on the fish. Oxygen was pumped into the two larger totes (the holding tote and recovery tote) to ensure the fish were receiving sufficient oxygen. In the smaller tote, clove oil was added to the water. The clove oil immobilized the fish and made it easier to measure and record them before placing them in the recovery tote. After the fish from all three sweeps had been measured, counted, and had fully recovered, they were released back into the stream.

The data was then transferred from the field notebook to a Microsoft Excel document with formulas to determine the population estimate, probability of capture estimate, and brook trout per $100m^2$ estimate. The actual area was determined by measuring the length of the section and the bank to bank width of the stream at approximately 10cm intervals. The following formulas were used:

$$x = 2 * Pass\ 1 + Pass\ 2$$

$$y = Pass\ 1 + Pass\ 2 + Pass\ 3$$

$$p = \frac{\left(3 * x - y - \sqrt{y^2 + 6 * x * y - 3 * x^2}\right)}{2 * x}$$

$$P = \frac{\left(6 * x^2 - 3 * x * y - y^2 + y * \sqrt{y^2 + 6 * x * y - 3 * x^2}\right)}{18 * (x - y)}$$

$$\frac{BT}{100m^2} = P * \left(\frac{100m^2}{A}\right)$$

p = probability of capture

P = predicted population

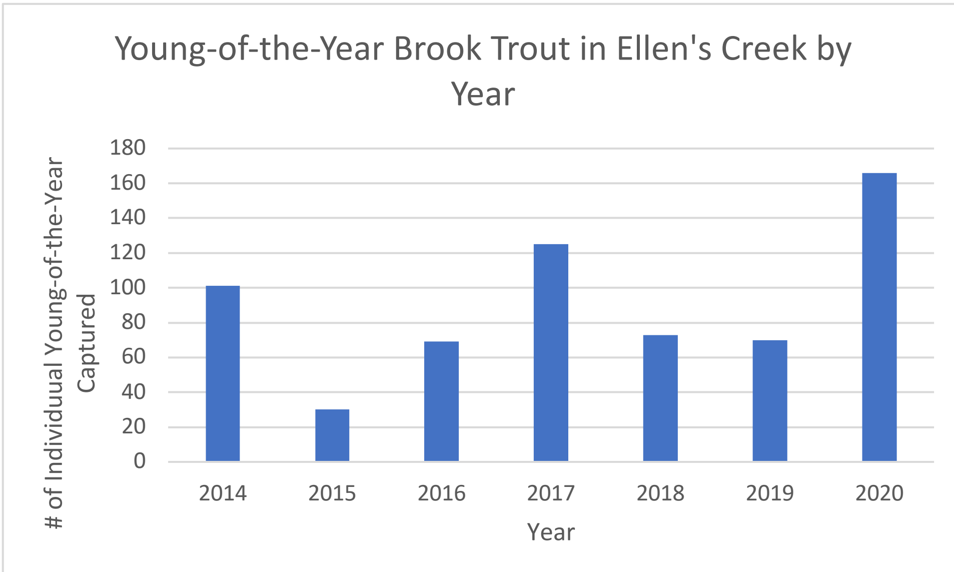
A = Area

$\frac{BT}{100m^2}$ = brook trout per $100m^2$

Results and Discussion

Figure 1

Young-of-the-Year Brook Trout in Ellen's Creek by Year



Note: Data was provided by the Ellen's Creek Watershed Group Inc. Young-of-the-year is described as brook trout which are not a year old and are determined by their size in relation to other age classes captured.

The years 2014, 2017, and 2020 saw the largest numbers of YOY brook trout, whereas 2015 saw the least amount of YOY brook trout. The numbers associated with 2015 are considered an outlier due to the flooding that took place December 11, 2014 which washed out a section of road above a prime spawning area for brook trout in Ellen's Creek. It is believed this flooding negatively impacted brook trout redds (spawning nests).

In 2014, there were 101 YOY captured using electrofishing surveys. In 2015, that number declined to 30 YOY due to flooding after spawning in 2014. In 2016, there were 69 YOY brook trout captured during the surveys. The number of YOY rose to 125 in 2017. In 2018, there were 73 YOY captured and in 2019 there were 70. Lastly, in 2020, there were 166 YOY captured during electrofishing surveys. These numbers fluctuated annually, and it was not evident that the adult population influenced the number of YOY produced. This pattern has also been seen in other studies with salmonid species (Hitt et al., 2016).

Table 1

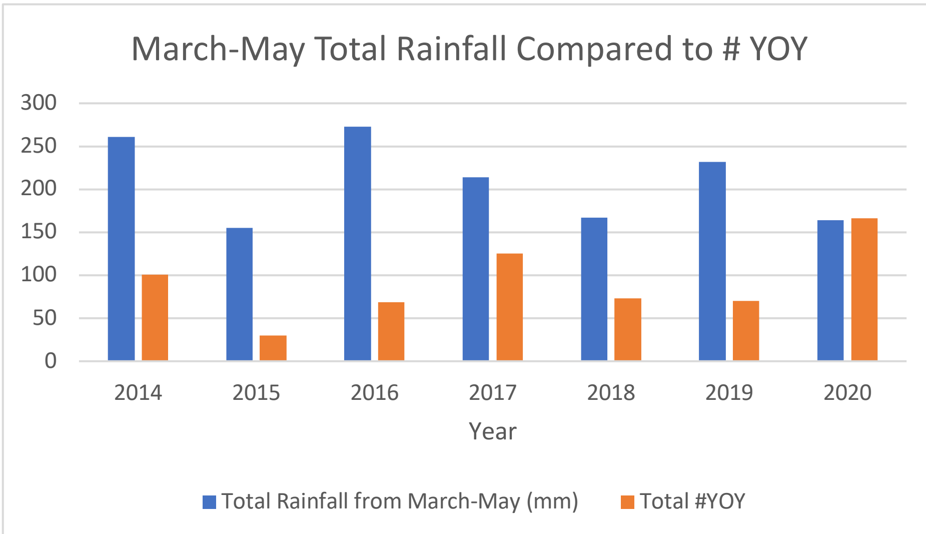
	Probability of Capture	Population Estimation	Brook Trout per 100m2 (BT/100m2)	Young-of-the-Year Brook Trout Captured
2014	0.634	122	81	101
2015	0.508	45	30	30
2016	0.637	90	60	69
2017	0.538	196	131	125
2018	0.585	128	85	67
2019	0.566	101	67	70
2020	0.496	211	141	166

Note: Data was provided by the Ellen's Creek Watershed Group Inc.

Weather data was collected from the Government of Canada's website from the weather station at the Charlottetown Airport which is approximately 2.3km from the site where electrofishing surveys took place. Daily temperature, rainfall, and total snow accumulation were assessed and compared to YOY brook trout numbers.

Figure 2

March- May Total Rainfall Compared to Number of Young-of-the-Year Brook Trout

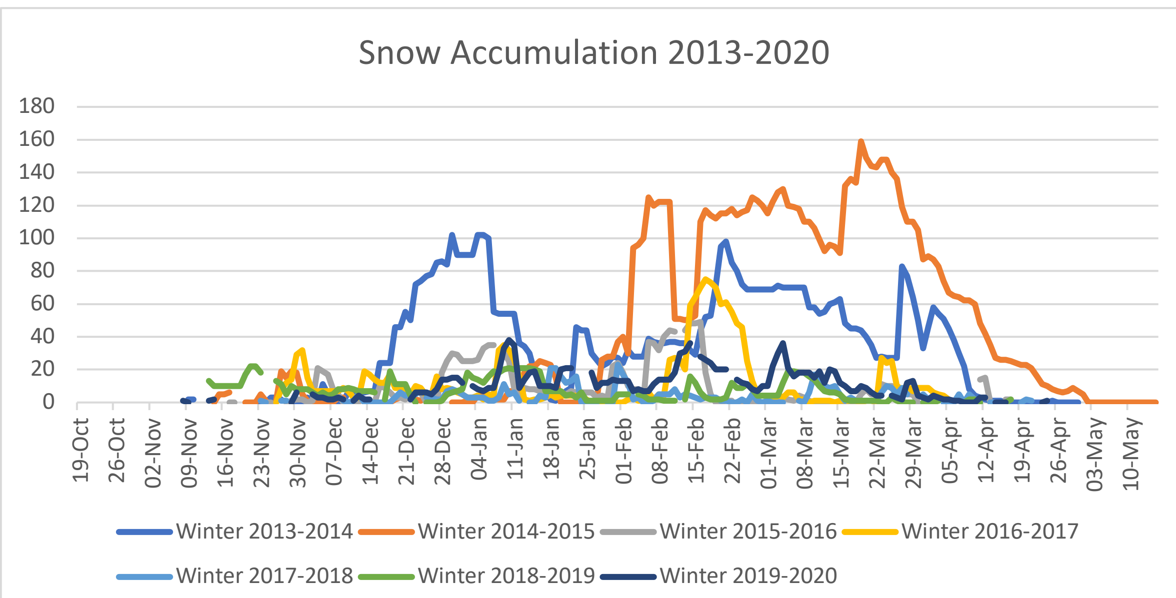


Note: Weather data was collected from the Government of Canada.

It was found that rainfall from September to December did not affect the number of YOY the following summer, despite some sources suggesting otherwise (Hitt et al., 2016). The amount of rainfall occurring from March to May could have a slight influence on the number of YOY that year, although the impact is not significant and other factors have a greater influence on YOY numbers. For instance, in 2014, there was a total of 261.2mm of rain from March to May and the number of YOY were the third highest that year with 101. In 2017, the rainfall from March to May was the fourth highest of the years recorded at 213.6mm and the YOY was the second highest at 125. In 2020, rainfall from March to May was second lowest at 163.8mm, however, YOY numbers were recorded at an all-time high, 166. The year with the highest rainfall was 2016 with 272.9mm, however, YOY was especially low that year at 69 YOY. Rainfall from March to May, alongside medium to high snow accumulation, may lead to snow melting, increasing the dissolved oxygen concentration in the water. The increasing waterflow from melting snow could lead to organic drift, where food sources from further upstream are brought downstream which could be beneficial for brook trout. However, if there is too much rainfall, this could result in temperatures in the stream which are inhospitable for brook trout and too high of a water flow in the stream resulting in eroding banks releasing sediment into the stream. This can suffocate YOY brook trout. Other factors resulting from fast-flowing water include brook trout dying from being unable to find sufficient shelter from the fast flow. This concludes that YOY are not entirely dependent on rainfall from March to May, but a sufficient amount of rainfall along with snow accumulation, may have a slightly positive influence on YOY brook trout.

Figure 3

Snow accumulation over the winter by year.



Note: Weather data was collected from the Government of Canada.

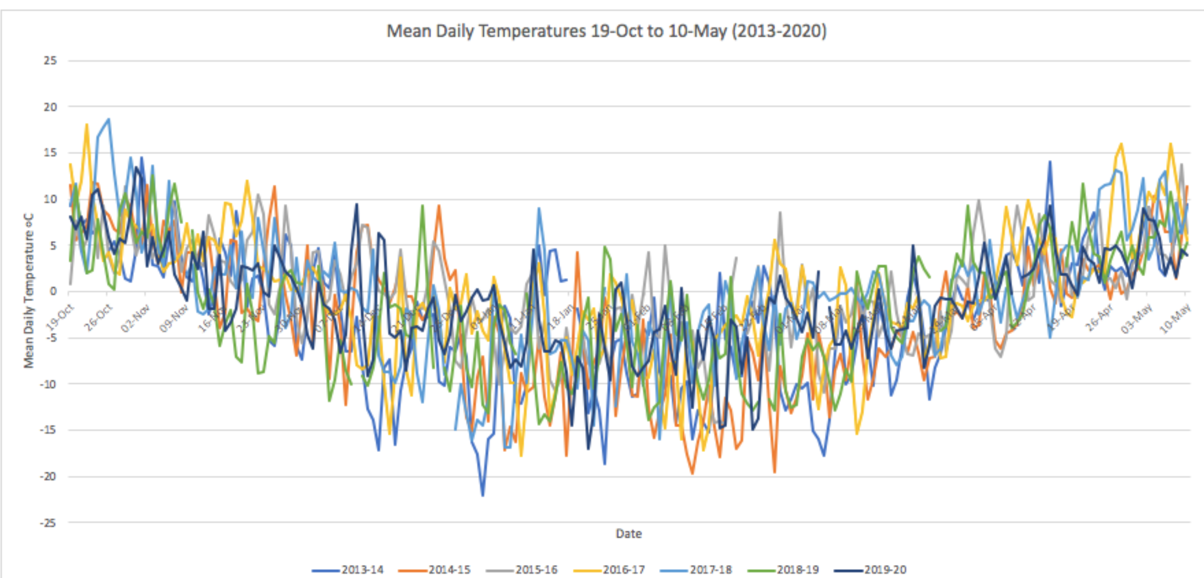
The snow accumulation data pictured in Figure 3, compared to the YOY brook trout captured by year in Figure 1 indicates that the number of YOY increases with more snow accumulation throughout the winter, if snow accumulation is followed with cold and consistent temperatures. In this case, little accumulation is described as being 25cm or less. Medium snow accumulation is described as being over 25cm and up to 60cm. High snow accumulation is described as being over 60cm. 2013-14, 2014-15, and 2016-17 all had high snow accumulation. 2015-16, and 2019-20 all had medium snow accumulation. 2017-18, and 2018-19 all had little snow accumulation. Snow accumulation provides insulation for the ground and keeps the water in the stream at a consistent temperature. Without snow accumulation, temperatures fluctuate, leading to premature run off into the stream, increasing stream flow, and decreasing the temperature of the stream quite rapidly. If brook trout were to hatch at water temperatures below 4°C, many YOY would not survive at that temperature (Hutchings, 1991). Therefore, in order for them to survive during late winter when hatching, snow coverage, ensuring consistent temperatures above 4°C, is vital. Another reason the amount of snow accumulation positively correlates with the number of YOY brook trout is that snow accumulation blocks light from reaching the water. Brook trout larvae require a dimly lit environment, or they will suffocate one another whilst trying to find shelter from the light (Hutchings, 1991). If snow accumulates on top of the ice on the stream, it blocks a significant amount of light.

Brook trout also require a great deal of oxygen in the water (Moyle, 1993). Factors such as sewage and sediment (Alberto et al., 2017) can negatively affect the dissolved oxygen concentration in the water or impede the ability of brook trout to receive oxygen in the water. According to the United States Geological Survey (n.d.), cold water contains more dissolved oxygen than warmer water, meaning that as the snow melts and emits cold water into the stream, the stream remains cold and stocked with dissolved oxygen concentration. So, the more snow accumulation there is, the more dissolved oxygen is released into the water when the snow melts and cools the water. However, as previously mentioned, if the snow melts too suddenly, the water may reach inhospitable temperatures for the brook trout, resulting in loss of YOY.

Insects found in Ellen's Creek such as *Chironomidae* (midges) and Tricoptera (caddisflies) are also affected by snow accumulation. Insect larvae is a staple food source for YOY brook trout (Fechney, 1988; Hassler & Tebo, 1963; Hewitt, 1913; Leonard, 1937; Meissner, & Muotka, 2006). A benthic analysis carried out in 2019, in Ellen's Creek, indicated that there was a substantial amount of *Chironomidae* (midges) at 438, Diptera (true flies) at 129, Ephemeroptera (mayflies) at 197, Tricoptera (caddisflies) at 26, and Oligochaeta (aquatic worms) at 23 (Costello et al. 2019 p. 62). All of these macroinvertebrates are food sources for brook trout. YOY brook trout eat a substantial amount of insect larvae. Insect larvae depend on consistently cold temperatures during the winter months instead of cycles of thawing and freezing. Cycles of thawing and freezing lead to larvae hatching prematurely, meaning that there would be fewer larvae hatching in the spring when the insects could actually survive (MacPhee, 2017). If there are a lack of food sources, such as insects in the spring, YOY brook trout lack a major food source, as well as older brook trout.

Figure 4

Mean daily temperatures collected from the Government of Canada.



Shown in Figure 4, temperatures during the winter of 2013-14 did not fluctuate greatly, therefore, the ground stayed frozen, benefitting both the insect larvae and by association, the brook trout eggs. In the winter of 2014-15, temperatures remained consistently cold keeping the ground frozen. However, due to flooding in Ellen's Creek on December 11, 2014, critical habitat for brook trout eggs was disrupted by a culvert washout further upstream. It is believed this resulted in lower numbers of YOY brook trout in 2015. Otherwise, 2015 was expected to have a substantial amount of YOY brook trout if not for this flood. The winter of 2015-16 temperatures fluctuated slightly, likely resulting in the thawing and refreezing of the ground, negatively impacting the YOY brook trout that year. The winter of 2016-17 saw somewhat consistent temperatures, but the snow accumulation was high with a maximum of 73cm, meaning that the ground likely stayed frozen, and leading to 125 YOY. During the winter of 2017-18, temperatures were somewhat consistent, however, there was little snow accumulation with a maximum of only 9cm, so the ground likely went through thawing and refreezing cycles leading to only 73 YOY. Winter 2018-19 was similar as the temperatures were not very consistent and there was little snow accumulation with a maximum of only 20cm, leading to 70 YOY. The winter of 2019-20 saw medium snow accumulation with a maximum of 38cm and somewhat consistent temperatures leading to 166 YOY in Ellen's Creek.

Conclusion

YOY brook trout in Ellen's Creek, Prince Edward Island, are greatly affected by weather patterns, particularly in the winter months. As air and water temperatures rise along with less and less snow fall anticipated with every coming year due to climate change, (Groisman et al. 2004, as cited in Rodgers, 2015) YOY brook trout populations can be expected to decline due to their dependence on snowfall and cold temperatures. High YOY brook trout populations were seen in the years 2014, 2017, and 2020 with populations of YOY being over 100 individuals each of those years. In each of these years in question, snow accumulation was medium or high and had relatively consistently cold temperatures throughout the winter. This consistency insulated the water, meaning the temperatures were warm enough to keep the brook trout eggs alive and growing, yet cold enough to keep the ground frozen in order to prevent insect larvae from hatching prematurely. The snow also prevented too much light from reaching the eggs or newly hatched brook trout, as too much light leads to the suffocation of the brook trout. Overall, it appears that rising temperatures due to climate change will negatively impact brook trout as the years where the winter temperatures are consistently cold, and have medium or high snow accumulation, are the years where the most YOY survive. If winters get warmer, there will be cycles of thawing and refreezing which are not beneficial for brook trout directly and indirectly. Since climate change is expected to increase temperatures during the winters, cycles of freezing and thawing will become more frequent, along with less snow accumulation, both of which put brook trout at risk both directly and indirectly.

Recommendations

More research needs to be done in order to solidify the hypothesis that YOY brook trout numbers are positively correlated with consistently cold winter temperatures along with medium or high snow accumulation. In order to do so, electrofishing surveys should continue to take place at the same site in Ellen’s Creek. Also, to fill gaps in the data, water temperature should be taken in Ellen’s Creek. The PEI Watershed Alliance provides data loggers to its members which would measure both the depth and temperature of the water (Ramos, R. personal communication, July 30, 2020). It would be most beneficial to install one of these year-round nearest the spawning area of the brook trout. Another recommendation is that macroinvertebrate studies should take place yearly in order to identify any correlation between the weather and the numbers of certain macroinvertebrates used as food sources for the brook trout.

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