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The Avon Partner Project 2020

Sustainable Westbury-on-Trym SusWoT

USING LESS, LIVING MORE

RMP01: Assessing Pollution Levels in the Trym and its Suitability for Fish

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Abstract

The 21st century has provided considerable scientific advances in understanding the implications that an increasingly urbanised globe is having upon natural ecosystems. With urbanisation comes the development of infrastructure and importantly to this investigation, roads. Roads have provoked complications within rivers, yet this is a concept largely neglected by researchers in the UK. This paper reports on an investigation into the presence of heavy metals in the River Trym and the consequences that this will have upon aquatic life, more specifically trout, within the river. Between Sea Mills and Westbury on Trym, a total of 10 sites were established, measuring the concentration of heavy metals and various parameters to assess water quality. Overall, the results reflected a healthy body of water with conditions inside the tolerable range for trout. The heavy metals data did not provide any indication that road run-off affects the rivers suitability for trout however, there is an insufficient amount of data to confidently suggest that the roads have no effect on the quality of the water.

1. Introduction

The effect that road run off may have on rivers and habitats is a notion little explored by research in the UK. Considering that in 2016, there was an estimated 246,500 miles of roads in the UK (GOV.UK, 2020), a figure which is expanding each year, it would be surprising if they had no influence on the water quality of rivers that flow beneath them. This investigation took place along the River Trym between Sea Mills (by the mouth to the River Avon) to Westbury on Trym, Bristol. This was in partnership with Sustainable Westbury on Trym, a volunteer group with a drive to improve the ecology of the river and provide a healthy habitat for fish. A sewage leak in 2013 resulted in the loss of much aquatic life within the river which SusWoT aim to restore. A total of 10 sites were established and at each location, measurements of dissolved oxygen, pH, conductivity, temperature and turbidity were taken to assess the quality of the water body. The focus of this research was about the effect of road run-off on the Trym, so two main roads were identified (Shirehampton Road and Falcondale Road) with measurements taken before and after both. Four heavy metals associated with road run-off were identified: Cadmium (Cd), Copper (Cu), Zinc (Zn) and Nickel (Ni), mainly coming from car brake pads and tyres (Gobel et al, 2007). The presence of these heavy metals in the Trym would indicate the presence of road run-off in the river system, which could be detrimental to the health of the river's aquatic life. It is crucial to note that a river called Hazel Brook meets with the Trym and has been reported as highly polluting, so a site was allocated to this river to allow for comparison with the Trym. Kick samples were also taken from all 10 sites, enabling us to identify macroinvertebrate species which can act as a good indicator for water quality, and would help us identify if there was an adequate food source for trout. Three research questions that have been addressed in this investigation are: Is the River Trym suitable for brown trout? Is Hazel Brook impacting on the quality of the Trym? Is there a significant difference in heavy metal concentrations before and after the main roads?

2. Background

2.1 Requirements for Trout and Westbury on Trym

Westbury on Trym is a village in northwest Bristol, England. The River Trym runs from South Bristol and connects to the River Avon at Sea Mills, running below Falcondale Road, Gloucester road and Westbury on Trym during its course. Its surrounding areas consist of a nature reserve called Blaise Castle, a golf course and city parks. In 2013, a blocked sewage pipe resulted in raw sewage spilling into the River Trym (GOV.UK, 2014) which had a detrimental impact on the ecology of the river, with "112 eels, 200 sticklebacks, 1000 bullheads all found dead as a result of the pollution and an estimated 90% of river invertebrates" (GOV.UK, 2014).

Literature and background research indicates that brown trout are commonly found across lakes and rivers in the UK (Wild Trout Trust, 2020). This research identified the basic and optimal parameters of water quality for trout, which shall be discussed in the following section of this paper.

2.2 Parameters to Determine Water Quality

Determining the suitability of a river for aquatic life, in this case trout, requires the assessment of numerous variables, most notably water quality, available food sources and physical attributes of the river. The requirements of specific biotic species relative to the measurement of the rivers physical, chemical, biological and radiological attributes (Diersing, 2009) determines the quality of the water (Johnson et al, 1997). Several parameters can be used to identify and monitor the quality, such as pH, conductivity, turbidity, dissolved oxygen and temperature.

2.2.1. pH

pH is determined by its hydrogen ion concentration and is a good indicator for how corrosive a body of water is. A higher hydrogen ion concentration returns a lower pH value which is more acidic, hence a more corrosive nature. Extreme pH values which are above or below the tolerable range (typically less than 6.5 and greater than can stress aquatic systems and cause physical damage, rendering them vulnerable to diseases (Leivestad and Muniz, 1976). The optimum pH levels for trout range between 6.8 – 7.8, however older trout can survive in more acidic waters (Grande et al., 1978: Molony, 2001).

2.2.2. Conductivity

A greater measure of conductivity reflects a high level of total dissolved salts and inorganic materials such as chlorides, sulfides and carbonate compounds. Within freshwater streams, the expected conductivity value ranges between 100 and 2000uS/cm, 55000uS/cm in seawater and for comparison, in distilled water it is 0.5-3uS/cm (SWRCB, 2002; American Public Health Assoc., 1999). Geology greatly affects the conductivity of the water (Bhateria and Jain, 2016). To give an example, the inertia of granite means it is unable to ionise water that percolates through it, resulting in a lower conductivity of any stream travelling over a granite dominated bedrock. There is a significant relationship between conductivity and salinity, demonstrating its importance in this investigation as most aquatic organisms, such as saltwater, euryhaline, anadromous, catadromous, and freshwater species can only tolerate a specific salinity range (SWRCB, 2002). External sources such as misconnections and agricultural run-off may input additional dissolved ions such as chloride, phosphate and nitrate ions which can alter conductivity levels, negatively impacting on the water quality (EPA, 2012).

2.2.3. Turbidity

Turbidity measures the relative clarity of a liquid based on the shape, size and concentration of suspended particles in the water. Low turbidity is commonly understood as an indicator of healthy water (Anderson, 2005). Sediments that have a low mass are often unable to settle in the river so remain suspended within the flow, producing a cloudy or turbid appearance. Clay, silt, algae, coloured organic compounds, microscopic organisms and organic matter are typically carried in a body of water. A variety of factors can cause the development of a highly turbid river however, the growth of phytoplankton (Northcote et al., 2005), along with anthropogenic activities such as construction, mining and pollution from road and bridge run-off are frequently responsible (EPA, 2005). Water of high turbidity can restrict light from reaching lower depths of the river, altering the ecological productivity such as the rate of photosynthesis, thus reducing dissolved oxygen in the river which can cause stress to aquatic life (Lloyd, 1987). A linear correlation between turbidity, run-off from land use and precipitation (Shen et al., 2018; Memon et al., 2014) is prominent during periods of heavy rainfall as greater run-off from human settlements and roads enables suspended solids and pollutants to enter the river. Trout thrive in waters with a turbidity of less than 50ppm (Raleigh, Zuckerman and Nelson, 1984).

2.2.4. Dissolved Oxygen

Dissolved oxygen is crucial for the survival of all forms of aquatic life. A deficiency is a sign of an unhealthy river (Rounds et al., 2013). Atmospheric and biochemical reactions such as photosynthesis are the main sources of dissolved oxygen. From the atmosphere, the oxygen either diffuses across the surface of the water or mixes into the body through aeration which can either be a natural process or anthropogenically induced by structures such as weirs (EPA, 2012). It is crucial to note that the solubility of oxygen varies depending on temperature (Wetzel, 2001); the higher the temperature, the lower the solubility. Trout require highly oxygenated water with greater than 7mg/L of dissolved oxygen (Raleigh, Zuckerman and Nelson, 1984).

2.2.4. Temperature

Temperature of water is an "abiotic master factor" affecting the properties of environments and conditions for aquatic organisms (Brett, 1971). Establishing temperature is valuable when considering metabolic rates, photosynthesis production, conductivity, salinity, pH and water density in research (Wilde, 2006). Temperature is closely linked to the river depth as shallow water is warmed faster resulting in a lower concentration of dissolved oxygen, as aforementioned (Wild Trout, 2020). Brown trout, particularly juveniles, require cold temperatures as they are more sensitive to low oxygen concentrations than larger, older fish (Doudoroff and Shumway, 1970 in Weithman and Haas, 1984). This has been supported in Sweden by Elkov et al. (1999) where a relationship between high oxygen concentrations and a high density of older trout was found. However, population density can also be affected by the presence of ammonium in the water as oxygen concentrations are reduced when microorganisms oxidise it to nitrate (Elkov et al., 1999). J.M. Elliott studied the effects of summer droughts and small water pools on the survivability of trout. His results suggested that a mix of cold water and high oxygenation is favourable, however they tend to remain near the bed where the water is cooler, despite the lower levels of dissolved oxygen (Elliott, 2000). Water temperatures that are suitable for trout lie between 5 – 19 ^{o}C and their critical thermal maxima is 25 ^{o}C (Currie et al., 2004).

2.2.6. Heavy Metals

Heavy metals are metallic elements produced from natural and anthropogenic sources with relatively high density in comparison to water. Their properties of high toxicity, bioaccumulation, non-degradability and pervasive nature (Bibi et al, 2007; Lehto et al, 2017), can lead to complications for the water quality in the river (Demirak et al, 2006). Guan et al. (2018) suggested that rapid development of population and social economy, together with urbanisation and long-term over-cultivation, have heightened environmental pressure from heavy metal contamination (Cu, Pb, Zn, Cr, Cd, Ni, As, and Hg). Historic mining activities have been understood to contaminate nearby sediments and subsequently river basins with heavy metals (Mn, Co, Cu, Zn, Mo, Cd, Pb) over a long timescale (Gabrielyan, Shahnazaryan and Minasyan, 2018). Although heavy metals can be produced from natural sources, the distribution and chemical fraction of heavy metals in a natural system are dominated by anthropogenic sources which includes road run-off. Chemical contents such as hydrocarbons and heavy metals are introduced in to the river (Krein and Schorer, 2000), mostly constituted by car components such as tyres (rubber, soot and heavy metal oxides [Zn, Pb, Cr, Cu, Ni]), brake pads (Ni, Cr, Cu, Pb) and brake drums (Fe) (Göbel, Dierkes and Coldewey, 2007). The concentration of these chemicals enhances during periods of rainfall when run-off is higher (Göbel, Dierkes and Coldewey, 2007). Of these elements, Mercury, Cadmium, Copper, Lead and Zinc interfere with and have the greatest consequences for aquatic life (Authman, 2015). Monitoring the concentration of these heavy metals is of great importance as they compromise the vital operations and reproduction of fish, fundamentally weakening the immune system and inducing pathological changes (Authman, 2015).

For this reason, the main focus of this investigation was to measure the heavy metal concentrations before and after the two main roads. Previous studies showed that Cadmium, Copper, Zinc and Nickel has little effect on egg and fry survival (Sayer, Reader and Morris, 1991). A larger study on trout in Norway in the Spring of 2007, an in-situ experiment with 24 hour simulated run-off episodes, which had sediment ponds under a four-lane highway outside of Oslo, studied the effects of road run-off. Fish that were exposed to highway runoff had higher concentrations of trace metals in gill and liver tissue, an increased activity of antioxidant defense system, complications with regulating plasma ions and increased levels of glucose and pCO_2. This has been attributed to the mixture of heavy metals, high salt concentrations and fluctuations in oxygen saturation. Measuring in Spring meant that there was a high level of salt run-off from roads as approximately 137,000 tonnes of salt grit was applied in the winter period of 2006-2007 (Meland, Salbu and Rosseland, 2009). Results showed that after a heavy rainfall event, the concentration of heavy metals drastically increased and there was a strong positive correlation between road salt and dissolved concentrations of Ni, Cu and Zn (Meland, Salbu and Rosseland, 2009). Overall, they found that even in the "least polluted exposure tank where pond outlet water was mixed with stream water, signs of physiological disturbances were evident" (Meland, Salbu and Roseland, 2009).

A study in Valley Creek, Valley Forge, Pennsylvania studied the impacts that urbanisation has on brown trout along with other fishes and macroinvertebrates. Generally, there was an absence in brown trout in areas which were more urbanised, whereas in non-urbanised areas there was a productive population present. (Kemp and Spotila, 1997). Younger trout were more abundant in cooler waters while lacking in warmer regions, highlighting the importance of cold water for this species, particularly for the spawning season. In areas that have become more urbanised, species would decline and become replaced by more adaptable life which can handle water of higher pollution levels (Kemp, Spotila, 1997).

2.3 Dietary requirements and physical attributes of the river

2.3.1. Dams

Typically, trout feed during the night on common invertebrates such as mayflies and water shrimp but adults have been known to eat small mice (Trust, 2020) and feed in the day if the temperature is cool enough (Trust, 2020). After identifying an inadequate amount of research on the effects that a release of warm surface water from dams can have upon macroinvertebrates and fish, Lessard and Hayes (2003) conducted an investigation in the Michigan lower peninsular, containing trout despite a lack of fish passage. They looked at how the population of fish varied due to the change in temperature before and after the dam and found that the temperature of the water increased for a 2-3 km stretch after the dam. “Downstream communities responded to warming below dams with shifts in the macroinvertebrate community, increased fish species richness, and reductions in brown trout, brook trout and slimy sculpin population densities” (Lessard and Hayes, 2003).

2.3.2. Requirements at Different Stages of Their Life Cycle

Brown trout require access to distinct habitats for the three key stages of their lifecycle: spawning, juvenile and adult. During spawning season, coarser sediment, shallower water and more shading is necessary to provide cooler water (Wild Trout, 2020). The University of Washington have studied the effects of turbidity and suspended solids on salmonids as they can alter their physiology, behavior and habitat which may lead to physiological stress and a reduction in survival rates. They found that “excessive sediment in hatchery water may smother eggs by depriving them of oxygen and reducing the ability of juveniles to capture prey” (Bash, Bolton and Berman 2001).

3. Methodology

3.1. Underlying Assumptions and Research Problem

Underlying assumptions during this investigation include:

- The water conditions will not change during the time taken to walk between sites
- The chosen sampling methods will not unintentionally influence results as every effort had been taken to minimise this by designing a robust methodology

3.2. Site Locations and Justifications

Figure 1 shows a map of the River Trym form Westbury on Trym (Site 10), downstream to the mouth which connects to the Avon (Site 1). The sites were selected based on their distinct characteristics which will be discussed below.

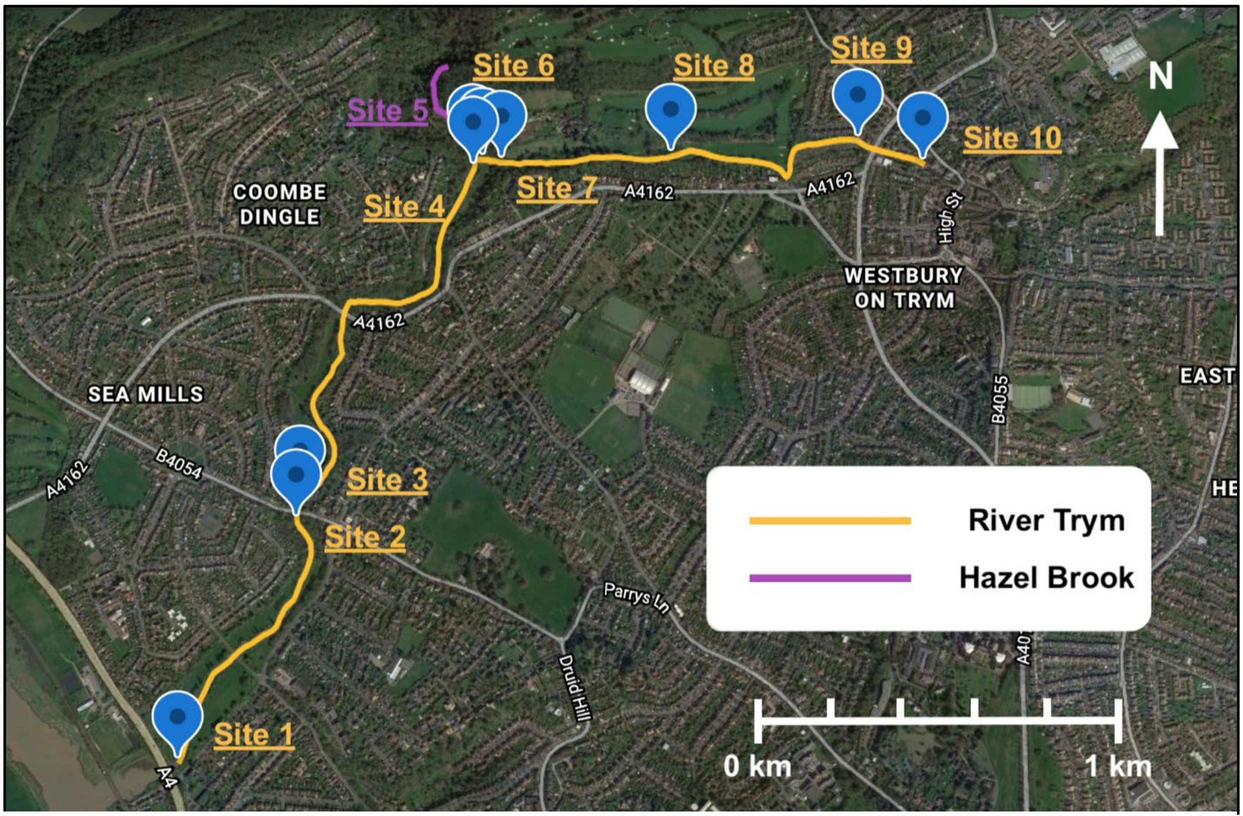

Figure 1 – Map to show each site location along the River Trym. The yellow line follows the Trym path and the purple line indicates Hazel Brook.

Site 1 (3.45km downstream) – Connection of the River Trym to the River Avon. This is the location where trout will first enter the Trym.

Site 2 and 3 (2.68km and 2.62km downstream respectively) – Before (3) and after (2) Shirehampton road. This is to identify if road run-off is impacting the water quality.

Site 4 (1.38km downstream) – Just after the confluence of the Trym and Hazel Brook

Site 5 (1.34km downstream) – Hazel Brook. This river has been reported to be highly polluted.

Site 6 and 7 (1.3km and 1.24km downstream respectively) – Both are slightly before the confluence and are before (7) and after (6) a weir.

Site 8 (0.77km downstream) – Henbury Golf Club. This measurement acts as a baseline for future work as fertilizer will soon be introduced.

Site 9 and 10 (0.21km and 0.2km downstream respectively) – Before (10) and after (9) Falcondale Road. This is to identify if road run-off is impacting the water quality.

3.3. Field Methodology

At each site, 1 measurement was taken per probe, 1 water sample for turbidity and 3 water samples for heavy metal analysis to allow for anomalous results as concentrations of heavy metals are not evenly spread in water. Designated 'clean hands' (individual collecting the sample) and 'dirty hands' (individual wearing rubber gloves to minimise contamination of samples) were assigned to individuals as recommended by the University Handbook. For the purpose of explaining the methodology with ease, 'clean hands' and 'dirty hands' will be used.

3.3.1. Methodology Step by Step

1. All equipment was collected and calibrated in the lab and carried to Sea Mills to begin at Site 1. Training for equipment use and calibration was received.

2. At this site, the task was divided into 4:

    a. Samples collected to analyse for turbidity and heavy metals
    b. Probe measurements for oxygen, pH, conductivity and temperature
    c. Kick sampling and collection of macroinvertebrates
    d. Photographing characteristics of the river and labelling of sample bottles

3. Water samples for turbidity and heavy metals: 'dirty hands' wore waders and collected a sample from the center of the stream using a 400ml plastic beaker.
   This was rinsed out 3 times per sample, downstream of the individual to avoid contamination. This is a standard practice and allows the sample bottle to be adequately rinsed. The depth at which the sample bottle was held underwater was set and remained consistent at all 10 sites to prevent unreliable results.

   For turbidity, 'dirty hands' passed the beaker to 'clean hands' who proceeded to fill a 50ml sample bottle with river water. This process was repeated 2 more times, totaling 3 per site.

   For heavy metals, 'clean hands' opened the sealed bag which contained 6 bottles with 1ml of concentrated nitric acid in each. It was critical that others members of the team stood upwind of this to avoid inhaling vaporised acid. Approximately 100ml of sample water was poured into each bottle, repeating this 2 more times at each site, totaling 3 per site. The lids were screwed on tightly, bottles were labelled, sealed back in the bag and placed in the cool box for preservation.

4. Probe measurements (pH, oxygen and conductivity): a second 'dirty hands' wore waders, stood in the middle of the river upstream of the kick sampling and switched each probe on. After the AR had stopped flashing on the display, measurements were taken and recorded by another member of the team.

5. Kick-net sampling for macroinvertebrates: after the heavy metal sample had been taken, 'dirty hands' held a kick-net downstream of themselves and the other 'dirty hand' individual to ensure that the other readings were not disrupted from the disturbed riverbed.

   The riverbed was kicked for 30 seconds using 1 foot, ensuring all uplifted sediment flowed into the net. The contents were tipped into a white plastic tray on the riverbank where the sediment was sorted through. A pipette was used to transfer macroinvertebrates and their larvae into a clean, labelled sample bottle containing river water.

6. Qualitative analysis: photographs were taken at each site, accompanied with a brief description of the rivers characteristics and noted the coordinates for each location.

7. Steps 3, 4, 5 and 6 were completed for every site, if it was deemed safely accessible.

8. After completing steps at Site 10, all equipment was returned to the Geographical Science Department and water samples, including macroinvertebrate samples, were refrigerated to slow down the rate of oxidation so they could be appropriately analysed the following day.

3.4. Lab Methodology

3.4.1. Field Measurements: pH, Conductivity, Oxygen

1. Data collected in the field was imported into Excel and Rstudio
2. Initial exploration was conducted for each dataset
3. Patterns were identified
4. Thresholds of optimal conditions for trout were considered for each parameter

3.4.2. Turbidity

1. Hach Turbidity Meter was switched on 30 minutes before use. Each sample bottle was shaken and 25ml was poured into a glass sample cell, then placed in the meter.
2. Results were recorded and later inputted into the computer.

3.4.3. Heavy Metals

1. Filtering tubes were used to prepare samples for analysis using 0.2uM, 25mm, Whatman Cellulose and Nitrate Filter.
2. 30 samples were obtained: 3 per site.
3. Samples were sent to Earth Sciences to test for Cu, Zn, Cd and Ni using the ICP-OES (Inductively Coupled Plasma – Optical Emission Spectrometry).
4. Results were returned later that week.

3.4.4. Macroinvertebrates

1. A microscope was used to inspect the macroinvertebrates at each site.
2. A total count was recorded at each site.
3. Identifying species in each sample was attempted through the use of microscope by placing them in separate petri-dishes, recording the species name and quantity found at each site.
4. Photographs were taken of various petri dishes with a ruler for scale and labelled.

3.4.5. Secondary Data

Secondary data was sourced from Bristol City Council and imported into Rstudio and used to calculate the outlier boundaries. The following equation was used where:

UQ = Upper Quartile,
LQ = Lower Quartile and
IQR = Inter Quartile Range

UQ+(IQR*1.5) = upper limit
LQ-(IQR*1.5) = lower limit.

Any data outside of this range was labelled as an outlier and removed from the data set.

4. Results

In order to address the aims of the investigation, data collected from both within the field and from further laboratory analysis has been explored to identify if road runoff has been impacting on the quality of water in the Trym. Comparison of results from sites located before and after Shirehampton Road (~2.65km downstream) and Falcondale Road (~0.10km downstream) allowed for this inquiry. The confluence of Hazel Brook and the Trym was considered: data from Site 5, collected from Hazel Brook, has been consistently highlighted in green throughout this paper and compared directly against results from the River Trym. Where appropriate, the results have been plotted with the optimal conditions and thresholds for brown trout, as established within the literature.

4.1. Field Measurements

4.1.1. pH

Figure 2 shows the pH measurements collected in the field which are fairly sporadic. Whilst there is a 0.277 increase in pH after Falcondale Road, there is minimal decrease after Shirehampton Road, showing no consistent pattern relating to the roads. The confluence with Hazel Brook at 1.34km downstream does not appear to have significantly impacted any of the downstream pH values. Overall, variation in the pH is limited, with a small range of 0.381. None of the data falls within the optimum bracket, 6.8-7.8 (Vtfishandwildlife.com, 2020), with the average pH value of 8.1375, lying 0.3375 units above the upper bound. However, all the datapoints lie comfortably within the tolerable pH band for Brown Trout (Vtfishandwildlife.com, 2020).

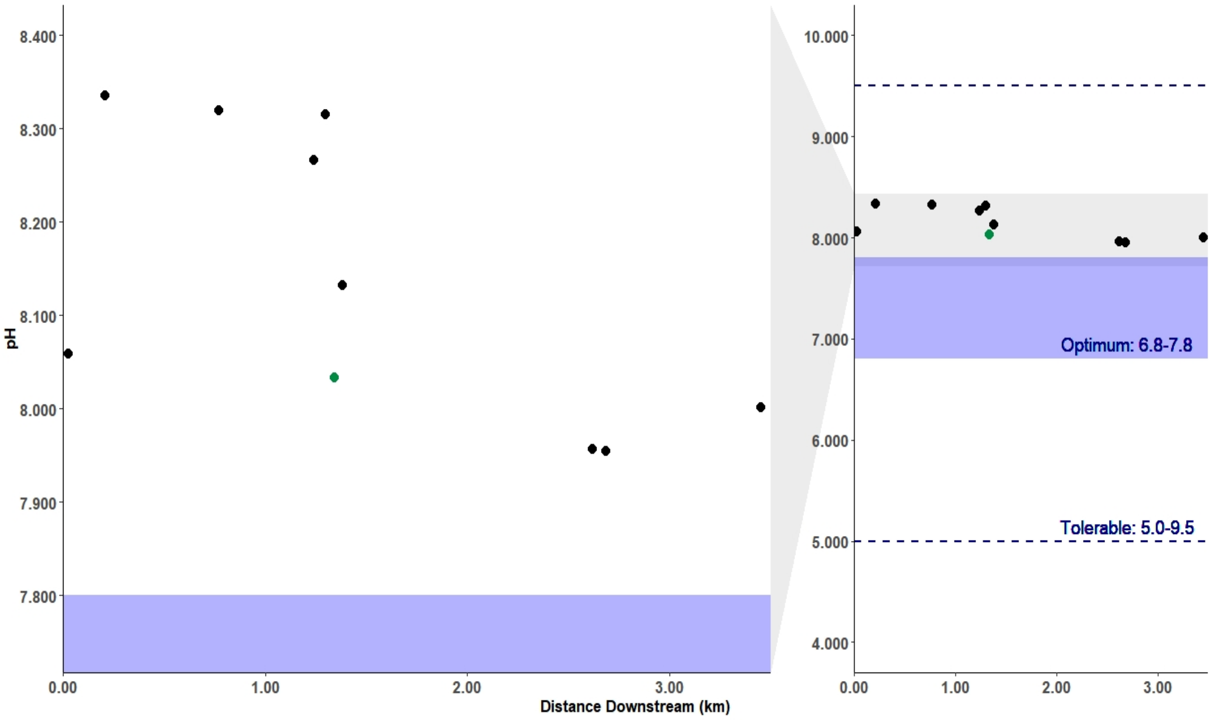

Figure 2 - pH measurements in the River Trym with Distance Downstream (km). The data does not show a clear relationship between pH and distance, with a noticeable range in pH values within close proximity between 1.24km and 1.38km downstream.

4.1.2 Conductivity

The measurements of conductivity downstream do not demonstrate a linear trend but do show a difference between Sites 6 – 10 (0 and 1.30km downstream), and those beyond. As seen in Figure 3, there is a small increase in conductivity after Shirehampton Road, but contrasting this, it decreases after Falcondale Road. The highest conductivity values were recorded at 1.34km downstream (Site 5 – Hazel Brook) and 3.45km downstream (Site 1 – Sea Mills) where the River Trym meets the River Avon. Despite this variation, the data has a small range of 85µS/cm, with all values falling within two standard deviations of the mean.

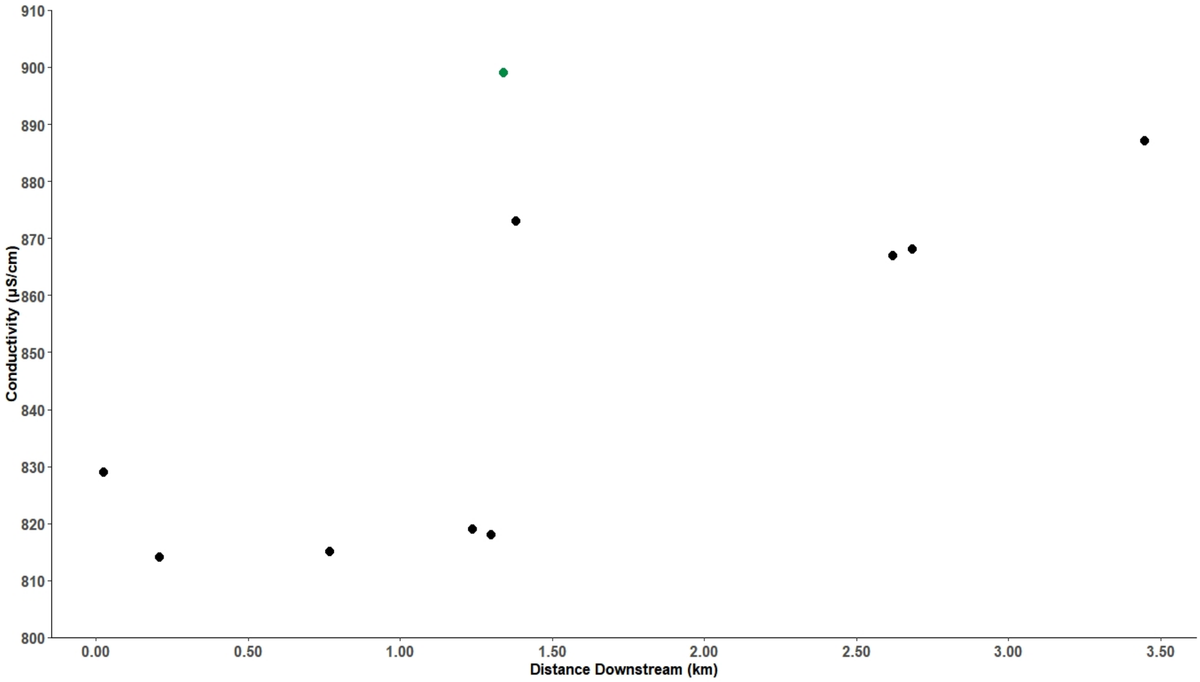

Figure 3 - Conductivity (µS/cm) measurements in the River Trym with Distance Downstream (km). The data shows a general positive correlation with the downstream sites generating higher conductivity measures than those upstream. Conductivity peaks at 899µS/cm, 1.34km downstream.

4.1.3 Dissolved Oxygen

The trends of dissolved oxygen, shown in Figure 4, show that the concentration decreases after both the major roads: oxygen content drops by 0.10ppm and 0.12ppm between 0.02-0.21km and 2.62-2.68km downstream respectively. However, these declines have a limited overall impact as all the values recorded lie significantly above the threshold of 7ppm required to sustain brown trout (Vtfishandwildlife.com, 2020).

4.1.4. Temperature

Results from water temperature analysis, represented in Figure 5, show that despite each site measuring more than 5.0ºC below the lower optimum temperature threshold of 12.0 ºC (Vtfishandwildlife.com, 2020), they are much closer to, or within, the temperature band suitable for reproduction. Since this data was collected on 21st January 2020, this result is in line with the breeding season for brown trout (January – March) (Vtfishandwildlife.com, 2020).

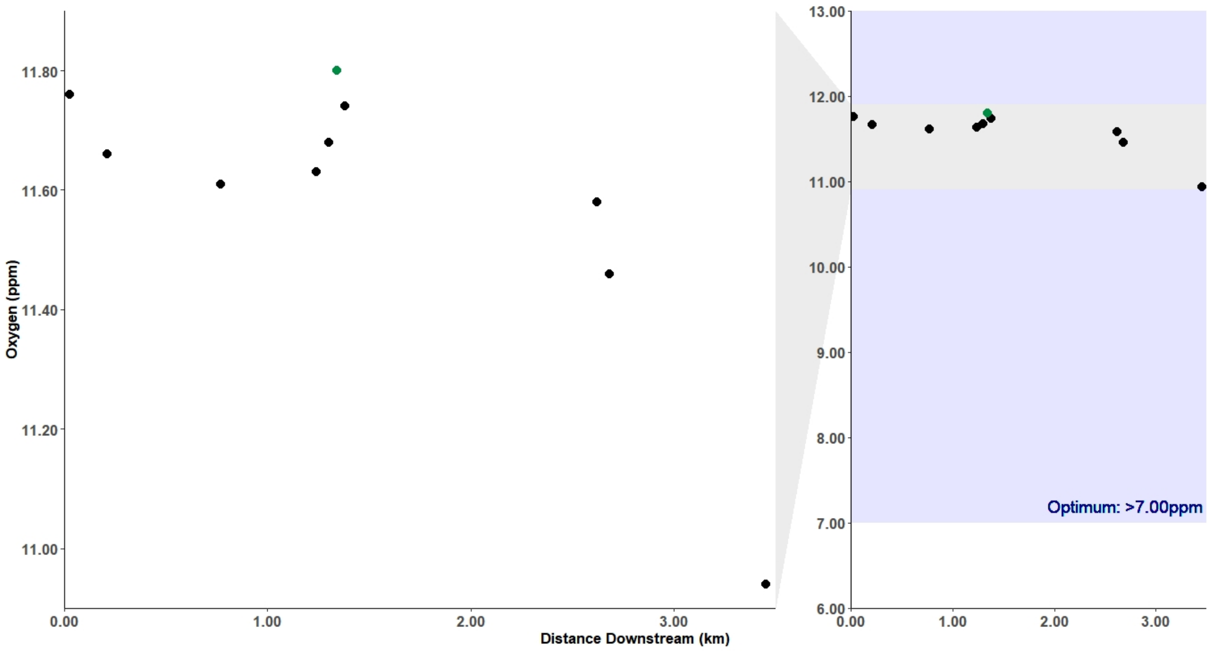

Figure 4 - Oxygen content (ppm) in the River Trym with Distance Downstream (km). There is a weak negative correlation, with oxygen content decreasing with distance. However, there are notable anomalies to this trend, particularly between 1.24-1.38km. The lowest oxygen values recorded – 10.94ppm at 3.45m downstream – is 3.94ppm above the minimum acceptable value of 7.00ppm.

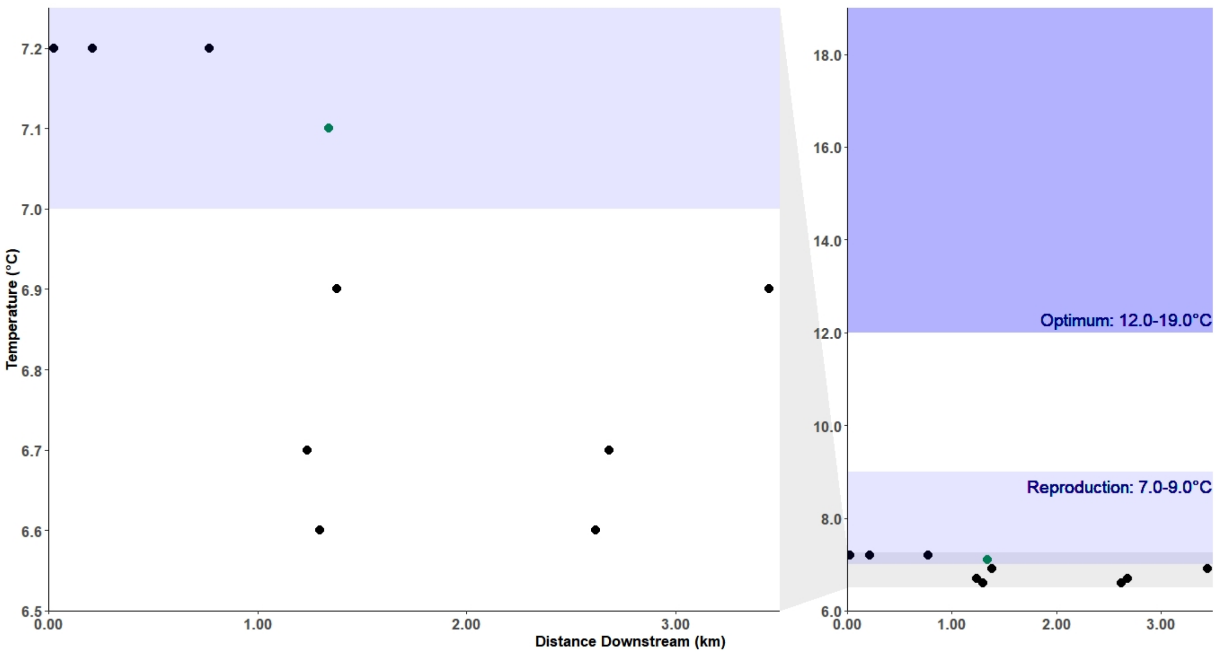

Figure 5 - Water temperature (ºC) in the River Trym with Distance Downstream (km). The scatter plot does not show any significant trend. The values vary randomly with distance but remain within a range of 0.6 ºC. Four recordings, taken at 0.02km, 0.21km, 0.77km and 1.34km downstream, are situated within the temperature band suitable for reproduction.

4.2. Secondary Water Data Quality

The primary dataset collected from the River Trym was small so had to be analysed against historic data. Outliers were removed from the Bristol River Water Quality data (Bristol City Council, 2020). The comparison of primary and secondary data, represented in Figure 6, shows that since the 2013 pollution incident, pH has risen, peaking in May 2015 at the end of the dataset. The average value of pH shows that it has since decreased but remains higher than it was prior to 2013. Average conductivity sits centrally in relation to past measurements, with a very similar value to those recorded a few years prior. There is no evidence that the pollution event had a long-term impact on conductivity in the river, with little change since and a decrease in variation after the event. Similarly, the average dissolved oxygen percentage lies within the range of past data and in the upper 50% of values, indicating relatively well oxygenated water. Overall, Figure 6 indicates that none of our averages lie outside the past ranges; our data does not indicate any problematic trends in relation to past values and so does not suggest any substantial areas of concern.

4.3. Laboratory Analysis

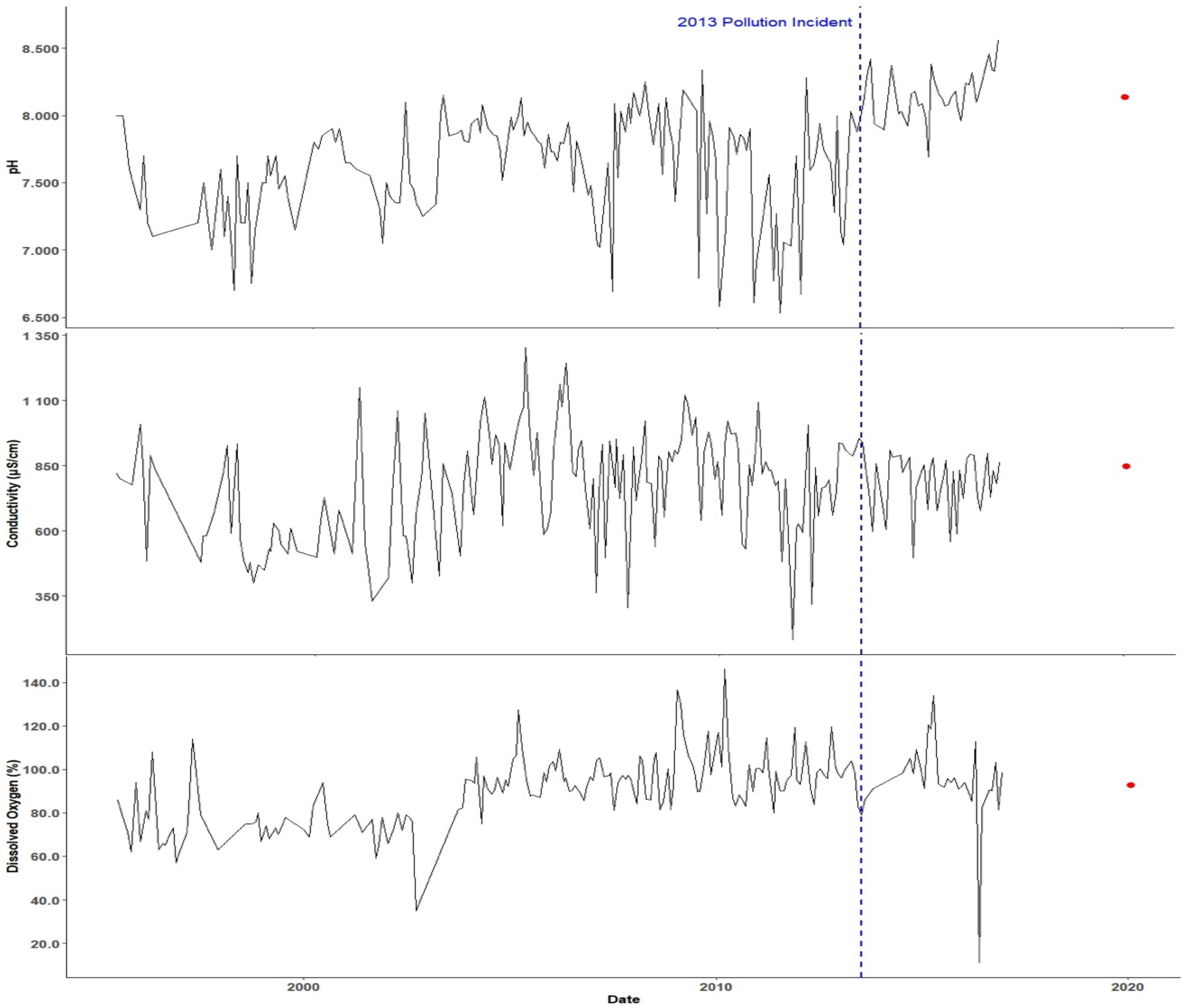

Figure 6 - Time series showing monthly pH, Conductivity (µS/cm) and Dissolved Oxygen (%) measurements take at Coombe Dingle between January 1995 and May 2016 by Bristol City Council (2020). For each parameter, the mean value of our 10 sites, from January 2020, have been plotted in red against the past data. The 2013 pollution event has also been labelled on the time series.

Turbidity analysis of samples from each site was undertaken to reveal the concentration of suspended solids in the water. This is represented in Figure 7. Between the sites, despite the increase in turbidity after both Shirehampton Road and Falcondale Road, the standard deviation is equal to 16.14% of the mean, a relatively low-level variation within the data. A turbidity of >50ppm, equivalent to 31.67NTU, is considered toxic to brown trout, so samples of good water quality should lie below this. Figure 7 illustrates the distance between the turbidity values the samples from the River Trym and the toxicity threshold.

.3.1. Heavy Metal Analysis

Heavy metal analysis was conducted to determine if Zinc, Cadmium, Copper or Nickel were present in toxic quantities in each site. It was expected that samples from Sites 2 and 9, located directly after Shirehampton Road and Falcondale Road respectively, will contain higher quantities due to run-off. Figures 8-11 dispute this presumption: Figure 8 shows that the metal content of Zinc in Sites 2 and 9 are lower than those taken from before the major roads, Sites 3 and 10, with little overlap between the pairs of boxplots. Figure 9 demonstrates a similar picture with a decrease in Nickel content after the major roads; however, there is a large overlap of the Site 2 and 3's boxplots, suggesting less of a significant difference. In the case of Cadmium and Copper, Figures 10 and 11 show there is no consistent pattern around the roads: in both cases, there is minimal change between Sites 2 and 3, suggesting no significant difference. Whilst from Site 10 to Site 9, Cadmium content appears to increase in Figure 10, but Copper content decreases in Figure 11. The heavy metal data therefore does not display a regular pattern in relation to the position of the major roads. Further analysis of statistical difference between water samples before and after the roads is not appropriate due to the small size of the dataset restricting a reliable outcome. However, between site variation is likely to have limited impact as all the heavy metal content measurements lie below their respective toxicity thresholds. The upper value of Site 5's Cadmium content, 5.09ppb, is the closest value to a threshold lying 1.19ppb below the toxicity limit of Cadmium (Nabby et al., 2014), This sample may be considered as an anomaly as the other samples from Site 5 only contained 0.13ppb and 0.17ppb of Cadmium, demonstrated by the large spread seen in Figure 10.

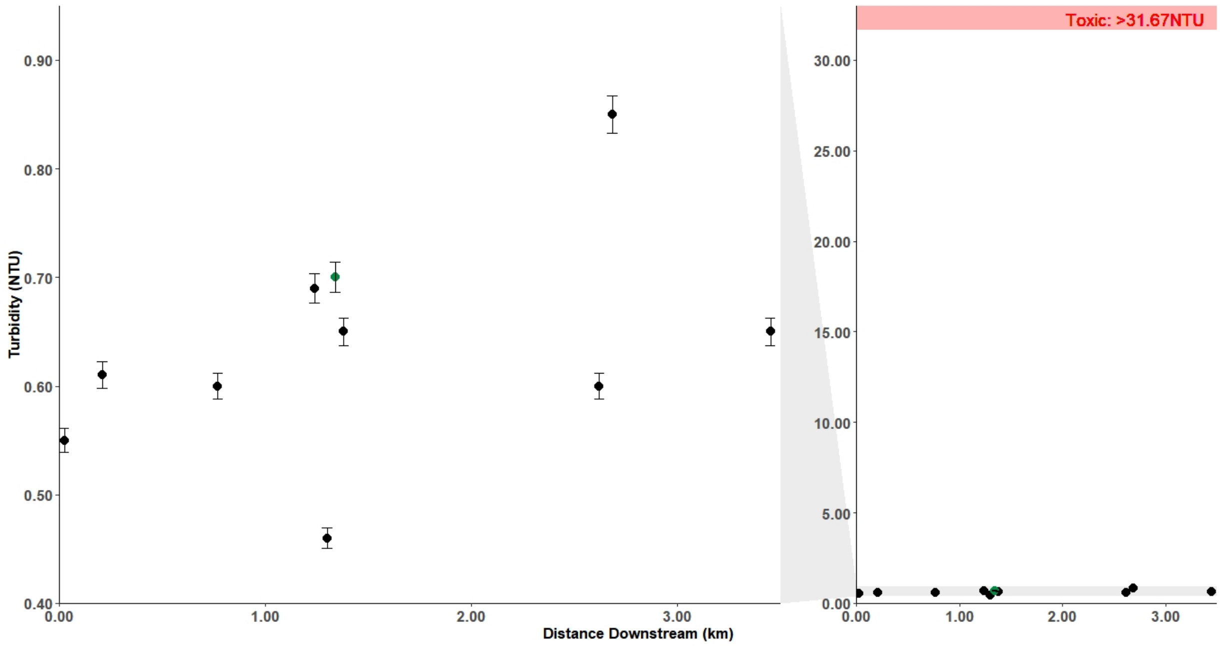

Figure 7 - Turbidity (NTU) in the River Trym with Distance Downstream (km). Turbidity values show no correlation with distance downstream, distributed randomly. With a highest value of 0.85NTU at 2.68km downstream, all the values are situated drastically below the toxicity threshold (red line).

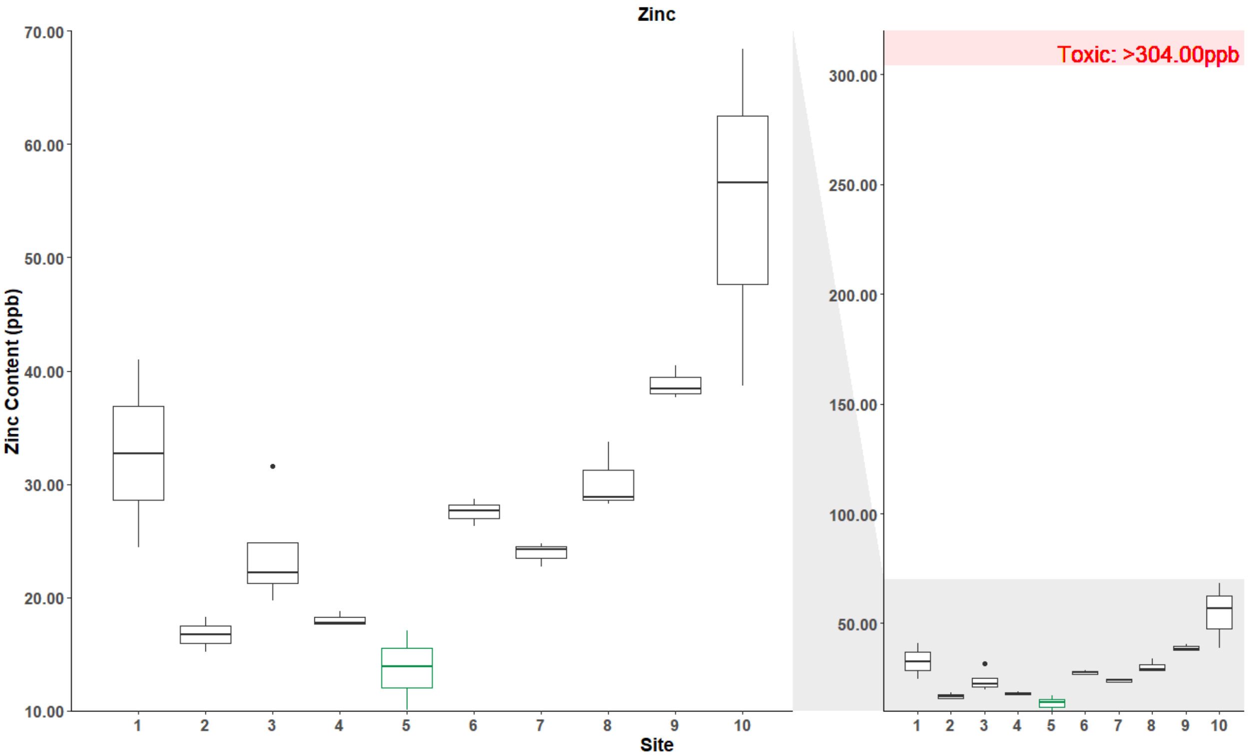

Figure 8 - Boxplot showing the spread of Zinc content in the samples collected from each Site, in relation to the toxicity threshold. Generally, Zinc content decreases downstream, from Site 10 to Site 2, but Site 1 is an anomaly to this trend. Site 5, from Hazel Brook has the lowest average Zinc content, whilst Site 10 has the highest. All values lie over 200ppb below the toxic level.

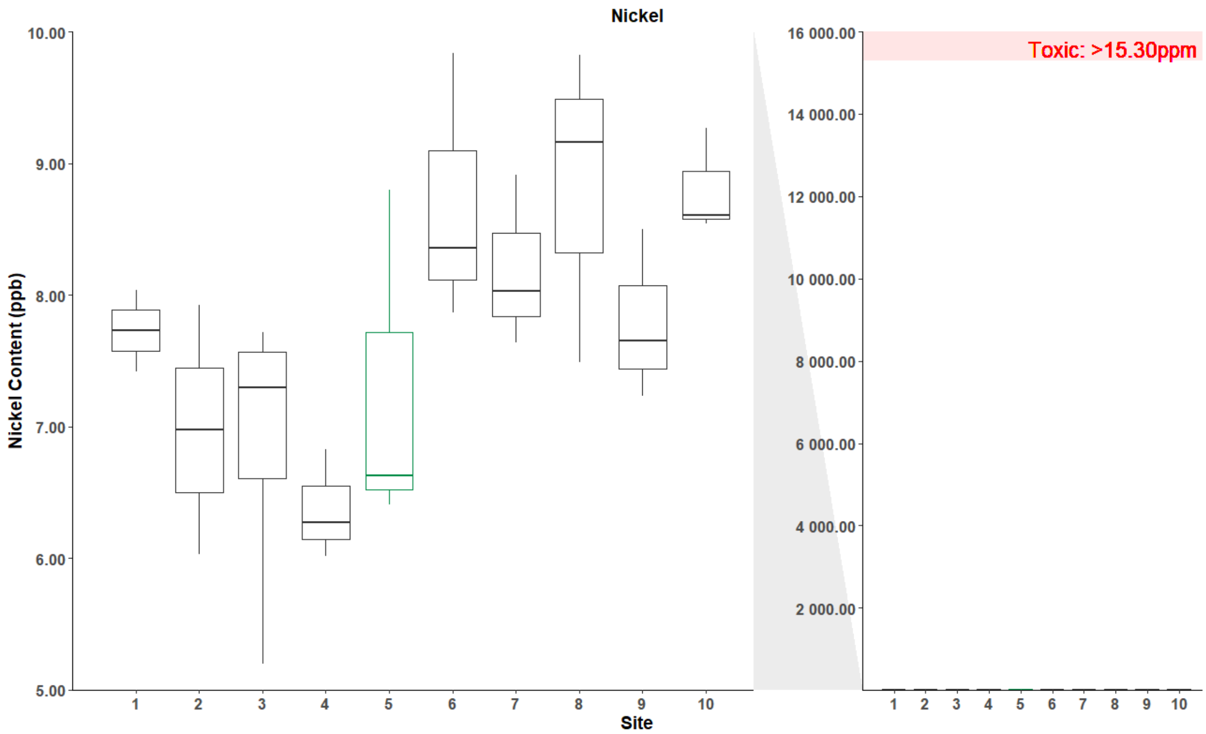

Figure 9 - Boxplot showing the spread of Nickel content in the samples collected from each Site, in relation to the toxicity threshold. Nickel content distribution is relatively random, but Sites 6 to 10 – in the upstream section of the River Trym - have higher average values than downstream, Sites 1 to 5. The toxicity threshold is drastically higher than any of the measurements.

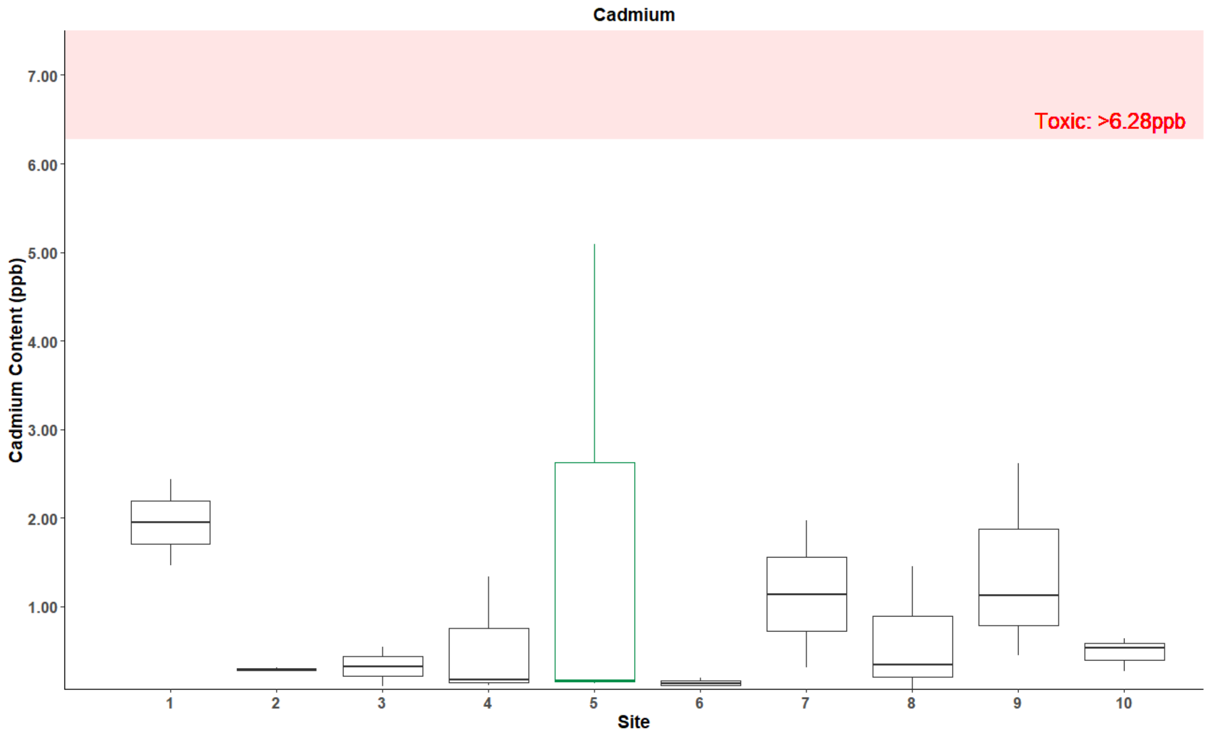

Figure 10 - Boxplot showing the spread of Cadmium content in the samples collected from each Site, in relation to the toxicity threshold. Site 5, from Hazel Brook has the greatest spread within its samples, but the mean of the site is not high in relation to the other sites. The Cadmium measurements for all sites are below the 6.28ppb toxicity threshold.

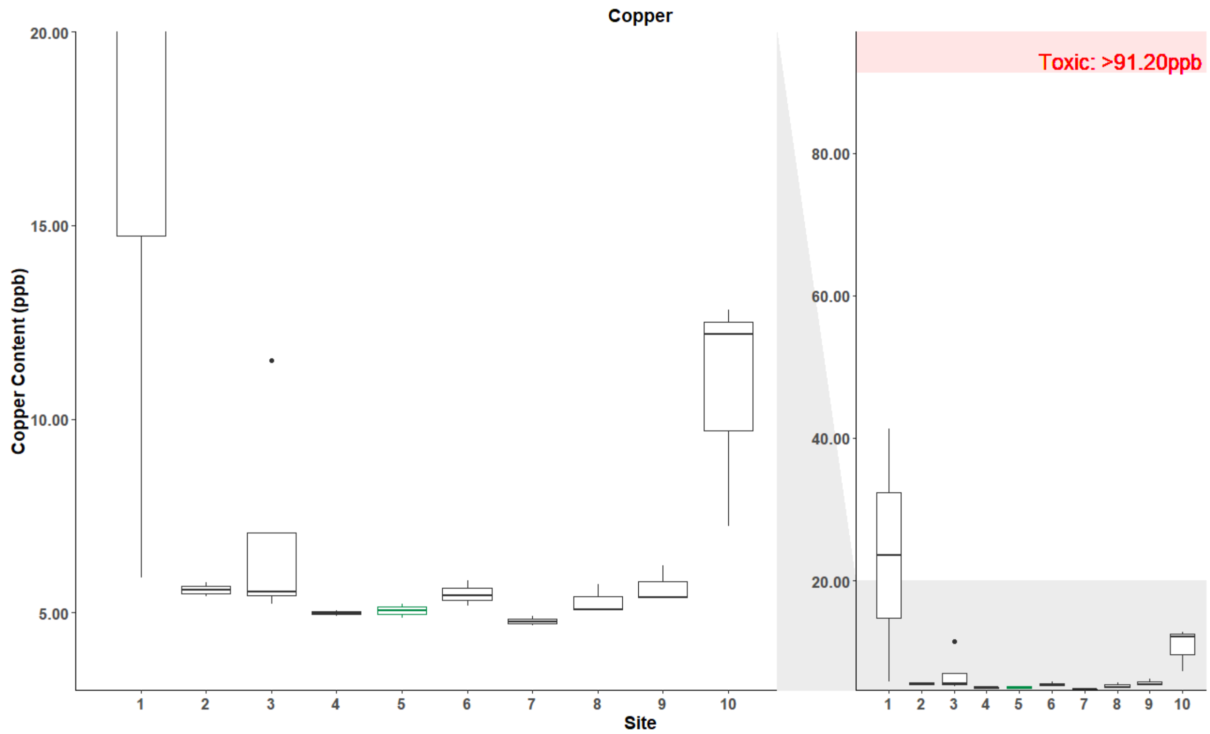

Figure 11 - Boxplot showing the spread of Copper content in the samples collected from each Site, in relation to the toxicity threshold. Sites 1 and 10 have the highest level of Copper in their water samples, with the spread of Site 1 stretching to 41.28ppb. The majority of measurements are over 5 times lower than 91.20ppb, the toxicity limit of Copper.

4.4. Macroinvertebrate Identification

Having identified the macroinvertebrate species collected from each site, these were categorized into groups: worms, larger invertebrates and other. In the downstream section of the River Trym, very few invertebrates were found; organisms found here were small, simple worms. Contrasting this, Figure 12 demonstrates the proportional dominance of large invertebrates in the upper section of the stream. Samples collected from Sites 5-9 contained more complex organisms: including species of water shrimp, water slaters and mayflies. Further identification showed these to include Baetis-Ephemeroptera and Oligocheata Worms as seen in Figures 13 and 14 respectively. Site 7, located 1.24km downstream and just before a weir, had the greatest proportion of larger invertebrates, with 98%, as well as the greatest biodiversity, with 7 different species collected and identified. A Macroinvertebrate Identification Key (Appendix.1) shows that mayfly nymphs are very intolerant to pollution; the identification of Baetis-Ephemeroptera collected from Sites 5-8 therefore suggests reasonable water quality in these areas. Their absence beyond 1.34km downstream, as seen in Figure 12, may therefore be significant. The aquatic worms collected from sites in the downstream section of the River Trym are much more tolerant of pollution and do not require water of very high quality.

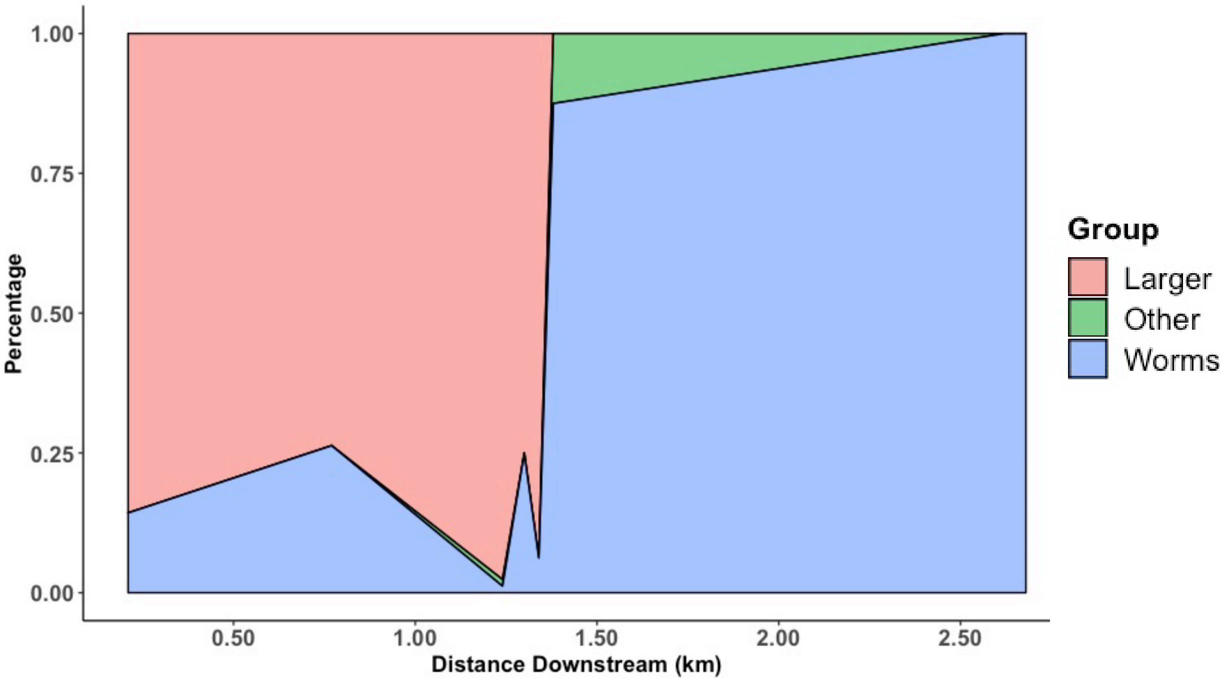

Figure 12 - Area plot of showing the proportion of macroinvertebrate species groups with Distance Downstream (km). Larger invertebrates are only found within the upper 1.34km of our section of the River Trym, where they represent over 73% of the sample populations from Sites 5-9. Beyond this point, Worms are the dominant macroinvertebrate found in the samples.

Figure 13 - Microscopic image of a Baetis-Ephemeroptera collected from Site 7.

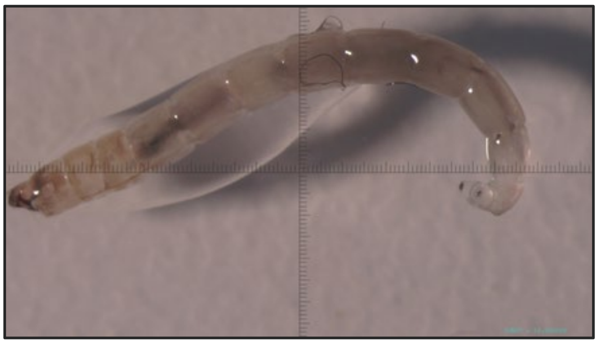

Figure 14 - Microscopic image of an Oligocheata Worm collected from Site 6.

5. Limitations

The number of samples we were able to collect was limited, and consequently we were unable to perform many statistical tests on our data. This limitation was most prevalent when attempting to analyse any statistical difference in heavy metal concentrations prior to and after road bridges. For these calculations our sample size was limited to 6 pieces of data. This inability to statistically test our data, meant that we were unable to confirm any results to the 95% significance level, reducing the assurance of our conclusions.

In addition, our data was only collected from the River Trym at one time. Prior to data collection, the Bristol area had not received significant precipitation for multiple days. Therefore, the volume of water entering the river as a result of road run-off was reduced when compared to during a period of precipitation. This means that we were unable to analyse the concentration of heavy metals in the river when a significant volume of road run-off was entering the river system. As a result, we were unlikely to identify any notable changes in heavy metals before and after road bridges as the majority of road run-off from previous precipitation would have been removed from the system relatively quickly.
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Differences in sediment on the riverbed caused inconsistencies in our kick-sampling. The area adjacent to the river from sites 1 to 3 had previously been used to deposit building rubble during World War II. As a result, at these sites the riverbed was filled with large debris that was difficult to displace, and therefore the area for data collection was restricted to the edges of the river. As a result, it was extremely challenging attempting to maintain consistent in terms of the amount of matter displaced in the river when collecting the invertebrates.

6. Discussion

6.1. Suitability for Trout

Heavy metal analysis returned results that were all considerably lower than the toxicity thresholds. The level of cadmium, however, is significantly higher than that of zinc, copper and nickel as a percentage of the toxicity threshold. It is possible that historic mining could be an explanation for this. A report from the Environment Agency stated that certain Welsh river catchments that contain abandoned metal mines show increased levels of Cadmium in the river system (Environment Agency, 2008). Despite this, the concentrations recorded in the River Trym fell well below the limit, suggesting that the River Trym has heavy metal concentrations within the tolerable range for trout. However, the impact of recent precipitation on the river is an unknown. Four days later, a second observation of the river at Site 3 demonstrated the impact that different weather conditions can have. Figure 15 was taken on 21st January during data collection and Figure 16 was taken on 26th January during a litter pick. Precipitation during the second visit increased the river volume noticeably, as did the turbidity. It is highly likely that the volume of road run-off would significantly greater at this period, and as a result heavy metal concentration would also be increased.

The data collected during kick-net sampling demonstrated an abundance of macroinvertebrate life, particularly from sites 6 – 8. These populations have demonstrated a strong recovery since the 2013 pollution incident in which 90% of invertebrates were killed (Water & Watewater Treatment, 2014). The presence of sensitive mayfly larvae is especially notable at these sites. A study by Jop (1991) found that cadmium, copper and zinc all serve to hinder the development on mayfly larvae (Jop, 1991). This hindrance to development occurs as a result of heavy metal particles being ingested by the mayfly larvae during feeding on detritus on the riverbed (Fialkowski et al., 2003). If the concentration of heay metal particles found in the debris on the riverbed was significantly high, then no mayfly larvae would be present. This is therefore indicative of a high level of water quality in the River Trym. However, the presence of mayfly larvae at these sites poses a question about their absence at the sites closer to the river mouth. Data collected from sites 1 to 4 demonstrates strong similarities to sites further upstream in terms of the river conditions we measured, therefore suggesting the reason for this absence is not pollution. This absence could be related to the condition of the riverbed at the sites furthest downstream, as the bed at these sites was covered with a layer of silt. Multiple studies have reported the negative relationship between river silt inputs and macroinvertebrate density, and this therefore could be a part of the explanation (e.g (Fossati, et al., 2001)). The introduction of salt water at these sites due to the River Avon's tidal nature could also be an explanation, as many of these macroinvertebrates are found in freshwater only.

Weirs also present complications regarding the migration of fish. Aarestrup and Koed revealed that an introduction of juvenile brown trout upstream and downstream of a succession of weirs resulted in a 71% loss (Aarestrup & Koed, 2003). According to our data collected, the greatest numbers of large macroinvertebrates are found between sites 6 and 8 on the River Trym, and these sites are currently dissected by a weir between 6 and 7. There is no passage to allow for the movement of fish past this weir, meaning that any fish would be unable to move freely to feed within the most macroinvertebrate-dense region of the river. Whilst smaller fish were likely present upstream of the weir prior to the 2013 event, it is important to note that they may have been present prior to its construction. The construction of a fish passage adjacent to this weir would accommodate for the migration of fish such as trout during their various life stages, along with allowing smaller fish to reintroduce themselves upstream of the weir, should conditions be suitable. The weir at the mouth of the Trym to the River Avon may also present an issue for fish migration. The Avon is a tidal river and while it does reach a level high enough for trout to pass into the River Trym, this occurs twice daily and lasts a few hours which could inhibit the free movement of fish between the rivers.

The depth of the river is a potential issue for the introduction of trout. In recent years, the river has seen a decreased base flow, likely as a result of infrastructure projects in the Trym and Hazel Brook catchments, such as the construction of the large Cribbs Causeway Mall in 1998. These projects serve to decrease the consistency in river discharge by increasing the proportion of precipitation entering the river system as surface flow as opposed to throughflow and groundwater flow. Whilst smaller fish such as bullheads and stickleback were present before the 2013 pollution event, brown trout were not. It is possible that the river would not be deep enough to support these larger fish, particularly in drier summer months.

6.2. Hazel Brook

The heavy metal data for zinc, copper and nickel appear to show little difference before and after the confluence from Hazel brook. However, the results for cadmium show a higher concentration in the Hazel Brook river than in the Trym before and after the confluence (sites 6 and Site 4 respectively). It is possible that a contaminated sample caused this result as one sample at Site 5 was almost thirty times larger than the other two from the same location.

The data shows an increase in conductivity downstream from the confluence which indicates that Hazel Brook is impacting the Trym. However, the River Avon's tidal nature results in water from the Trym and Avon mixing from sites 1 to 4 during periods of high tide, possibly increasing the conductivity of the water. However, the impact on the conductivity is minimal, with the change in conductivity between sites 4 and 6 on the River Trym standing at just over 6%. Whilst the Hazel Brook's conductivity is higher than the River Trym at the confluence, the oxygen concentration value from the Hazel Brook demonstrates that the source of the increased conductivity value is not resulting in hypoxic conditions in the water. However, the Hazel Brook data was collected shortly after a weir, which could be an explanation for the high value. The Hazel Brook has no significant impact on the River Trym in terms of pH or turbidity.

7. Future Work

Having only tested the river at one time, it is important to investigate the impact that varying weather conditions may have on the river. The impact of recent precipitation would likely serve to increase the volume of road run-off entering the River Trym. It is therefore reasonable to theorise that heavy metal concentrations could increase during and after this time. A second visit during a period of heavy precipitation demonstrated how weather conditions can have a visible impact on the river; the flow rate was increased, and the water seemed significantly more turbid. Prior to possible fish reintroduction, the River Trym should be sampled to determine whether the condition of the water is suitable for trout perennially. If data collected during periods of precipitation present heavy metal concentrations that are significantly closer to the toxic threshold of trout, then locations should be identified where point-source pollution is occurring, such as pipes, and sample these directly.

Analysis of river discharge during drier months would also be advisable. Prior to the pollution event in 2013, only smaller fish were present in the River Trym (Water & Wastewater Treatment , 2014). A possible explanation for this is that the river flow is not sufficient throughout the year to sustain larger fish. Before the introduction of brown trout, considering the reintroduction of these smaller species found in the river prior to 2013 is advised.

Exploring the feasibility of a weir fish pass construction project between sites 6 and 7 to allow the free movement of fish is also advisable, particularly if the idea of introducing larger fish such as brown trout to the river is being considered. If this is not feasible, then the introduction of fish may have to be limited to downstream of the weir.

The benefits of the data collected from this study would be dramatically increased when used in conjunction with other organisations also currently working on investigating the environmental condition of the River Trym. The Environment Agency has detailed plans for improving this ecosystem, having previously classified an extent of issues contributing to the overall water body (Appendix 2), but there are notable gaps in their classifications in recent years. Several of these parameters overlap with those measured in this study: physio-chemical quality elements as well as zinc and copper pollution. In 2013 and 2014, both zinc and copper pollution were considered as “High”; contrasting this, the concentrations recorded from our January 2020 samples lay significantly below toxicity thresholds. As raw data for the Environment Agency’s qualitative descriptions is not publicly available, communication with the organisation, and the subsequent sharing of data, may allow greater understanding of the current condition of the River Trym and how it may have improved in the last few years and further into the future.

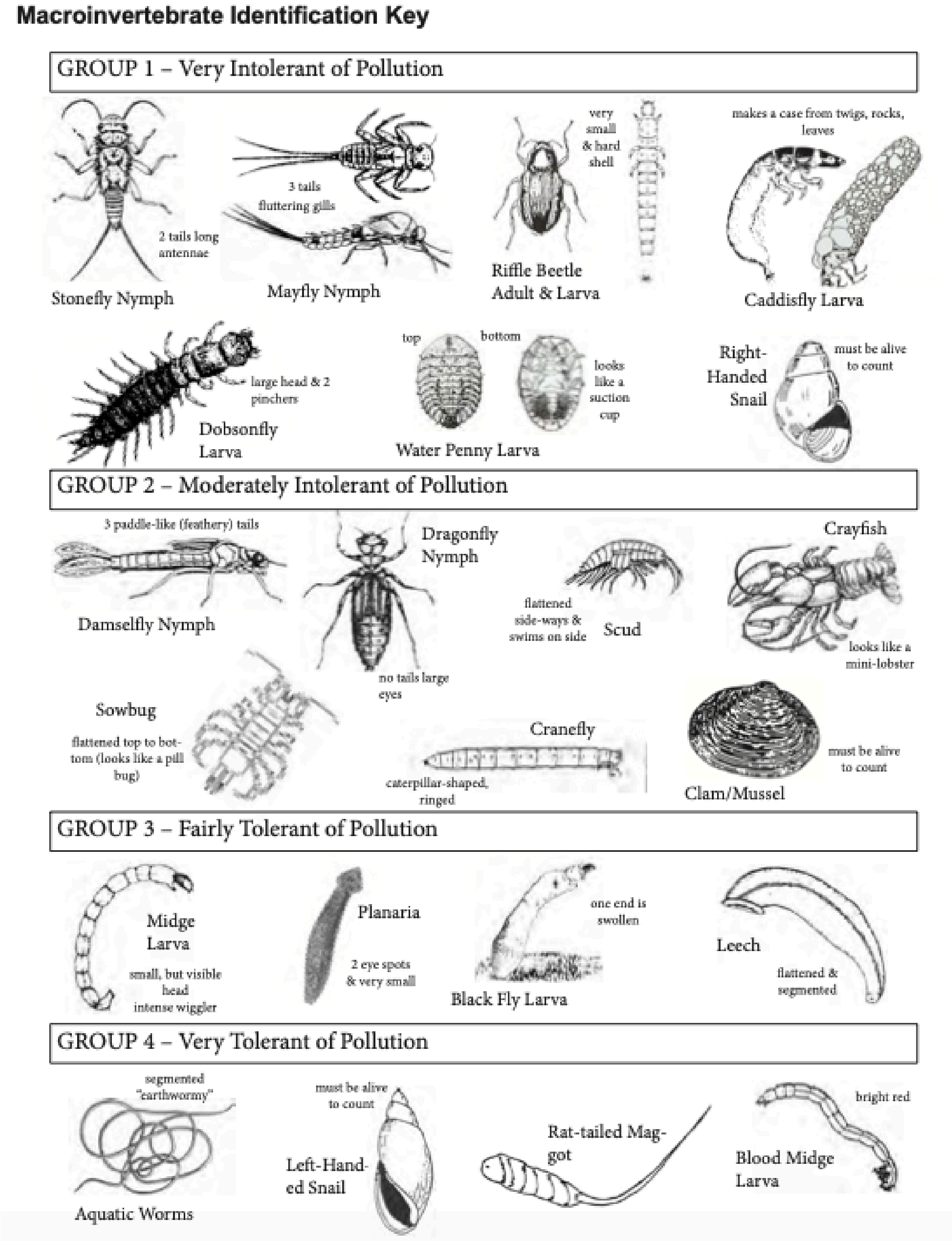
8. Conclusion

The heavy metal concentrations measured in this investigation were not considered fatal to trout: there was no noticeable pattern of pollution or heavy metal increase after Falcondale and Shirehampton Road and this research could provide no statistical significance as the dataset was too small. Similarly, the temperature, pH, conductivity, dissolved oxygen and turbidity measured under the toxic threshold for aquatic life. The pH was not within the optimum level however it sat comfortably within the tolerable level. These results indicate that the 2013 pollution event did not have any long-term impacts on the water quality and the results suggest that the Trym remains a healthy body of water which would be able to sustain trout. The presence of larger macroinvertebrates was highest between Sites 5 and 8 which are a good food source for trout and provides further reassurance that the quality of the water is suitable for aquatic life. There was also no drastic increase in pollution after Hazel Brook confluence (Site 4) despite cadmium and conductivity recording their highest values in Hazel Brook (Site 5) which provides evidence that this river should not be much of a concern when looking at improving the ecology in future years.

This data, however, was taken on a single day in the winter which does not account for seasonal variation in precipitation and temperature. During the summer, when the average weekly temperature is higher, the height of the river is likely to decline which proves challenging for the welfare of trout due to decreased dissolved oxygen concentrations and the hindering of free movement. Moreover, on the day of data collection, there had not been significant rainfall for a few days which means that the readings may not have represented the true significance of road run-off on the river. Secondly, during the winter, roads are more likely to be de-iced during times of heavy frost which will flow into the Trym, again providing misleading results as this may not be the case all year round.

These results suggest that physical aspects of the river could be having a much greater impact upon the suitability of the River Trym for trout. The weir between Site 6 and 7 in particular is impassable, causing serious complications during spawning season when shallow, gravel-based waters are required. Since the rest of our data at this time suggests that the water is tolerable, it is crucial to consider these physical aspects. Therefore, this investigation provides no evidence to suggest that Hazel Brook or road run-off are detrimentally impacting the ecology of the River Trym. However, due to the complex nature of the ecosystem, and questions surrounding physical characteristics, without further research it would not be reasonable to suggest that the River Trym is currently suitable for trout.

8. Appendix



Appendix 1 - Macroinvertebrate Identification Key showing difference species and their groupings dependent on tolerance to pollution (Hoosier Riverwatch, 2019).

Appendix 2 - Environment Agency Cycle 2 Classifications identifying the environmental condition of aspects of the River Trym water body. Categories range from Bad to High. (Environment Agency, 2020)

Classification Item	2013	2014	2015	2016
Overall Water Body	Moderate	Moderate	Moderate	Moderate
Ecological	Moderate	Moderate	Moderate	Moderate
Supporting elements (Surface Water)	Moderate	Moderate	Moderate	Moderate
Biological quality elements	Moderate	-	Bad	Bad
Fish	-	-	Bad	Bad
Invertebrates	Moderate	-	Moderate	Moderate
Hydromorphological Supporting Elements	Supports Good	Supports Good	Supports Good	Supports Good
Physico-chemical quality elements	Moderate	Moderate	Moderate	Moderate
Ammonia (Phys-Chem)	High	High	High	High
Dissolved oxygen	High	High	High	High
pH	High	High	High	High
Phosphate	Moderate	Moderate	Moderate	Moderate
Temperature	High	High	High	High
Specific pollutants	Moderate	Moderate	High	High
Triclosan	Moderate	Moderate	High	High
Copper	High	High	-	-
Zinc	High	High	-	-
Chemical	Fail	Fail	Good	Good
Priority substances	Good	Good	Does not require assessment	Does not require assessment
Other Pollutants	Does not require assessment	Does not require assessment	Does not require assessment	Does not require assessment
Priority hazardous substances	Fail	Fail	Does not require assessment	Good

Appendix 3 – Table of probe measurement results from initial walk with SusWot on 21st January 2020

Site	Latitude	Longitude	pH	Conductivity (uS/cm)	Oxygen (%)	Oxygen (ppm)	Temperature (°C)	Turbidity (NTU)	Distance downstream (km)
1	51.48106	-2.648099	8.002	887	88.6	10.94	6.9	0.65	3.45
2	51.486609	-2.643725	7.955	868	91.1	11.46	6.7	0.85	2.68
3	51.487239	-2.64367	7.957	867	91.7	11.58	6.6	0.6	2.62
4	51.495679	-2.636697	8.132	873	93.9	11.74	6.9	0.65	1.38
5	51.495704	-2.636944	8.033	899	94.6	11.8	7.1	0.7	1.34
6	51.495636	-2.63654	8.315	818	92.6	11.68	6.6	0.46	1.3
7	51.495596	-2.635827	8.266	819	93	11.63	6.7	0.69	1.24
8	51.495755	-2.629075	8.32	815	93.2	11.61	7.2	0.6	0.77
9	51.496072	-2.621762	8.336	814	94.1	11.66	7.2	0.61	0.21
10	51.495426	-2.619311	8.059	829	95.2	11.76	7.2	0.55	0.02

Appendix 4 – Total amount of each macroinvertebrate species per site.

Identified Species	Number found at:								
	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9
Flatworm	0	0	10	3	3	6	1	0	2
Oglicheata worm	0	4	4	4	0	0	0	10	0
Larvae	0	0	0	1	0	0	0	0	0
Caddisfly larvae	0	0	0	0	3	2	4	6	7
Baetide -Ephemeroptera (mayflies)	0	0	0	0	15	7	18	2	0
Hydropsychidae larvae with pronotum	0	0	0	0	20	3	10	5	3
Water slaters	0	0	0	0	1	0	4	1	0
Water shrimp	0	0	0	0	6	6	46	14	2
Glossiphoniidae	0	0	0	0	0	0	1	0	0

Appendix 5 – Table of detection limits– this is the number at which the equipment can no longer detect the level of heavy metals

Element	Detection Limit (ppb)
Cd	0.23
Cu	0.25
Ni	0.71
Zn	0.05
BLD	Below limit of detection

Appendix 6 – Concentration of heavy metals and corresponding standard deviations.

Sample	Concentration of heavy metals (ppb) and corresponding standard deviations											
	Cd 226.502	SD	Cu 324.754	SD	Ni 230.299	SD	Zn 202.548	SD	Zn 206.200	SD	Zn 213.857	SD
Site 1.1	0.55	0.08	11.51	0.3	7.52	0.03	21.82	0.26	22.27	3.68	23.77	0.28
Site 1.2	2.44	0.19	41.28	0.92	7.42	0.98	40.63	0.46	39.02	2.88	43.37	0.54
Site 1.3	1.46	0.22	5.89	0.69	8.04	1.48	23.56	0.32	24.45	3.53	25.28	0.75
Site 2.1	0.27	0.04	5.77	0.11	7.92	1.11	16.92	0.64	18.89	4.86	18.93	0.37
Site 2.2	0.31	0.03	5.41	0.39	6.03	0.87	13.71	0.26	16.06	1.07	15.95	0.29
Site 2.3	7.34	0.23	5.66	1	8.47	1.26	54.48	0.53	58.53	0.8	57.31	0.31
Site 3.1	BLD	0.12	5.57	0.45	7.72	1.12	21.37	0.68	21.08	2.42	23	0.28
Site 3.2	0.1	0.09	5.23	0.68	5.2	1.39	19.22	0.41	19.69	1.36	20.29	0.29
Site 3.3	BLD	0.07	5.51	0.58	7.08	0.83	31.06	0.76	31.28	3.22	32.56	0.08
Site 4.1	0.18	0.21	5.06	0.18	6.83	0.22	17.28	0.97	16.94	1.6	19.11	0.2
Site 4.2	1.34	0.09	4.92	0.4	6.02	0.62	17.53	0.08	16.33	2.03	18.93	0.71
Site 4.3	0.11	0.1	4.99	0.28	6.27	0.6	18.88	0.37	17.35	2.12	20.14	0.42
Site 5.1	0.13	0.1	5.23	0.37	6.41	0.84	15.79	0.34	18.06	1.62	17.35	0.14
Site 5.2	5.09	0.05	5.05	0.56	6.63	0.43	10.05	0.16	9.09	3.86	11.14	0.14
Site 5.3	0.17	0.09	4.87	0.59	8.8	0.35	13.56	0.59	12.82	2.19	15.43	0.18
Site 6.1	0.2	0.21	5.45	0.35	9.84	0.23	26.62	0.43	28.03	0.85	28.47	0.29
Site 6.2	0.13	0.17	5.82	1.05	7.87	1.16	27.76	0.23	29.09	2.93	29.18	0.35
Site 6.3	0.1	0.15	5.18	0.17	8.36	0.99	25.27	0.42	26.77	0.28	26.84	0.18
Site 7.1	BLD	0.24	4.66	1.14	7.64	0.69	24.02	0.7	25.19	4.88	25.07	0.64
Site 7.2	0.31	0.35	4.76	0.21	8.91	1.07	23.3	0.16	24.65	2.21	24.83	0.24
Site 7.3	1.97	0.12	4.9	0.54	8.03	1.48	21.4	0.29	23.63	1.68	23.12	0.48
Site 8.1	1.45	0.28	5.06	0.38	7.49	1.36	28.18	0.64	28.55	2.03	29.95	0.48
Site 8.2	0.34	0.12	5.74	0.42	9.82	1.05	32	0.31	35.01	2.8	34.06	0.22
Site 8.3	0.07	0.03	5.08	0.76	9.16	0.78	27.62	0.62	27.8	0.89	29.37	0.29
Site 9.1	1.13	0.14	5.39	0.81	7.23	1.47	38.89	0.23	41.57	4.01	40.96	0.78
Site 9.2	2.62	0.29	6.22	0.63	8.5	1.38	38.12	0.9	37.32	3.33	39.73	0.05
Site 9.3	0.45	0.11	5.38	0.12	7.65	0.84	37.72	0.27	35.64	6.78	39.53	0.13
Site 10.1	0.64	0.08	12.2	0.44	8.54	0.41	66.49	0.59	69.71	2.85	68.89	0.66
Site 10.2	0.27	0.12	12.83	0.36	9.27	1.2	55.75	0.78	55.83	2.4	58.27	0.39
Site 10.3	0.53	0.11	7.22	0.27	8.61	1.03	37.77	0.65	38.44	2.96	39.94	0.63

Appendix 7 – Ethics Form of the Project

SCHOOL OF GEOGRAPHICAL SCIENCES

RESEARCH ETHICS MONITORING FORM, 2019-20

D: UNDERGRADUATE COURSEWORK

Research by all academic and related Staff and Students in the School of Geographical Sciences is subject to the standards set out in the Code of Practice on Research Ethics.

It is a requirement that prior to the commencement of all funded and non-funded research that this form be completed and submitted to the School's Research Ethics Committee (REC). The REC will be responsible for issuing certification that the research meets acceptable ethical standards and will, if necessary, require changes to the research methodology or reporting strategy.

A copy of the research proposal which details methods and reporting strategies must be attached. *Submissions without a copy of the research proposal will not be considered*.

The REC seeks to establish from the form
that researchers have (i) thought purposefully about potential ethical issues raised by their proposed research; and (ii) identified appropriate responses to those issues.

Name: **Yeung Cheuk Ip (Justin)** email: **du18331@bristol.ac.uk**

Title of dissertation: **Trout in the Trym Phase 1**

				External/lay scrutiny required?
		YES	NO	Action
1.	Does your research involve living human subjects?		**X**	If NO, go to Q.3, 12, 13, & '*Declaration*'
2.	Does your research involveONLYthe analysis of large, secondary and anonymised datasets?	N/A	N/A	If YES, go to Q.3, 12, 13, & '*Declaration*'
3.	Do others hold copyright or other rights over the information youwill use, or will they do so over information you collect?	**X**		If YES please provide further details below
4.	Will you give your informants a written and/or verbal summary of your research and its uses?	N/A	N/A	If NO, please provide further details below.
5.	Does your research involve covert surveillance (for example, participant observation)?	N/A	N/A	If YES, please provide further details.
6.	Will your informants*automatically*be anonymised in your research?	N/A	N/A	If NO, please provide further details below.
7.	Will you explicitly give*all*your informants the right to remain anonymous?	N/A	N/A	If NO, please provide further details below.
8.	Will monitoring devices be used openly and only with the permission of informants?	N/A	N/A	If NO, why not? – give details below.
9.	Have you considered the implications of your research intervention on informants?	N/A	N/A	Please provide details below.
10.	Will data/information be encrypted/secured, and stored separately from identification material to maintain confidentiality??	N/A	N/A	If NO, why not?
11.	Will your informants be provided with a summary of your research findings?	N/A	N/A	If NO, please provide further details.
12.	Willthere be restrictions onyour research beingavailablethrough the university data archive (e.g.bythesponsoring authoritiesor from participants)?		**X**	Please provide details below
13.	Whatotherpotentialethical issues arising fromthis research have youidentified?			Please state below how they will be taken into consideration.

Further details: *please start paragraph(s) with the question-number to which they refer.*

3 & 12: Sustainable Westbury on Trym (SusWoT) is our partner organisation for the Avon project. SusWoT would like us to identify pollution of the River Trym and Hazel Brook caused by road traffic. The findings of our report would be used as evidence to identify places where water quality in the Trym could be improved, hence the restoration of trout to the Trym. SusWoT has links with the Environmental Agency, Wessex Water, Friends of Blaise, Friends of Badock's Wood, BART, Bristol Waste and Bristol City Council. They plan to send out report to these organisations and publish the report online on a dedicated website.
The underlying data will be required to facilitate ongoing monitoring of water quality trends.

Secondary Data regarding trout's optimum water quality and living conditions (i.e. Trym and Hazel Brook WTT Advisory Report) as well as River Trym' geographical features (i.e. Digimap) will be used to compare with our primary data in our research. Sources will be accredited. There should be no restrictions on our research being available through the university data archive. The research will be mainly informative and there will be no potential conflicts of interest between SusWoT and us.

13: We will be collecting water samples from 10 sites along the River Trym and bring them back to the lab to analyse them. Proposed research methods include macroinvertebrates sampling, turbidity sampling, heavy metal sampling and taking measurements on site. Potential ethical issues are mainly environmental and social. These include the disturbance of the riverbed through 'kick-sampling' to collect and identify macroinvertebrates and social disturbance through field work activities. The team was briefed to pay extra attention to these areas. The team leader will ensure that the group do not block the public path as they carry out the fieldwork and will answer any questions courteously.

Continuation sheet ~~YES/~~ NO (delete as applicable)

Declaration

I have read the School's Code of Practice on Research Ethics and believe that my research complies fully with its precepts.
I will not deviate from the methodology or reporting strategy without further permission from the School's Research Ethics Committee.

Student

Signed **Yeung Cheuk Ip (Justin)** Date **23 January 2020**

Project advisor

Signed ………………………………………………………. Date …………

Progress:

(please leave blank)

A	**Submission complete**				
B	**Clarification requested**				
C	**Approval granted**				

9. References

Aarestrup, K. & Koed, A., 2003. Survival of migrating sea trout (Salmo trutta) and Atlantic salmon (Salmo salar) smolts negotiating weirs in small Danish rivers. Ecology of Freshwater Fish, 12(3).

Anderson, C. W. (2005). Turbidity 6.7. In USGS National Field Manual for the Collection of Water-Quality Data. U S Geological Survey. American Public Health Assoc., American Water Works Assoc. & Water Environment Federation. (1999)

Albury Estate Fisheries. (2020). Trout Facts. [online] Available at: https://alburyestatefisheries.co.uk/aboutalbury/trout-facts/ [Accessed 28 Feb. 2020]. 04/03/2020 4/6

Authman, M. (2015). Use of Fish as Bio-indicator of the Effects of Heavy Metals Pollution. Journal of Aquaculture Research & Development, 06(04).

Bash, J., Bolton, S. and Berman, C. (2001). Effects of Turbidity and Suspended Solids on Salmonids. Centre for Streamside Studies, University of Washington. [online] Available at: https://www.researchgate.net/publication/50416893_Effects_of_Turbidity_and_Suspended_Solids_on_Salmonids enrichId=rgreq-d48c39be3c87c8f38967e8bfa383b7c2-XXX&enrichSource=Y292ZXJQYWdlOzUwNDE2ODkzO0FTOjY2MzE5MDQyNTg0MTY2NkAxNTM1MTI4 [Accessed 28 Feb. 2020].

Bhateria, R. and Jain, D. (2016). Water quality assessment of lake water: a review. Sustainable Water Resources Management, 2(2), pp.161-173.

Bibi, M. H., Ahmed, F. & Ishiga, H. Assessment of metal concentrations in lake sediments of southwest Japan based on sediment quality guidelines. Environ. Geol. 52, 625–639 (2007).

Brett JR (1971) Energetic responses of salmon to temperature. A study of some thermal relations in the physiology and freshwater ecology of sockeye salmon (Oncorhynchusnerka). Amer Zool 11:99–113

Currie, R., Bennett, W., Beitinger, T. and Cherry, D. (2004). Upper and Lower Temperature Tolerances of Juvenile Freshwater Game-Fish Species Exposed to 32 days of Cycling Temperatures. Hydrobiologia, 523(1-3), pp.127-136.

Data.gov.uk. (2020). Bristol River water quality - data.gov.uk. [online] Available at: https://data.gov.uk/dataset/dd6658fc-7d1a-4ab2-9ea4-6aa936d21608/bristol-river-water-quality [Accessed 11 Feb. 2020].

Denby S. Lloyd, Jeffrey P. Koenings & Jacqueline D. Laperriere (1987) Effects of Turbidity in Fresh Waters of Alaska, North American Journal of Fisheries Management, 7:1, 18-33

Diersing, Nancy (2009). "Water Quality: Frequently Asked Questions." Florida Brooks National Marine Sanctuary, Key West, FL.

Demirak, A.; Yilmaz, F.; Levent Tuna, A.; Ozdemir, N. Heavy metals in water, sediment and tissues of Leuciscus cephalus from a stream in southwestern Turkey. Chemosphere 2006, 63, 1451–1458.

Eklov, A., Greenberg, L., Bronmark, C., Larsson, P. and Berglund, O. (1999). Influence of water quality, habitat and species richness on brown trout populations. Journal of Fish Biology, [online] 54(1), pp.33-43. Available at: https://onlinelibrary.wiley.com/doi/pdf/10.1111/j.1095-8649.1999.tb00610.x [Accessed 28 Feb. 2020].

Elliott, J. (2000). Pools as refugia for brown trout during two summer droughts: trout responses to thermal and oxygen stress. Journal of Fish Biology, [online] 56(4), pp.938-948. Available at: https://onlinelibrary.wiley.com/doi/epdf/10.1111/j.1095-8649.2000.tb00883.x [Accessed 28 Feb. 2020].

Environment Agency, 2008. Assessment of Metal Mining-Contaminated, Bristol: Environment Agency.

EPA. (2012). 5.2 Dissolved Oxygen and Biochemical Oxygen Demand. In Water Monitoring and Assessment

EPA. (2012). 5.9 Conductivity. In Water: Monitoring and Assessment

Fialkowski, W., Klonowska-Olejnik, M., Smith, B. D. & Rainbow, P. S., 2003. Mayfly larvae (Baetis rhodani and B. vernus) as biomonitors of trace metal pollution in streams of a catchment draining a zinc and lead mining area of Upper Silesia, Poland. Environmental Pollution , Volume 121, pp. 253-267.

Gabrielyan, A., Shahnazaryan, G. and Minasyan, S. (2018). Distribution and Identification of Sources of Heavy Metals in the Voghji River Basin Impacted by Mining Activities (Armenia).

Göbel, P., Dierkes, C. and Coldewey, W. (2007). Storm water runoff concentration matrix for urban areas. Journal of Contaminant Hydrology, 91(1-2), pp.26-42.

GOV.UK. (2014). First Enforcement Undertaking accepted from water company. [online] Available at: https://www.gov.uk/government/news/first-enforcement-undertaking-accepted-from-water-company [Accessed 28 Feb. 2020].

Grande, M., Muniz, I. and Andersen, S. (1978). Relative tolerance of some salmonids to acid waters. SIL Proceedings, 1922-2010, 20(3), pp.2076-2084

Guan, J., Wang, J., Pan, H., Yang, C., Qu, J., Lu, N. and Yuan, X. (2018). Heavy metals in Yinma River sediment in a major Phaeozems zone, Northeast China: Distribution, chemical fraction, contamination assessment and source apportionment. Scientific Reports, 8(1).

Gupta, Paul M (2010) The seasonal variation in ionic composition of pond water of Lumding, Assam, India. Hoosier Riverwatch. (2019). Volunteer Stream Monitoring Training Manual. (2019). [ebook] p.77. Available at: https://www.in.gov/idem/riverwatch/files/volunteer_monitoring_manual_chap_5.pdf [Accessed 20 Feb. 2020].

Inland Waterways Association , 2013. Facts and Issues Associated With The Bristol Avon (by Alan Aldous). [Online] Available at: https://www.waterways.org.uk/avonandwilts/a_picture_the_current_situation_on_bristol_avon [Accessed 27 February 2019].

Johnson, D.L., S.H. Ambrose, T.J. Bassett, M.L. Bowen, D.E. Crummey, J.S. Isaacson, D.N. Johnson, P. Lamb, M. Saul, and A.E. Winter-Nelson (1997). "Meanings of environmental terms." Journal of Environmental Quality. 26: 581–589.

Jop, K. M., 1991. Concentration of Metals in Various Larval Stages of Four Ephemeroptera Species. Bulletin of Environmental Contamination and Toxicology, Volume 46, pp. 901-905. Water & Watewater Treatment, 2014. Wessex Water's civil sanction for polluting River Trym. [Online] Available at: https://wwtonline.co.uk/news/wessex-water-s-civil-sanction-for-polluting-river-trym [Accessed 25 February 2019].

Kemp, S. and Spotila, J. (1997). Effects of Urbanization on Brown Trout Salmo trutta, Other Fishes and Macroinvertebrates in Valley Creek, Valley Forge, Pennsylvania. American Midland Naturalist, [online] 138(1), p.55. Available at: https://www.jstor.org/stable/2426654?seq=1#metadata_info_tab_contents [Accessed 28 Feb. 2020]. 04/03/2020 5/6

Krein, A. and Schorer, M. (2000). Road runoff pollution by polycyclic aromatic hydrocarbons and its contribution to river sediments. Water Research, 34(16), pp.4110-4115.

Leivestad, H. and Muniz, I.P. Fish kill at low pH in a Norwegian river. Nature 259, 391–392 (1976).

Lehto, N. J., Larsen, M., Zhang, H., Glud, R. N. & Davison, W. A mesocosm study of oxygen and trace metal dynamics in sediment microniches of reactive organic material. Sci. Rep. 7, 11369 (2017).

Lessard, J. and Hayes, D. (2003). Effects of elevated water temperature on fish and macroinvertebrate communities below small dams. River Research and Applications, [online] 19(7), pp.721-732. Available at: https://onlinelibrary.wiley.com/doi/epdf/10.1002/rra.713 [Accessed 28 Feb. 2020].

Meland, S., Salbu, B. and Rosseland, B. (2010). Ecotoxicological impact of highway runoff using brown trout (Salmo trutta L.) as an indicator model. J. Environ. Monit., [online] 12(3), pp.654-664. Available at: https://www.researchgate.net/publication/44576394_Ecotoxicological_impact_of_highway_runoff_using_brown_ [Accessed 28 Feb. 2020].

Memon, S., Paule, M., Lee, B., Umer, R., Sukhbaatar, C. and Lee, C. (2014). Investigation of turbidity and suspended solids behavior in storm water run-off from different land-use sites in South Korea. Desalination and Water Treatment, 53(11), pp.3088-3095.

Molony, B. (2001). Environmental requirements and tolerances of Rainbow trout (Oncorhynchus mykiss) and Brown trout (Salmo trutta) with special reference to Western Australia: A review. Department of Fisheries, [online] 130(1-27). Available at: http://237671953_Environmental_requirements_and_tolerances_of_Rainbow_trout_Oncorhynchus_mykiss_and_ [Accessed 28 Feb. 2020].

Miller, R. L., Bradford, W. L., & Peters, N. E. (1988). Specific Conductance: Theoretical Considerations and Application to Analytical Quality Control. In U.S. Geological Survey Water-Supply Paper.

Nabby, R., Cohen, A. and Stubblefield, W. (2014). The interactive toxicity of cadmium, copper, and zinc to Ceriodaphina Dubia and Rainbow Trout (Oncorhynchus Mykiss). [ebook] pp.809-815. Available at: https://setac.onlinelibrary.wiley.com/doi/pdf/10.1002/etc.2870 [Accessed 27 Feb. 2020].

Raleigh, R., Zuckerman, L. and Nelson, P. (1984). Habitat suitability index models and instream flow suitability curves. Washington, D.C.: Western Energy and Land Use Team, Division of Biological Services, Research and Development, Fish and Wildlife Service, U.S. Dept. of the Interior.

Rounds, S.A., Wilde, F.D., and Ritz, G.F., 2013, Dissolved oxygen (ver. 3.0): U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A6.2

Sayer, M., Reader, J. and Morris, R. (1991). Embryonic and larval development of brown trout, Salmo trutta L.: exposure to trace metal mixtures in soft water. Journal of Fish Biology, [online] 38(5), pp.773-787. Available at: https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1095-8649.1991.tb03164.x [Accessed 28 Feb. 2020].

Shen, C., Liao, Q., Titi, H. and Li, J. (2018). Turbidity of Stormwater Runoff from Highway Construction Sites. Journal of Environmental Engineering, 144(8), p.04018061. 04/03/2020 3/6 SWRCB. (2002). Electrical Conductivity/Salinity Fact Sheet . In The Clean Water Team Guidance Compendium for Watershed Monitoring and Assessment State Water Resources Control Board.

T. G. Northcote , F. R. Pick , D. B. Fillion & S. P. Salter (2005) Interaction of Nutrients and Turbidity in the Control of Phytoplankton in a Large Western Canadian Lake Prior to Major Watershed Impoundments, Lake and Reservoir Management, 21:3, 261-276

Trust, W. (2020). [online] Woodland Trust. Available at: https://www.woodlandtrust.org.uk/trees-woods-andwildlife/animals/fish/brown-trout/ [Accessed 28 Feb. 2020].

U.S. Environmental Protection Agency (EPA). Washington, D.C. "National Management Measures to Control Nonpoint Source Pollution from Urban Areas." Chapters 7 and 8. Document No. EPA 841-B-05-004. November 2005

Vtfishandwildlife.com. (2020). Brown Trout | Vermont Fish & Wildlife Department. [online] Available at: https://vtfishandwildlife.com/learn-more/vermont-critters/fish/brown-trout [Accessed 11 Feb. 2020].

Water & Wastewater Treatment , 2014. Wessex Water's civil sanction for polluting River Trym. [Online] Available at: https://wwtonline.co.uk/news/wessex-water-s-civil-sanction-for-polluting-river-trym [Accessed 27 February 2019].

Wetzel, R. G. (2001). Limnology: Lake and River Ecosystems (3rd ed.). San Diego, CA: Academic Press.

Weithman, A. and Haas, M. (1984). Effects of Dissolved-Oxygen Depletion on the Rainbow Trout Fishery in Lake Taneycomo, Missouri. Transactions of the American Fisheries Society, [online] 113(2), pp.109-124. Available at: https://www.tandfonline.com/doi/abs/10.1577/1548-04/03/2020 6/6 8659(1984)113%3C109%3AEODDOT%3E2.0.CO%3B2 [Accessed 28 Feb. 2020].

Wild Trout Trust. (2020). About Trout: Challenges | Wild Trout Trust. [online] Available at: https://www.wildtrout.org/content/about-trout-challenges [Accessed 28 Feb. 2020].

Wild Trout Trust. (2020). Brown Trout | Wild Trout Trust. [online] Available at: https://www.wildtrout.org/content/brown-trout [Accessed 28 Feb. 2020].

Wilde, F. (2006). Temperature 6.1. In USGS Field Manual.