

Using macroinvertebrates to assess the ecological and environmental recovery of the Afon Cynon over the past 60 years

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Ioan Jeffries | Environment Sustainability and Climate Change

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Abstract

Monitoring and reporting the long-term recovery of historically polluted catchments is important for ensuring full recovery and preventing further degradation. While efforts are often made to monitor these rivers by Environment Agencies and local rivers trusts, long term changes are often under reported, especially in more rural catchments. This study aimed to assess the ecological and environmental recovery of the Afon Cynon in the South Wales Valleys by assessing macroinvertebrate community compositions and chemical data to determine the speed and extent of recovery. Historical data as well as more recent sources of invertebrate data were compiled, analysed and assigned a Whalley Hawkes Paisley Trigg (WHPT) score including an Average score per taxon (ASPT) and Number of taxon (NTAXA). These results were then compared with the river prediction and classification system (RIVPACS) predicted model to assess the rate of recovery of the Afon Cynon. Results showed that the lower sections of the Afon Cynon showed the greatest signs of recovery with the recolonisation of many previously extirpated pollution sensitive families like Ephemeroptera, Plecoptera and Trichoptera. Lower sections came close to achieving the RIVPACS predicted model indicating these sites have almost fully recovered. The speed of recovery is thought to be attributed to the largely unpolluted upper section which allowed for faster recolonisation rates. These upper sections however have recently shown potential signs of gradual degradation with decreasing dissolved oxygen levels and reducing macroinvertebrate diversity due to potential organic pollution. Future studies on the Afon Cynon should focus on continual and consistent monitoring in order to assess whether these reducing conditions are temporary fluctuations or signs of a larger degradation trend.

1. Introduction

1.1. Background

It is common for historically industrial areas in the UK to have degraded environments such as their rivers (Environmental Audit Committee, 2022). Over the 19th and 20th centuries many industries such as factories utilised near-by rivers to dispose of effluent and waste materials which led to the rapid degradation of local environmental conditions (SIM, 2021; Whelan et al., 2022). While many of these rivers have recovered greatly from the effects of this heavy industry, it is still important to monitor these water courses to ensure they continue to improve as well as prevent them from regressing in quality. Many rivers in the South Wales valleys were at the centre of the heavy industry that dominated the area during the 19th and 20th century including the Afon Cynon which flows through the Cynon Valley (Humphrys, 1972) (Figure 1). The main industries that were located within the Cynon valley at the turn of the 19th century was firstly iron which was subsequently surpassed by coal (CVHS, 2013). According to Gareth Edge, project officer of “A river for all project”, the industry that took place within the Cynon valley has had a devastating effect on the ecology of the lower sections of the Afon Cynon (O’keeffe, 2021).

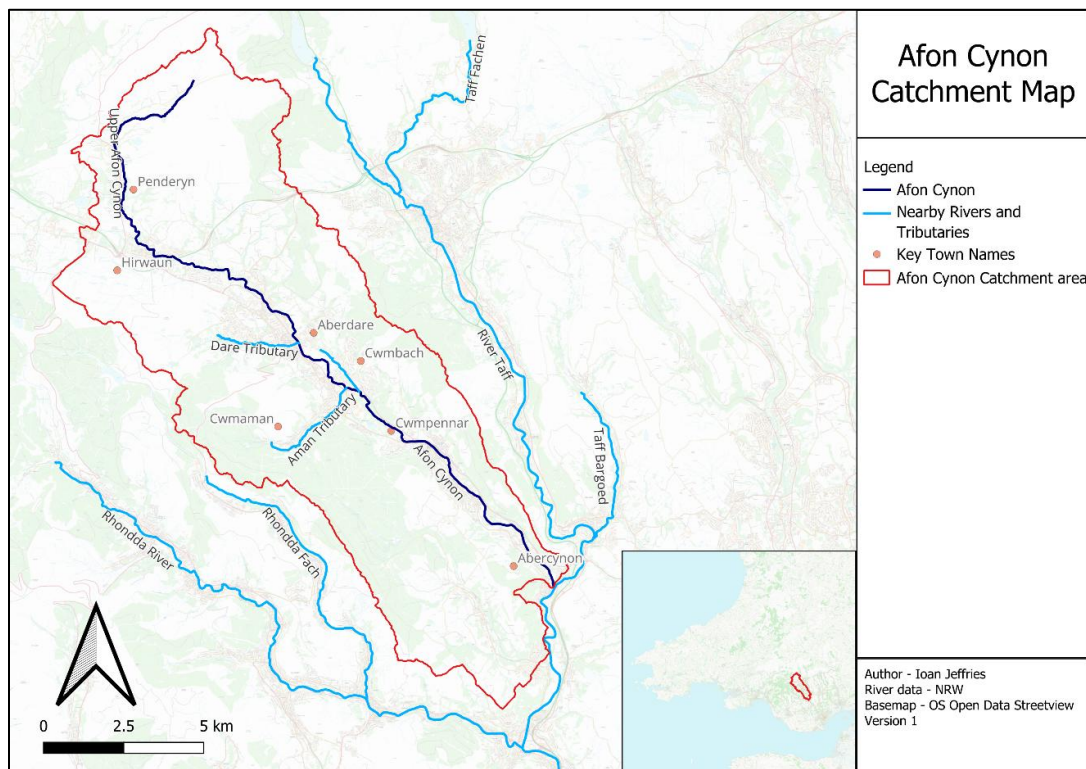


Figure 1 The Afon Cynon catchment along with the Afon Cynon and other nearby rivers.

The earliest published study looking at the state of the Afon Cynon was published in 1971 which aimed to describe the structure of macro-fauna species in the river (LEARNER et al., 1971). This study contains some of the earliest biological and chemical data of the river with one of the main conclusions being a dramatic reduction in diversity of fauna below the sampling station located just upstream of the village Hirwaun. This study was conducted while many heavy polluting facilities were still in operation with the study mentioning a number of coal washeries as well as sewage works discharging effluent directly into the river (LEARNER et al., 1971).

Aside from this study, the only other reports discussing the environmental conditions of the Afon Cynon is the Water Framework Directive classifications published by Natural Resources Wales (NRW). The WFD outlines the need to improve water quality within the UK and requires the classification of defined catchments with the goal of all rivers achieving a “Good status” as set out in the regulation (UK Government, 2017). The first of these reports was released in 2015 which classified the Afon Cynon as “poor” (NRW, 2015). The most recent classification published by NRW improved the Afon Cynon to being of “moderate” condition (NRW, 2026). This classification however was not published in a publicly available report and was found using datamap Wales. While these reports and classifications do look at the Afon Cynon and evaluate its ecological and environmental conditions and how they are changing, there is a gap in the literature evaluating long term trends beginning during the heavy industry that degraded the quality of the river in the first place.

1.2. Aims and Objectives

This study aims of this study are to:

- Use this historic data as well as more recently published data to look at the rate of ecological and environmental recovery since the 1971 study was published and identify the rate at which the water quality of the Afon Cynon has improved.

The objectives of this research are to:

- Extrapolate data from the 1971 study on the conditions of the Afon Cynon including macroinvertebrate communities and chemical readings and compare this with more recent data from various sources.
- Using invertebrate prediction tools such as RIVPACS, assess how the macroinvertebrate communities have changed over the past 60 years and compare this to the predicted natural levels of macroinvertebrates that would be expected.

2. Literature Review

2.1. Characteristics of flowing water

Flowing water and the species that can live within it is affected by a large number of factors from the hydrology of the stream and local geological conditions (Stanford, 2006). These conditions can create different variables of the water flow such as the velocity and the river discharge levels (Gore, 2006). The velocity of the river differs depending on location within the cross section. Water velocity is typically slowest on the riverbed and riverbank where friction is the highest (Earle, 2019). The variability in the water velocity means that different species with different flow tolerances will inhabit different areas of the river. For example, in a study by Hoover and Ackerman (2011) they looked at factors which caused the distribution of macroinvertebrates in a high velocity stream. The study found that certain mayfly species migrated to areas of high-water velocity due to them being adapted to a higher shear force than many other species. This potentially gave them more protection from predators as well as a higher abundance of food. This shows that some species are better adapted to survive in different habitats within the stream than others and so differing invertebrates will inhabit different sections of the river.

2.2. Macroinvertebrates in freshwater systems

Benthic macroinvertebrates are widespread across almost the entire planet and cover a wide range of taxa groups (Dalu et al., 2024). These species can be categorised into 5 distinct feeding roles which each fulfil a specific niche within the river. These roles are as follows;

- Scrapers
- Shredders
- Suspension feeders
- Collector-gatherers
- Predators

Scrapers are characterised as organisms that feed on algae and other microbial debris that is attached to rocks and other hard surfaces. They can cover a wide range of other organisms from grazing fish like *Camptostoma anomalum* (Veatch et al., 2018) to many types of tadpoles (Dodds and Whiles, 2020). Macroinvertebrate shredders include certain families of mayfly nymph like Heptageniidae. These can often be found in fast flowing sections of the river that have abundance

of hard surfaces to cling to and lots of sunlight that algae require to grow (Cummins, 2021; Gmeiner et al., 2025). This provides ideal habitat to feed and survive.

Shredders are a specialised kind of macroinvertebrate that play an important role within the river ecosystem. Shredders eat detritus such as leaves and rotting wood that fall into the river. This is done by breaking up or shredding the debris, turning it from coarse particulate organic matter (CPOM) to fine particulate organic matter (FPOM) (Dodds and Whiles, 2020). This process contributes significantly to the cycling of nutrients in the river ecosystem and means that these nutrients are available not only to themselves but other organisms within the ecosystem (Cereghetti, 2024).

Collectors are one of the feeding groups which cover both suspension feeders and Collector-gatherers. These feeding groups tend to consume FPOM and consist of a number of groups such as Trichoptera and Ephemeroptera (Merritt and Cummins, 2006).

Suspension or filter feeders, consume FPOM in the water column through a number of filter methods and so often inhabit areas of intense particle movement (Szałkiewicz, Kałuża and Grygoruk, 2022). An example of this is net spinning caddisflies like *Hydropsyche* which spin silk nets in order to gather food suspended in the stream (Hauer and Resh, 2006).

Collector-gatherers such as the family Baetidae, often feed on detritus deposited within the sediment on the riverbed (Gholizadeh and Heydarzadeh, 2017).

The final feeding role is predators. These are macroinvertebrates that rather than feeding on CPOM or FPOM, will instead feed on tissue, cells or ingest other macroinvertebrates partially or whole (Merritt and Cummins, 2006). An example of this is the family Perlodidae which are predominantly predators in the benthic environment and will predate on other macroinvertebrates (Thorp and Covich, 2008).

2.3. Environmental factors that affect macroinvertebrates

There are several factors that affect different macroinvertebrate communities within the river ecosystem, both natural and anthropogenic. One of these factors is dissolved oxygen (DO) levels. This is the amount of dissolved oxygen levels present within the water system which is affected by a number of variables such as temperature increases (Hutchings et al., 2024) and organic pollution

(Eriksen et al., 2022). One factor that can effect DO occur from industrial waste such as coal effluent which will dramatically decrease levels of dissolved oxygen (Kumar, Anand and Iqbal, 2015). This lowered level of DO is detrimental to families such as Ephemeroptera, Plecoptera and Trichoptera (EPT) (Malison et al., 2020; Prommi, Seetapan and Vitheepradit, 2025; Vilenica et al., 2020), while can be greatly beneficial to other groups such as Oligochaeta and Diptera (Abubakr et al., 2017; Timm and Haldna, 2019). This is because groups like Oligochaeta are adapted to low oxygen environments since their habitats are often underground and in burrowing environments (Glasby, Erséus and Martin, 2021). This means that in pollution events where DO levels are reduced in the river system, they are able to thrive while other species are unable to cope with the stresses.

Biological Oxygen Demand (BOD) is another metric for measuring water quality. This metric is useful for assessing levels of organic matter in water sources and takes advantage of aerobic bacteria breaking down organic matter. The process of measuring BOD involves collecting a sample of water, measuring the levels of DO and then incubating the sample for exactly 5 days at 20°C then measuring the DO levels after (Pan, 2026). The 5-day period was first decided on by The Royal Commission on Sewage Disposal (1915) which concluded that 5 days was the maximum amount of time it would take water to travel from source to mouth in any river in the UK. A high BOD indicates high levels of organic material within a water course and can indicate high levels of effluent such as sewage. This will cause levels of DO within the water to decrease as the aerobic bacteria consume oxygen while breaking down the organic matter (Pan, 2026).

pH change is another factor that can affect macroinvertebrate communities. The optimum pH of a river will differ depending on the region and local geology of the catchment. For example, a limestone rich catchment will often lead to a river with a higher pH than a granite rich catchment (Liu et al., 2020). Low pH can also come from anthropogenic sources such as agriculture runoff (Kellner and Hubbart, 2017) and acid mine drainage (Wolkersdorfer, 2022). Lower pH has a big effect on macroinvertebrate communities both directly and indirectly. Low pH makes many heavy metals such as copper and mercury a lot more bioavailable which can cause more harm to these species and overall lowers the species richness in the benthic environment (Fornaroli et al., 2018).

Due to the fact that many macroinvertebrates are sensitive to these changes in conditions as well as their short life cycles, lack of mobility and their ease sampling, this makes them particularly valuable for the monitoring of water quality within river systems. This is know as biological monitoring (Strangeways, 2007).

2.4. Biological monitoring

Biological monitoring is the process of using composition, diversity and abundance of benthic organisms as indicators of the ecological health of rivers or streams (Johnston and Wiederholm, 1993). This method of river monitoring has a number of advantages and disadvantages compared to chemical analysis. One key advantage of biological monitoring is that it provides a long-term picture of a rivers ecological health compared with single point chemical analysis. In the event of a high pollution incident, there is the potential for chemical analysis to miss these spikes in pollution. An example of this occurring is the Upper Arkansas river basin in Colorado. Between 1989 and 1991 a number of invertebrate samples were collected in order to determine the effects of a local lead mine that was leaching heavy metals into the river. While chemical grab sampling missed some of the heavy spikes in pollution released, it was found that the river downstream of the mine was dominated predominantly by pollution tolerant species while pollution sensitive species were more prevalent upstream (Clements, 1994). This does mean however that while biological monitoring can be useful for assessing general and long-term trends of the river's health, it isn't very good for pinpointing and measuring exact pollution sources (Bonada et al., 2006). This is why it is important to use both monitoring methods to get a complete understanding of potential pollution causes and their effects.

2.4.1. History of biological monitoring and biotic indices

The monitoring of European rivers using biological indicators has been in use since the early 1900s. A study conducted in Cardiganshire in the 1920s looked at a heavily polluted trout and salmon stream and noted three stages of biological recovery after the closure of a local lead mine. The first stage of recovery included the establishment of certain species of flora as well as limited invertebrates such as a variety of worms and flatworms. As these stages progressed a key change was the return of more pollution sensitive species such as Trichoptera (Carpenter, 1926). This demonstrates how certain key species, especially macroinvertebrates that are sensitive to pollution events could be used to assess the water quality of a river and assess its recovery back to a more natural state.

One of the first widespread biotic indices in use in the UK was developed by the Trent river board and a team of biologists and would later be known as the Trent Biotic index (TBI) (Woodwiss, 1960). The TBI was a landmark in water quality assessments as it was a foundation for other biotic

indices and allowed for non-biologists to more easily utilise and compare results from biological monitoring (Metcalf, 1989). This like many other biotic indices that followed rely on 2 key biological effects of river pollution;

- The reduction of diversity in benthic communities
 - The loss of key species that are sensitive to pollution events
- (Gray, 2017)

While it was a landmark biotic index, it does have some disadvantages. One of which is its limited use outside of the Trent/Severn regions. The index was devised for this region and must be adapted and altered to work as effectively elsewhere (Andersen, Rigét and Sparholt, 2003). Species drift can also cause large skews in results. Even a single high scoring species that accidentally drifts into the area can cause highly differing results as abundance of individuals is not accounted for (Gray, 2017).

The growing environmental awareness throughout the 1970s led the Department of the Environment to set up the Biological Monitoring Working Party (BMWP) which created a standardised way to conduct national water quality surveys across the UK (A. Hawkes, 1998). Individual scores are assigned from 1-10 based on key family groups, with Ephemeroptera and Plecoptera scoring 10 while Oligochaeta and Chironomidae scoring 1. Some family groups like Trichoptera are split into different scores due to differing pollution tolerances. The scores are then added together to present the total BMWP score or averaged together to calculate the average score per taxa (ASPT). The number of scoring taxon present can also be added to calculate the number of taxon (NTAXA) (Bartram et al., 1996).

The BWMP was the standard metric used when assessing macroinvertebrate communities until 2015 where it was superseded by the Walley Hawkes Paisley Trigg (WHPT) index for WFD monitoring (Paisley, Trigg and Walley, 2014). One key flaw of the BMWP metric is the fact that it does not account for abundance of species. When using the BMWP metric, if a stressed site was sampled and contained a single instance of a high scoring family while a less stressed site contained considerably more of the same family, they would both receive the same score for that family (Green and Overall, 2023). This was accounted for in the WHPT index by implementing abundance categories based on the number of individuals of a certain family found (Figure 2) (appendix A). With this setup, scores are more accurately calculated with family abundance being accounted for

in the final score. This is the index currently standardised in the WFD for biological monitoring (WFD UKTAG, 2023).

Taxon	BMWP	Presence only (PO) WHPT		WHPT for abundance category 1 (1-9)	WHPT for abundance category 2 (10-99)	WHPT for abundance category 3 (100-999)	WHPT for abundance category 4+ (1000 +)
Baetidae	4	5.5		3.6	5.9	7.2	7.5

Figure 2 BWMP and WHPT scores for the mayfly family Baetidae from the WHPT calculator to demonstrate the differing abundance categories (FBA, 2025).

2.4.2. Invertebrate prediction models

While Biotic indices are great for determining the health for a river and are useful for monitoring changes on individual sites, they are not a universal measurement of all rivers as the species richness can vary not just between rivers but different sections of the same river due to natural factors such as geological conditions and individual river conditions (Magallón Ortega et al., 2021). In order to accurately compare different sites, a prediction model is used. The River Prediction and Classification System (RIVPACS) is one such model and is incorporated into the River Invertebrate Classification Tool (RICT) software. This takes into account site location, altitude, river discharge as well as a number of other environmental factors (Table 1). Using this information, it can predict the value of species expected at any site within the UK in its natural state in terms of the ASPT and NTAXA values (Clarke, Wright and Furse, 2003). Comparing this with what species are present represented by the WHPT ASPT and NTAXA allows for an accurate measurement of the rivers health and how it may be affected by anthropogenic sources (Kral et al., 2017; RICT Steering Group, 2025).

Table 1 Site data required by RIVPACS to predict a sites expected ASPT and NTAXA scores.

Site
Waterbody
NGR
Easting
Northing
Altitude (M)
Slope (M/KM)
Discharge (Category)
Distance From Source (KM)
Mean Width (M)
Mean Depth (CM)
Alkalinity (mg/L)
Boulder/cobbles %
Pebbles/gravel %
Sand %
Silt/clay %

2.5. History of the Afon Cynon and surrounding valley

2.5.1. Formation of the valley

The Cynon valley is thought to have formed between 230 – 280 million years ago during the Triassic to early Tertiary periods. It is theorised that the Afon Cynon River was once much larger than it currently is as a river of its current scale could not have been responsible for forming a valley of this scale (Roberts, 2026). The Cynon valley was once covered in dense swamps and forests which led its high volume of coal fields which cover most of the south Wales valleys (Roberts, 2026). This led to its vast industrial history as a hot spot for coal mining.

2.5.2. Industrial history

The Cynon Valley has a vast industrial heritage dating back to the industrial revolution. There were a number of different industries located in the valley such as the brickworks in Llwydcoed (Alison, 1985) and ironworks which were common in a number of sites across the valley over the 18th and 19th centuries (Evans et al., 2003; Ince, 1993). One of the most prominent and most impactful was the coal mining industry which began with the Abernant-Y-Groes Colliery which was first sunk in 1837. From 1837 to 2008 there were around 300 pits sunk across the valley ranging in size and

output (Mear, 2001). The final pit to be closed was Tower Colliery which began operations in 1864 and finally ceased in 2008 (Lawrence, 2012).

The heavy industry had a large effect on the environment in the South Wales Valleys, even after the closure of the mines and factories. An extreme example of this is the Phurnacite factory located in Abercwmboi which processed coal into smokeless fuel used in other industry. This site operated between 1942 and 1991 and caused a number serious health and environmental concerns in the surrounding area such as leaving tar pits and other dangerous chemicals in the ground (Lester et al., 2003).

One predominant feature of Tower Colliery was the coal washery which was designed to clean up coal extracted from the pit before shipping. This was located alongside the Afon Cynon and was mentioned in the 1971 Learner et. al study. It stated that it was known to be discharging coal effluent into the river at the time of the study along with effluent from old coal tips during periods of heavy rain (LEARNER et al., 1971). Other notable features that were identified in the study was sewage effluent points and industry waste which discharged directly into the Afon Cynon (Figure 3).

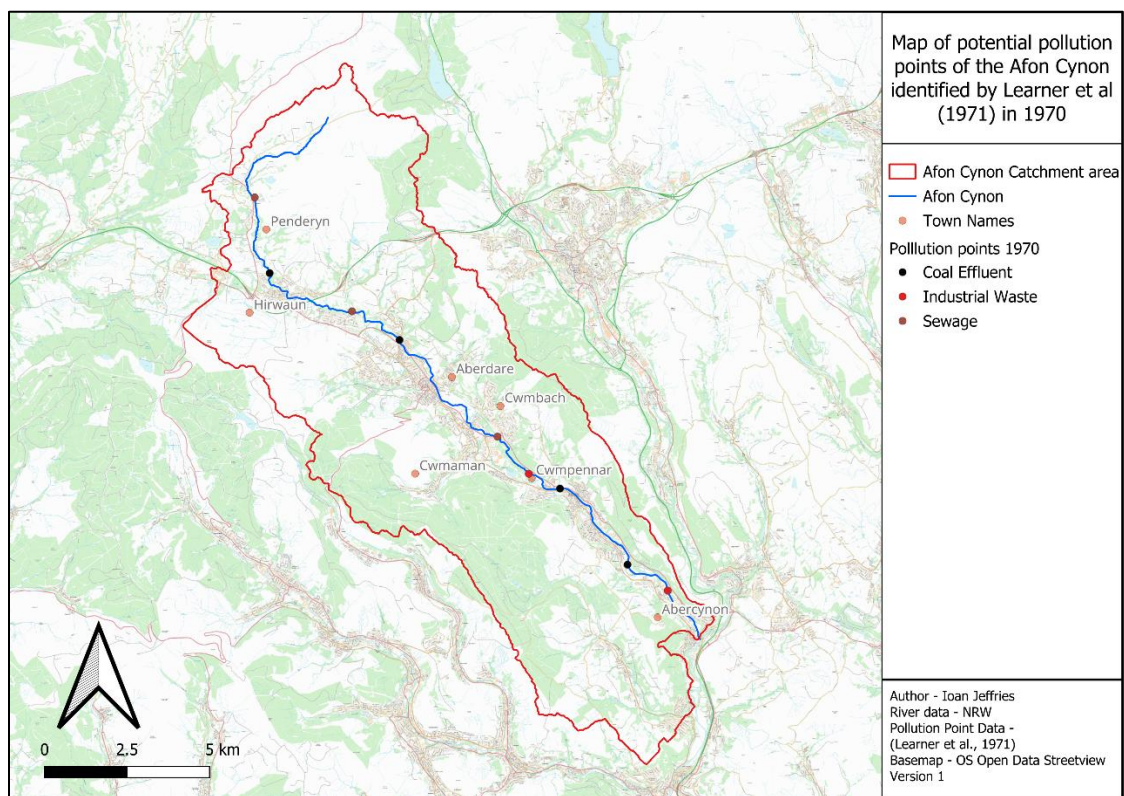


Figure 3 Map of potential pollution sources of the Afon Cynon identified by Learner et al (1971).

3. Methodology

3.1. Sample locations

The Afon Cynon is a tributary of the river Taff and is located in the Cynon valley of South Wales. According to NRW (2022) main rivers data it begins near Penderyn and flows 27 kilometres through several towns such as Hirwaun, Aberdare, Mountain Ash and finally joins on to the river Taff in Abercynon with a catchment area covering 134km² (Figure 4).

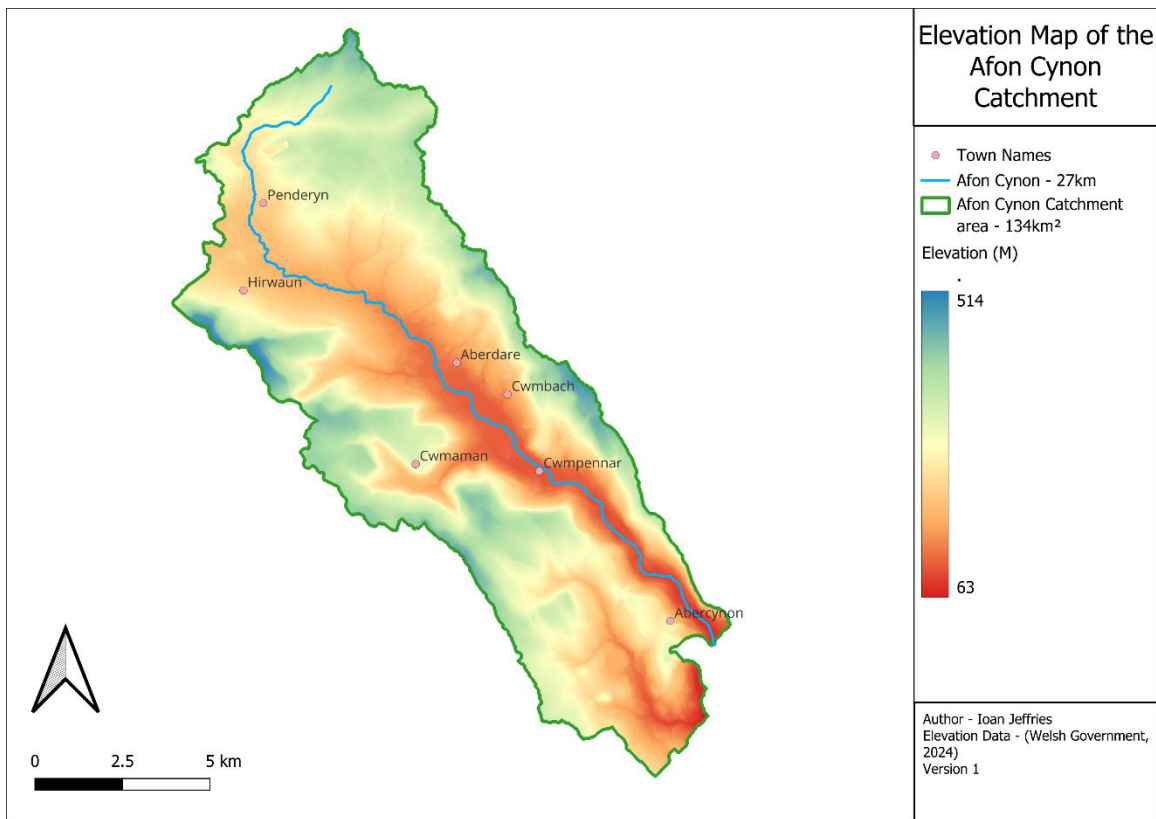


Figure 4 Elevation model of the Afon Cynon Catchment along with the catchment area and river length (Welsh Government, 2024).

There are a number of sampling stations used by various parties and organisations along the length of the river which will be utilised for this study (Figure 5). These samples cover a range of years with the oldest data coming from 1970 and the newest being collected in 2025. In this study there will be 3 sources of external data being utilised as well as data collected personally. As these data sources all use a range of sample sites along the river (Figure 5), it is important to use sites that have data from all sources. For this reason, 3 primary sites have been selected for comparison which

have results from all data sources within a 100m vicinity. These 3 sites that have been selected will here forth be referred to as Hirwaun (51.747434°N 3.517792°W) which is located on the upper section of the Afon Cynon. As well as Cwmpennar (51.688102°N 3.394360°W) and Abercynon (51.649222°N 3.328162°W) which are located on the lower section (Figure 6 Table 2).

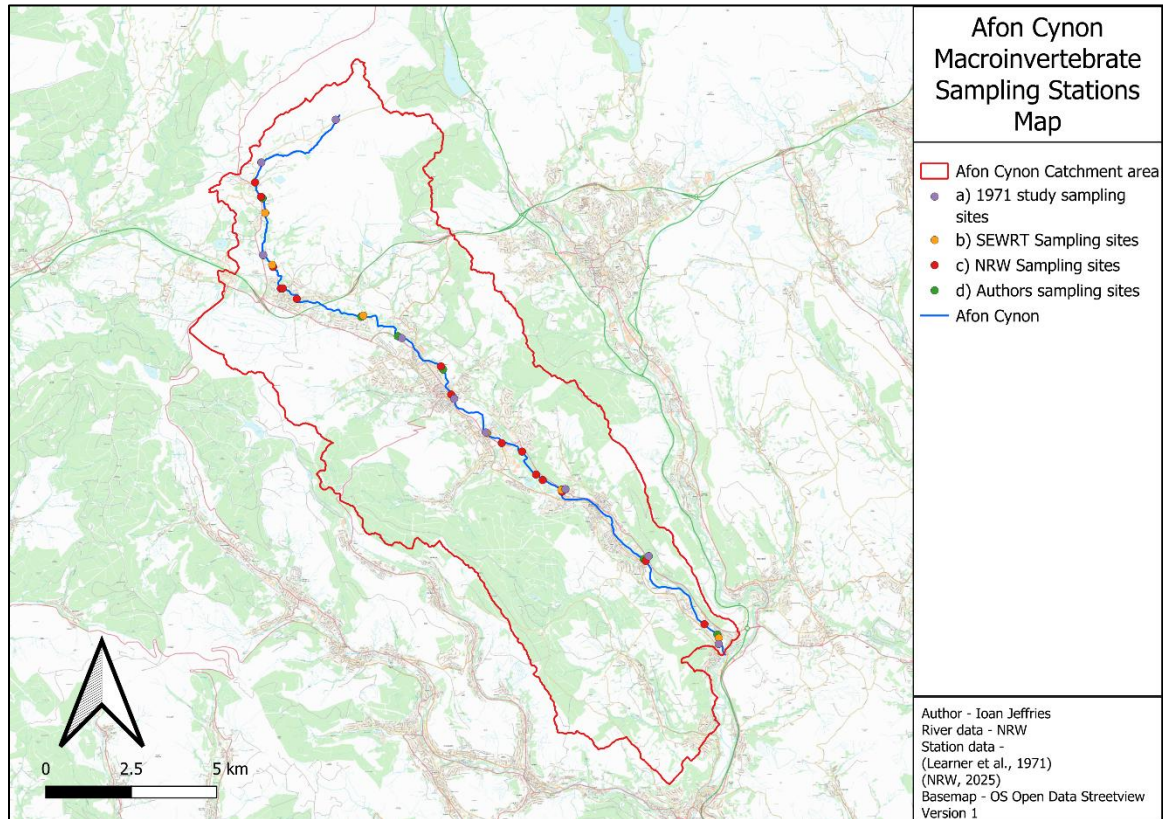


Figure 5 Map showing all known sampling stations on the Afon Cynon from a) the 1971 study (Learner et al., 1971). b) SEWRT. c) NRW (NRW, 2025). d) Authors own sampling stations.

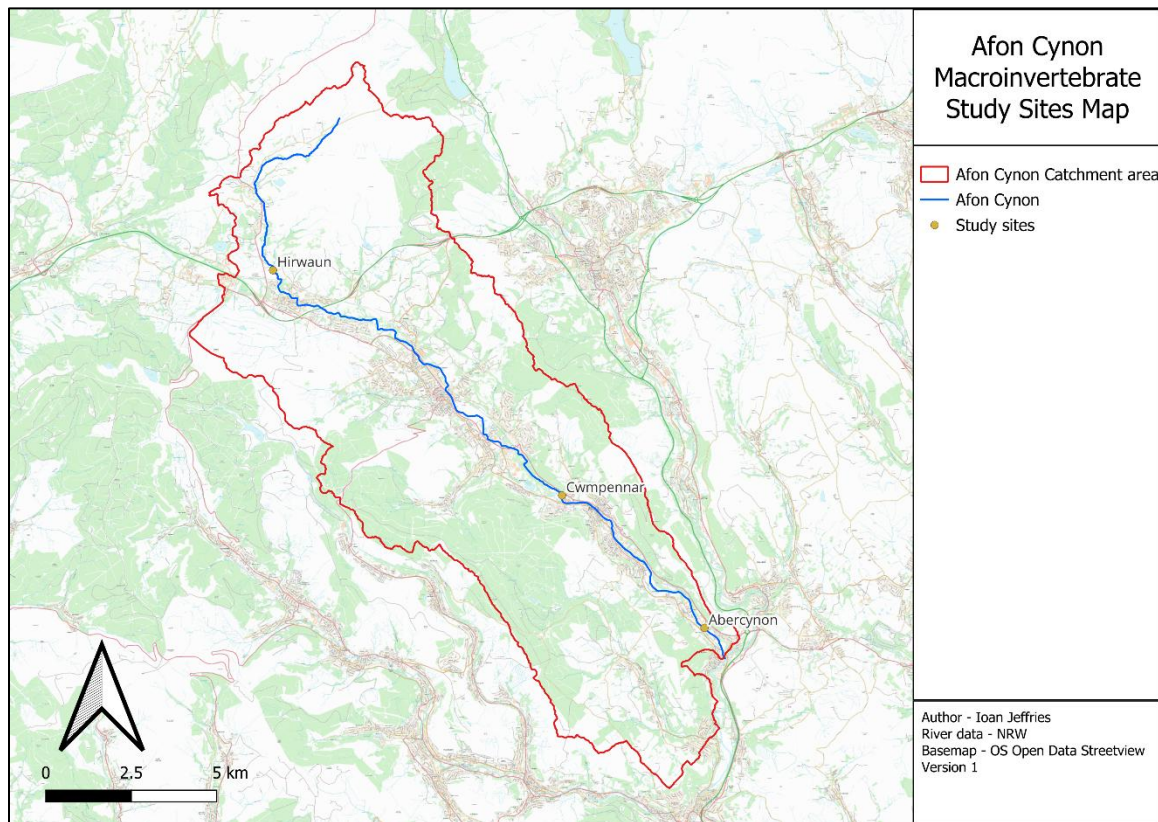


Figure 6 Map showing the selected sites of study

Table 2 Site names alongside their geographical coordinates

Site Name	Coordinates
Hirwaun	51.747434°N 3.517792°W
Cwmpennar	51.688102°N 3.394360°W
Abercynon	51.649222°N 3.328162°W

3.2. Data Sourcing

When sampling invertebrates across different regions and rivers it is important to use standardised practices which means that results are consistent wherever samples are collected. The standard method for macroinvertebrate sampling is the 3-minute kick sampling technique. This is standard for the Environment Agency in the UK including NRW and is used where possible when monitoring macroinvertebrate populations (NRW, 2026).

As discussed in the literature review, different species will inhabit different areas of the river depending on water velocity, light levels and cover. In order to sample invertebrates from all different microhabitats within the river, it is important to identify and sample all different sections of the river including fast moving riffles, shallow still water and amongst plant matter. These areas need to be identified before sampling can begin. Once the areas have been identified, rest the net against the riverbed and disturb the sediment up stream on the net with your heel to dislodge any invertebrates which will be carried into the net by the stream. This should be done for 30 seconds then move on to the next area of the river. Repeat this step until 3 minutes of sampling time have been completed. A 1-minute hand search should also be conducted of any large rocks and vegetation in order to capture species such as stoneflies who cling onto the underside of rocks (Pawley, Dobson and Fletcher, 2011). This method of macroinvertebrate sampling is widely used as it is easily repeatable and allows for a high yield of samples (Longstaffe et al., 2024).

In order to capture macroinvertebrate data along the Afon Cynon, sampling will be conducted along preselected points along the river. 6 sites have been selected which cover the length of the Afon Cynon (Figure 5). Sampling was conducted on the 9th of September 2025 using the standard 3 minute kick sample 1 minute hand search methods previously discussed. 3-minute sample was preserved in a preservation medium and taken to the lab for identification under a microscope. Each sample was sorted into Order and further narrowed down to Family level. In terms of identification, Family level identification will be ideal as that is the level of identification required to calculate a WHPT score for the sites. All identification of macroinvertebrates was based on the Freshwater Biological Association (FBA) guidebooks (Dobson et al., 2012; Pawley et al., 2011).

Other data sources are also being used to better compare changes over time. Macroinvertebrate data for the Afon Cynon is being utilised from 3 different sources. The first is from the study published in 1971 looking at the macro-fauna along the length of the Afon Cynon (LEARNER et al., 1971). This study collected macroinvertebrate samples along the river as well as in a number of tributaries

that feed into the Afon Cynon. As the study was conducted in the 1970s, standard practice was not as widely adopted and so sampling procedures such as the 3-minute kick sample, 1 minute hand search were not used. This makes the data harder to compare with more recently collected data and so this factor must be taken into consideration when analysing results. The study measures its samples as the number of macroinvertebrates per m² of substrate. In order to accommodate this alternative measurement, each sample was divided by 4 to more closely approximate the net size used in standardised sampling. While this isn't a perfect conversion, it more closely fits the standard methods by mimicking the size of the standard kick sampling net (Longstaffe et al., 2024). Macroinvertebrates in this study were identified down to the species level and so the data was consolidated into a spreadsheet and individually sorted based on family groups. Overall, this data source is fairly limited in terms of abundance values as the exact number of species will vary compared to standardised sampling. This will not affect the diversity of taxon however as this is measuring the species identified at the site.

The second data source that will be utilised is the publicly available data from NRW (2025). Macroinvertebrate data has been compiled by NRW starting since 1990 and covers multiple seasons a year. This data was collected via standardised sampling methods of 3-minute kick sampling 1 minute hand search meaning that it can be easily compared with other data sources (Longstaffe et al., 2024). Sampling took place between 1990 and 2013 but does not cover every year and does contain gaps. This means that although the data does not cover every single year, there is enough data to assess general trends over the years.

The final data source included is from the smart rivers project conducted by the South East Wales Rivers Trust (SEWRT). The smart rivers project is a citizen science project that conducts seasonal macroinvertebrate surveys at several sites along the Afon Cynon every year starting in 2020 and is an ongoing project. Once the samples are collected, they are taken to the lab where they are identified down to the species level. Due to the species level identification, individual taxon had to be individually taken for each sample and sorted into their family group. The project first began in 2020, and so macroinvertebrate data exists from 2020 until 2025. This is the most up to date data that exists for the Afon Cynon. Contributions were made by the author in the sampling, identification and inputting of this data for 2025 samples.

Chemical data will also be utilised in this study sourced primarily from NRW's publicly available data sets. Data was collected between 2000 to 2025 and measures a wide range of metrics such as heavy metal contents, BOD and water temperature. For this particular study the measurements that

will be utilised is pH, BOD and DO as these metrics can provide insight into the conditions of the river system and how it has been changing over the years. There is also limited data from the 1971 study however this only covers the single sample during the study. This means that it only provides a single snapshot of the conditions at the time of the sample.

Table 3 Data available for the Hirwaun site along with where this data was sourced from.

	Macroinvertebrate	pH	BOD	DO
1970	X	X	X	X
1990	X			
1991	X			
1992	X			
1993	X			
1994				
1995	X			
1996				
1997				
1998				
1999				
2000	X	X	X	X
2001				
2002	X	X	X	X
2003		X	X	X
2004		X	X	X
2005	X	X	X	X
2006		X	X	X
2007		X	X	X
2008	X	X	X	X
2009		X	X	X
2010		X	X	X
2011		X	X	X
2012		X	X	X
2013		X	X	X
2014		X	X	X
2015		X	X	X
2016				
2017				
2018				
2019				
2020				
2021	X			
2022	X			
2023	X	X		X
2024	X			
2025	XX	X		X

Data Source
1971 Study
NRW
SEWRT
Author

Table 4 Data available for the Cwmpennar site along with where this data was sourced from.

	Macroinvertebrate	pH	BOD	DO
1970	X	X	X	X
1990	X			
1991	X			
1992	X			
1993	X			
1994				
1995	X			
1996				
1997				
1998				
1999	X			
2000	X	X	X	X
2001		X	X	X
2002		X	X	X
2003		X	X	X
2004	X	X	X	X
2005		X	X	X
2006		X	X	X
2007	X	X	X	X
2008		X	X	X
2009		X	X	X
2010	X	X	X	X
2011		X	X	X
2012		X	X	X
2013	X	X	X	X
2014		X	X	X
2015		X	X	X
2016				
2017				
2018				
2019				
2020	X			
2021	X			
2022	X			
2023	X			
2024	X			
2025	XX	X		X

Data Source
1971 Study
NRW
SEWRT
Author

Table 5 Data available for the Cwmpennar site along with where this data was sourced from.

	Macroinvertebrate	pH	BOD	DO
1970	X	X	X	X
1990	X			
1991	X			
1992	X			
1993	X			
1994				
1995	X			
1996				
1997				
1998				
1999				
2000	X	X	X	X
2001		X	X	X
2002	X	X	X	X
2003		X	X	X
2004		X	X	X
2005	X	X	X	X
2006		X	X	X
2007		X	X	X
2008	X	X	X	X
2009		X	X	X
2010		X	X	X
2011			X	X
2012			X	X
2013	X	X	X	X
2014		X		X
2015		X		X
2016		X		X
2017		X		X
2018		X		X
2019		X		X
2020	X			
2021	X			
2022	X			
2023	X	X		X
2024	X	X		X
2025	XX	XX		XX

Data Source
1971 Study
NRW
SEWRT
Author

3.3. Metrics and measurements

In order to determine the environmental health of the river through the monitoring of benthic macroinvertebrates, biotic index scores must be assigned. The standard biotic index for the WFD will be used which is the WHPT index. Using this biotic index, 2 scores will be derived. The ASPT and NTAXA. The ASPT will be assigned by calculating the WHPT scores for present taxa including their abundance categories and averaging the results to calculate the average score per taxa. NTAXA will also be measured in order to assess the richness and diversity of the taxa found. This assigns a score based on the number of scoring families found. A low NTAXA score suggests a reduced diversity and species richness (Harrison, 2001).

Data from NRW and SEWRT have already been processed with the NTAXA and ASPT scores already being calculated for each of the sites selected. However, the WHPT score including the NTAXA and ASPT scores will need to be calculated for results from the 1971 study as well as samples collected for this paper. This will be calculated based off the WHPT calculator provided alongside the RICT software (Appendix A). Before 1990, data only exists for the year 1970, leaving a 20-year gap of data between 1970 and 1990. Data requests were sent to potentially acquire the missing data but with no results. This means that the trends before 1990 may not be as accurate and will need to be considered when drawing conclusions from the results.

Site details were collected by NRW which allows for the use of the RIVPACS prediction model to estimate the expected natural NTAXA and ASPT scores for each of the sites (Table 6). This site data can be used within the RICT software to calculate a predicted value of the expected WHPT ASPT and NTAXA scores that would be expected at the site naturally without any human impacts such as pollution.

Table 6 Site details for Hirwaun, Cwmpennar and Abercynon collected by NRW for the purposes of the prediction model RIVPACS (NRW, 2024).

Site	Hirwaun	Cwmpennar	Abercynon
WaterBody	Cynon	Cynon	Cynon
NGR	SN	ST	ST
Easting	95380	03699	07796
Northing	06448	99730	95784
Altitude (M)	200	110	90
Slope (M/KM)	12.5	1.6	10
Discharge (Category)	3	5	5
Distance From Source (KM)	7	19.1	25.5
Mean Width (M)	5	9.5	9.9
Mean Depth (CM)	24.67	30	27.33
Alkalinity (mg/L)	107.5	112.3	103.9
Boulder/cobbles %	70	53	77
Pebbles/gravel %	28	43	22
Sand %	2	3	2
Silt/clay %	0	0	0

Chemical data being utilised in this paper include pH, BOD and DO levels. pH and BOD measurements are consistent throughout the dataset with a few years of missing data between each of them but there is enough to demonstrate trends. The metrics used to measure DO levels is inconsistent. Between the years 2000-2007 DO is measured in mg/l but from 2007 onwards it is measured in % saturation. In order to consistently measure this attribute, a consistent metric must be used.

In order to convert DO as saturation % to mg/l there are a few factors that need to be known. As well as the DO %, the water temperature and elevation are also needed in order to accurately calculate the conversion. This is because the temperature and pressure have a significant impact on the amount of oxygen that can be dissolved in water with more oxygen being able to be dissolved at lower temperatures (Gray, 2017). Water on the web provides a DO converter which is based on

the following formula (Figure 7). This will be utilised to conduct the final conversion (Water on the Web, 2017).

Equation 1

$$\ln P = 5.25 \times \ln \left(1 - \frac{h}{44.3} \right)$$

where P = pressure (atm) at altitude h (km) relative to standard partial pressure (Pst) at 760 mm Hg or 101.325 kpa at sea level.

Now you can dive into equation 2 below. Oh, by the way, temperature in Kelvin (K) is equal to temperature in degrees C + 273.15 degrees and 1 atmosphere = 760 mm Hg.

Equation 2

$$C_p = C^* \times P \left[\frac{(1 - P_{wv}/P)(1 - \theta P)}{(1 - P_{wv})(1 - \theta)} \right]$$

C_p = equilibrium oxygen concentration at nonstandard pressure, mg/L
 C^* = equilibrium oxygen concentration at standard pressure of 1 atm, mg/L
 P = nonstandard pressure, atm
 P_{wv} = partial pressure of water vapor, atm, computed from:
 $\ln P_{wv} = 11.8571 - (3840.70/T) - (216,961/T^2)$
 T = temperature, °K
 $\theta = 0.000975 - (1.426 \times 10^{-5}t) + (6.436 \times 10^{-8}t^2)$
 t = temperature, °C

Note: $C^* = \exp[7.7117 - 1.31403 \cdot \ln(t + 45.93)]$

Now that you have solved for C_p you can finally determine %saturation based on your DO concentration (mg/L) by going one more step:

Equation 3

$$\% \text{ saturation} = \frac{(100 \times \text{DO}_{\text{mg/L}})}{C_p}$$

Figure 7 Formula used by Water on the Web to convert DO mg/l into DO saturation % and vice versa (Water on the Web, 2017)

A number of samples were collected each year for both macroinvertebrate populations and chemical data so in order to represent this data, the average scores were calculated for every year that data exists. In the event of any notably high/low scores, these will be highlighted individually.

4. Results

In the process of analysing the data collected, it was noted the large difference in scores between the authors results and the results from the other sources. The discrepancy in the data rendered it unsuitable for use in this study as it may affect the final result. This could be for a number of reasons including sampling methods, sample storage or identification errors. In the end it was decided to exclude this data from the final results. While personal samples will be excluded, samples collected and identified in collaboration with rivers trust will still be utilised under the SEWRT data set.

4.1. Hirwaun

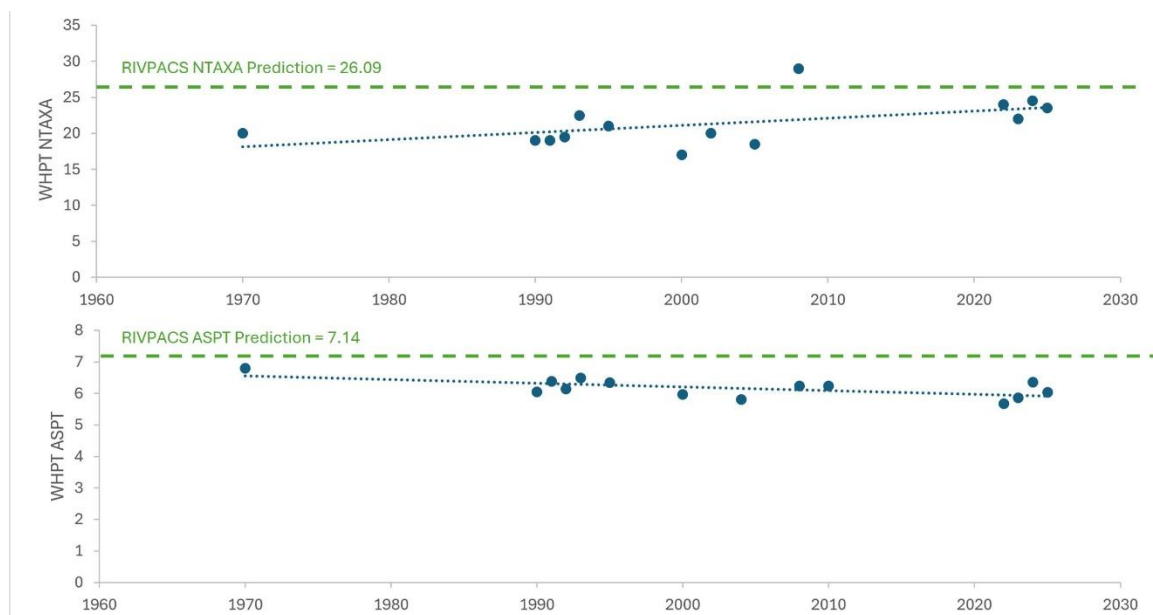


Figure 8 WHPT NTAXA and ASPT scores derived from data from the 1971 study, NRW and SEWRT for the Hirwaun site along with the RIVPACS predicted value for the Hirwaun site

As stated by multiple sources such as Learner et al., (1971) and Gareth Edge from SEWRT (O’keeffe, 2021), the Hirwaun site was located furthest upstream from the majority of the pollution sources such as the heavy industry and the coal washeries, as such has been mostly unaffected by the pollution. It was also one of the healthiest in terms of macroinvertebrate populations in the 1971 study.

Based on overall trends starting in 1970, the number of scoring taxa has remained fairly consistent aside from a particularly high scoring year in 2008 which peaked at 29 scoring families. Trends for the diversity of taxa appeared to be on the increase (Figure 8). Samples in the 1990s and beyond showed an increased diversity in high scoring taxa such as Trichoptera and especially Ephemeroptera and Plecoptera which both doubled in scoring families identified between 1970 and 2025.

The ASPT scores for Hirwaun were high in 1970 and declined thereafter which could be due to the sampling discrepancies. However, even when the ASPT score is disregarded from the results. The overall trend still shows signs of decline (Figure 9).

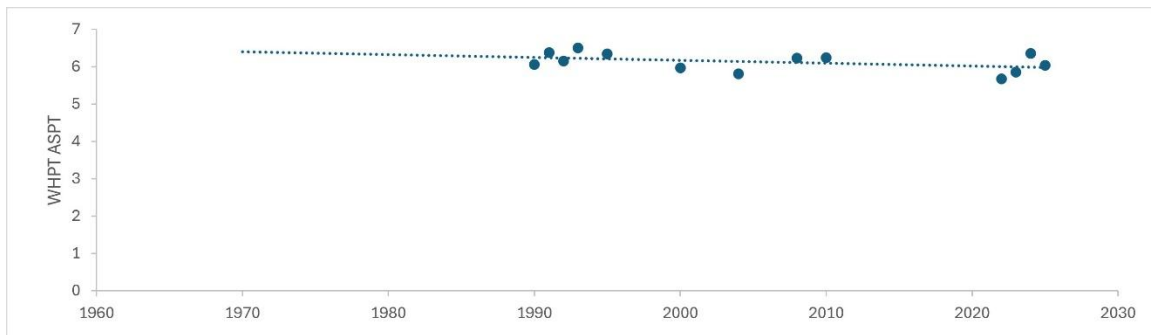


Figure 9 WHPT ASPT scores derived from data from the NRW and SEWRT for the Hirwaun site.

Major group	Taxon	WHPT Index Value			
		1970	1990	2000	2020
Triclada (flatworms)	Planariidae		4.7	4.7	
	Dugesidae		2.8	2.8	
Mollusca (snails, limpets and mussels)	Hydrobiidae			4.1	
	Bithyniidae			0	3.8
	Physidae			2.7	2.7
	Lymnaeidae		3.6	2.5	2.5
	Planorbidae		3.2	3.2	
	<i>Ancylus</i> group	5.5	5.8	5.5	5.8
	Sphaeriidae		4.4	4.4	4.4
Oligochaeta (worms)	Oligochaeta	1.4	2.3	1.4	2.3
Hirudinea (leeches)	Piscicolidae		5.2	5.2	
	Glossiphoniidae		3.4		
	Erpobdellidae		3.6		3.6
Crustacea (crayfish, slaters and shrimps)	Asellidae		4	4	4
	Gammaridae		4.5	4.5	4.5
Ephemeroptera (mayflies)	Baetidae	7.2	5.9	7.2	7.2
	Heptageniidae	10.3	10.3	10.3	
	Leptophlebiidae		8.8	8.8	8.8
	Potamanthidae			9.8	9.8
	Ephemeridae		8.3		8.3
	Ephemerellidae	9	8.5	7.9	7.9
	Caenidae		6.5	6.5	6.5
Plecoptera (stoneflies)	Taeniopterygidae		11	11	11
	Nemouridae		10.7		8.7
	Leuctridae	10.6	10.6	10.6	10.6
	Perlodidae		10.5	10.5	10.5
	Perlidae	12.6			
	Chloroperlidae			11.4	
Coleoptera (beetles)	Dytiscidae	4.8	4.8	4.5	4.8
	Gyrinidae				
	Hydrophilidae		5.8	5.8	
	Hydraenidae	8.5		8.5	
	Scirtidae				6.9
	Elmidae	7.4	7.4	7.4	7.4
Trichoptera (caddisflies)	Rhyacophilidae	8.1	9.2	8.1	8.1
	Glossosomatidae			7.8	7.6
	Hydroptilidae			6.5	
	Psychomyiidae	5.8	5.8	5.8	5.8
	Polycentropodidae		8.2		
	Hydropsychidae	5.8	7.2	5.8	5.8
	Limnephilidae		6.9	5.9	6.9
	Sericostomatidae	8.9	9.4	8.9	9.4
	Odontoceridae			11.1	11.1
	Leptoceridae			6.7	
Diptera (true flies)	Tipulidae	5.4	6.9	6.9	
	Psychodidae			4.5	4.5
	Ceratopogonidae	5.4	5.4	5.4	5.4
	Simuliidae	6.1	6.1	6.1	6.1
	Chironomidae	-0.9	1.3	-0.9	1.3
	Tabanidae	7.1	7.1		
	Empididae	7.6	7	7.6	
	Muscidae			4	4

Figure 10 Averaged WHPT scores for each present scoring family at the Hirwaun Site.

Major group	Taxon	Abundance Values			
		1970	1990	2000	2020
Triclada (flatworms)	Planariidae		9	5	
	Dugesiiidae		3	1	
Mollusca (snails, limpets and mussels)	Hydrobiidae			5	
	Bithyniidae				19
	Physidae			1	2
	Lymnaeidae		9	14	16
	Planorbidae		3	1	
	Ancylus group	115	8	14	2
	Sphaeriidae		3	1	1
Oligochaeta (worms)	Oligochaeta	105	73	140	11
Hirudinea (leeches)	Piscicolidae		3	1	
	Glossiphoniidae		3		
	Erpobdellidae		3		5
Crustacea (crayfish, slaters and shrimps)	Asellidae		3	1	3
	Gammaridae		19	22	78
Ephemeroptera (mayflies)	Baetidae	257	28	270	126
	Heptageniidae	28	23	10	
	Leptophlebiidae		3	5	5
	Potamanthidae			1	1
	Ephemeridae		3		4
	Ephemerellidae	114	19	4	5
	Caenidae	0	18	1	8
Plecoptera (stoneflies)	Taeniopterygidae		3	4	1
	Nemouridae		63		8
	Leuctridae	16	14	10	19
	Perlodidae		3	3	5
	Pertidae	1			
	Chloroperlidae			1	
Coleoptera (beetles)	Dytiscidae	32	12	3	14
	Hydrophilidae		3	5	
	Hydraenidae	1		1	
	Scirtidae				1
	Elmidae	94	23	55	86
Trichoptera (caddisflies)	Rhyacophilidae	2	15	6	4
	Glossosomatidae			6	90
	Hydroptilidae			83	
	Psychomyiidae	1	3	1	2
	Polycentropodidae		3		
	Hydropsychidae	1	19	2	4
	Limnephilidae		20	9	10
	Sericostomatidae	1	18	1	16
	Odontoceridae			2	2
	Leptoceridae			1	
Diptera (true flies)	Tipulidae	3	11	10	
	Psychodidae			1	2
	Ceratopogonidae	2	3	2	2
	Simuliidae	13	10	31	35
	Chironomidae	756	13	226	47
	Tabanidae	1	3		
	Empididae	28	3	12	
	Muscidae			1	5

Figure 11 Average abundance of scoring families at the Hirwaun site.

In terms of the Chemical data the pH levels show a gradual increase from the 1970 results showing 7.7 and the most recent reading from 2023 showing a pH of 8. The BOD results indicate an increase in organic matter within the river with some particularly high BOD scores in 2014. These high readings were all concentrated within a 3-month period between April and June of 2014 which could potentially indicate a specific pollution event which took place during this period. The DO levels at the Hirwaun station saw a gradual decline starting in the 1970s data and continuing until the last sampling in 2023 (Figure 12).

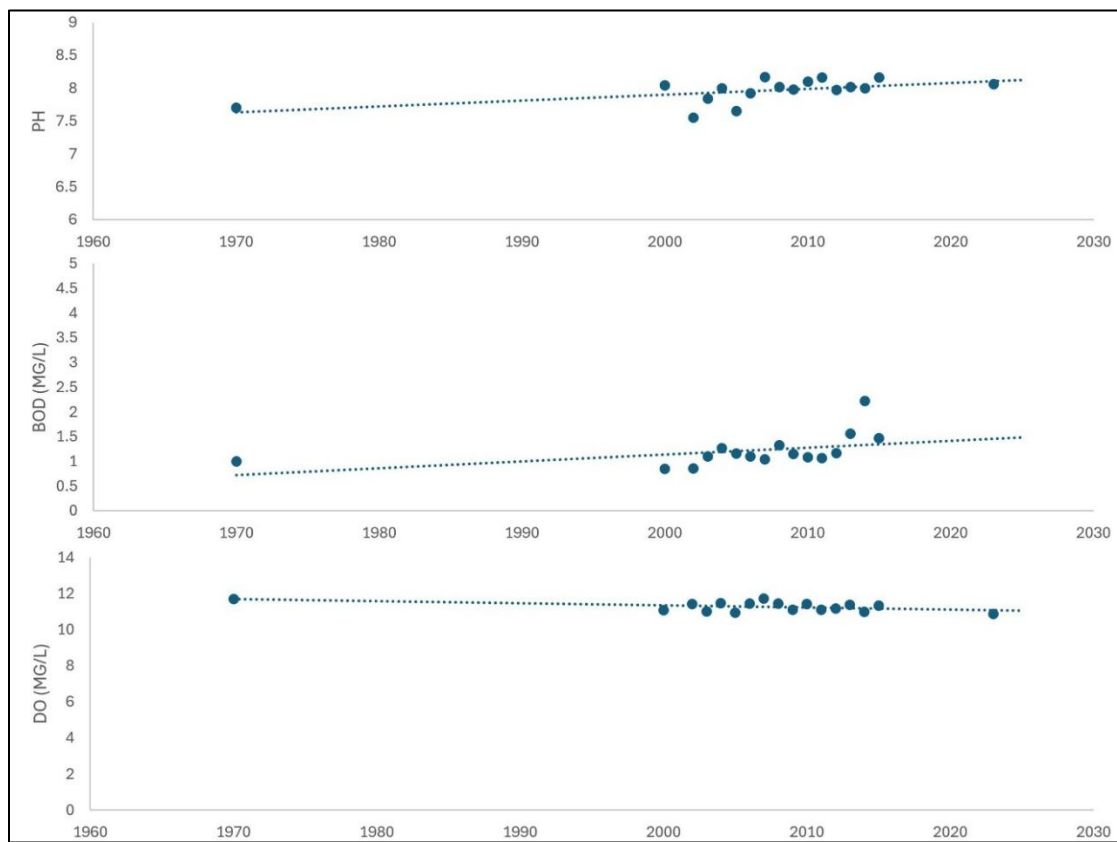


Figure 12 Chemical data including pH BOD and DO found at the Hirwaun site sourced from the 1970 study and NRW.

4.2. Cwmpennar

Cwmpennar was the first site out of the 3 used in this study that was located downstream of many of the pollution sources identified in the 1970 study which is evident in the macroinvertebrate data.

The Cwmpennar site showed a sharp reduction in the number of scoring species as compared with the Hirwaun site in 1970 with Hirwaun having 20 scoring families while Cwmpennar dropped by exactly half at 10 (Figure 8 and 13). Certain groups were completely extirpated from the site such as Plecoptera and Trichoptera while certain groups such as Oligochaeta saw a surge in their numbers which could indicate poor water quality such as low DO (Glasby, Erséus and Martin, 2021) (Figure 14 and 15). These extirpated taxa groups did return to the site as shown in the subsequent data by NRW and SEWRT as by 1990 many of the families had returned, increasing the NTAXA score significantly (Figure 13 and 15). As these high scoring families returned by the 90s, this also increased the ASPT which continued to increase throughout the 2000s and 2010s, almost achieving the RIVPACS prediction for the natural state of the site.

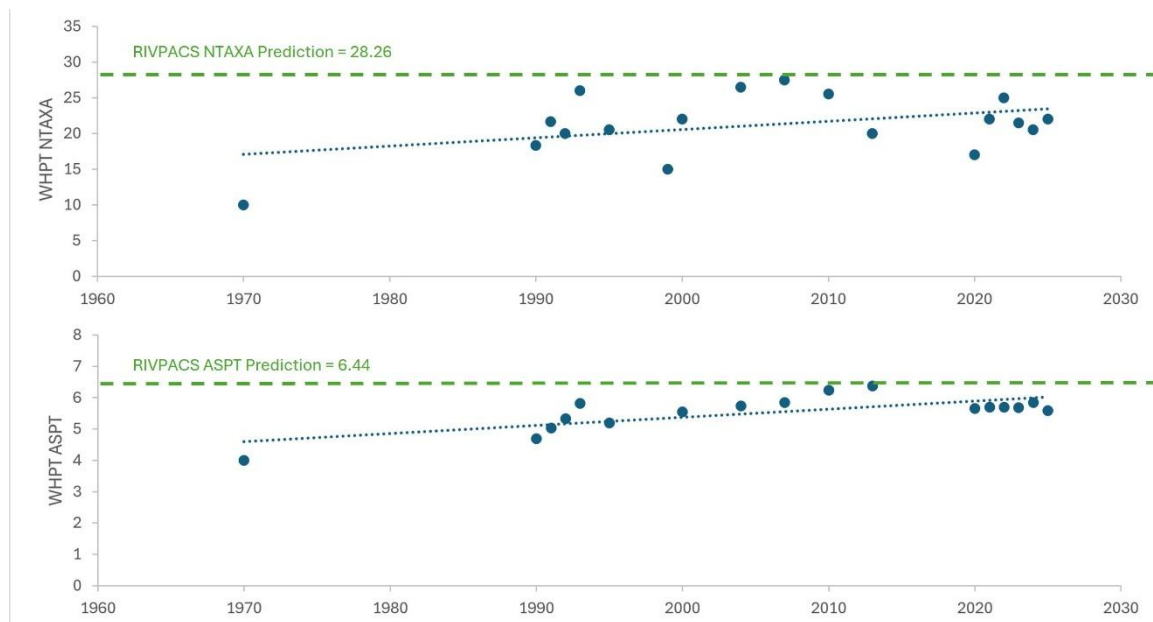


Figure 13 WHPT NTAXA and ASPT scores derived from data from the 1971 study, NRW and SEWRT for the Cwmpennar site.

Major group	Taxon	WHPT index value				
	Site name or code	1970	1990	2000	2010	2020
Triclada (flatworms)	Planariidae		5.4	4.7	4.7	
	Dugesidae			2.8		
	Dendrocoelidae		3	3		
Mollusca (snails, limpets and mussels)	Valvatidae			3.3		
	Hydrobiidae	4.2	4.2	4.6	4.1	
	Bithyniidae			3.6	3.6	3.6
	Physidae	2	2		2.7	2.7
	Lymnaeidae	0	2.5	3.6	3.6	2.5
	Planorbidae	0	3.2			3.2
	Ancylus group	5.5	5.5			5.8
	Sphaeriidae		4.4	4.4	4.4	4.4
Oligochaeta (worms)	Oligochaeta	-0.6	2.3	2.3	2.3	2.3
Hirudinea (leeches)	Piscicolidae		5.2			5.2
	Glossiphoniidae	3.4	3.4	3.4	3.4	3.4
	Erpobdellidae		2	2	3.6	2
Crustacea (crayfish, slaters and shrimps)	Asellidae		2.3	4	4	4
	Gammaridae		4.2	4.6	4.6	3.9
Ephemeroptera (mayflies)	Baetidae	7.2	7.2	7.2	7.2	7.2
	Heptageniidae		10.3	10.3	10.3	10.3
	Ephemeridae		8.3			8.3
	Ephemerellidae	7.9	8.5	8.5	7.9	
	Caenidae		6.5	6.5	6.5	6.5
Plecoptera (stoneflies)	Taeniopterygidae		11	11	11	
	Nemouridae		8.7	8.7	8.7	8.7
	Leuctridae		9.3	10.6	9.3	10.6
	Perlodidae		10.5		10.5	10.5
	Perlidae					12.6
Hemiptera (bugs)	Corixidae	3.7				
Coleoptera (beetles)	Halipidae		3.4			
	Dytiscidae			4.5	4.8	4.8
	Gyrinidae				8.1	8.1
	Hydrophilidae		5.8			
	Hydraenidae			8.5	8.5	8.5
	Elmidae	5.3	7.4	8.3	8.3	8.3
Trichoptera (caddisflies)	Rhyacophiliidae		8.1	9.2	8.1	8.1
	Glossosomatidae		0	7.8	7.8	
	Hydroptilidae		6.5	6.1		6.1
	Psychomyiidae					5.8
	Polycentropodidae					8.2
	Hydropsychidae		7.2	7.2	7.2	7.2
	Lepidostomatidae			0	9.9	9.9
	Limnephilidae		5.9	5.9	5.9	5.9
	Sericostomatidae		8.9	8.9	8.9	9.4
	Odontoceridae		11.1			
	Leptoceridae			6.7	6.7	6.9
Diptera (true flies)	Tipulidae		5.4	6.9	6.9	5.4
	Ceratopogonidae		5.4	5.5		5.4
	Simuliidae		6.1	5.8	5.8	6.1
	Chironomidae	-0.9	1.3	1.3	1.2	1.3
	Rhagionidae		9.6	9.6	9.6	
	Tabanidae		7.1			
	Athericidae					9.3
	Empididae	7	7	7.6	7	7
	Muscidae					4

Figure 14 WHPT scores for each present scoring family at the Cwmpennar Site

Major group	Taxon Site name or code	Abundance Value				
		1970	1990	2000	2010	2020
Triclada (flatworms)	Planariidae	13	6	2		
	Dugesidae		4			
	Dendrocoelidae	3	1			
Mollusca (snails, limpets and mussels)	Valvatidae		2			
	Hydrobiidae	10	68	180	4	
	Bithyniidae		5	1	1	
	Physidae	10	55	1	2	
	Lymnaeidae		48	2	3	13
	Planorbidae		3			3
	Ancylus group	24	19			4
	Sphaeriidae		3	5	3	1
	Oligochaeta	7081	56	76	39	17
Hirudinea (leeches)	Piscicolidae		3			3
	Glossiphoniidae	3	5	3	4	3
	Erpobdellidae		19	29	3	13
Crustacea (crayfish, slaters and shrimps)	Asellidae		23	3	4	5
	Gammaridae		8	196	468	1036
Ephemeroptera (mayflies)	Baetidae	145	100	477	153	181
	Heptageniidae		13	14	94	82
	Ephemeridae		3			2
	Ephemerellidae	5	63	21	1	
Plecoptera (stoneflies)	Caenidae		18	32	15	22
	Taeniopterygidae		3	5	4	
	Nemouridae		3	3	2	2
	Leuctridae		3	14	9	19
	Perlodidae		3		1	3
Hemiptera (bugs)	Perlidae					6
	Corixidae	1				
Coleoptera (beetles)	Halipidae		13			
	Dytiscidae			1	10	16
	Gyrinidae				1	4
	Hydrophilidae		3			
	Hydraenidae			2	7	6
	Elmidae	2	15	124	216	179
Trichoptera (caddisflies)	Rhyacophilidae		7	13	6	4
	Glossosomatidae			6	3	
	Hydroptilidae		18	3		1
	Psychomyiidae					2
	Polycentropodidae					3
	Hydropsychidae		22	12	10	17
	Lepidostomatidae				1	1
	Limnephilidae		3	5	3	2
	Sericostomatidae		8	7	8	28
	Odontoceridae		3			
	Leptoceridae			3	1	11
Diptera (true flies)	Tipulidae		3	30	17	3
	Ceratopogonidae		3	71	4	5
	Simuliidae		13	963	156	70
	Chironomidae	3356	68	60	9	17
	Rhagionidae		3	1	4	
	Tabanidae		3			
	Athericidae					1
	Empididae	2	3	14	1	1
	Muscidae					5

Figure 15 Abundance of scoring families at the Cwmpennar site

The pH scores for Cwmpennar remained consistent with no large deviations noted throughout the sample data. The pH remained at roughly 7.8. The BOD scores indicate a significant drop in organic matter at the Cwmpennar site from 1970 onwards. The BOD in Cwmpennar in the 1970s was 3.7 which had reduced to 1.68 by the next reading in 2000 (Figure 16). Levels of DO saw an overall increase between the 1970 reading and the more recent data. The 1970 and 2000 reading are fairly similar with DO levels being 4.5 and 4.45 respectively. More data in between these 2 samples could show if there were any changes between these dates or if it remained linear (Figure 16).

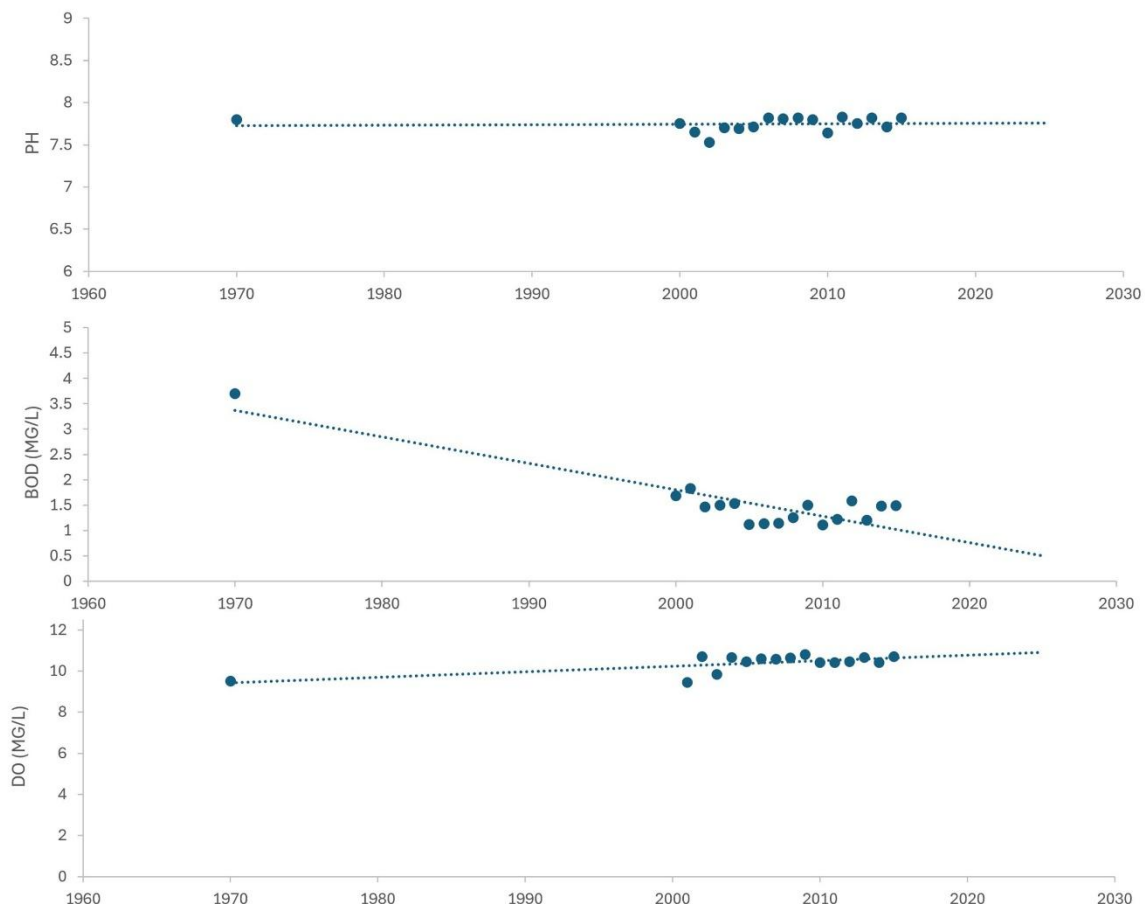


Figure 16 Chemical data including pH BOD and DO found at the Cwmpennar site sourced from the 1970 study and NRW

4.3. Abercynon

The Abercynon site follows a very similar trend to Cwmpennar with the reduction and extirpation of many high scoring groups such as Plecoptera and Trichoptera with these families recolonising the site by the 1990s and continuing to increase throughout the following decades (Figure 19). This has ultimately led to the ASPT scores at Abercynon increasing over the decades. Data from the SEWRT indicates that both the NTAXA and ASPT scores are almost in line with the RIVPACS predicted model in the 2020s. The group Oligochaeta had a drastic reduction across the time period with the 1970 data indicating roughly 3942 individuals while the 2020s had an average of 25 individuals found per sample (Figure 19).



Figure 17 WHPT NTAXA and ASPT scores derived from data from the 1971 study, NRW and SEWRT for the Abercynon site

Major group	Taxon	WHPT Index Value				
	Site name or code	1970	1990	2000	2010	2020
Triclada (flatworms)	Planariidae		5.4	4.7		
	Dendrocoelidae		3			3
Mollusca (snails, limpets and mussels)	Hydrobiidae	4.1	4.2	4.1	4.1	
	Bithyniidae			3.6	3.6	
	Physidae		2	2.7		2.7
	Lymnaeidae	2.5	2.5	2.5	3.6	2.5
	Planorbidae		3.2	3.2		3.2
	Ancylus group	5.5	5.5	5.8		5.8
Oligochaeta (worms)	Sphaeriidae		3.5	4.4		4.4
	Oligochaeta	-0.6	1.4	2.3	2.3	2.3
Hirudinea (leeches)	Piscicolidae			5.2		5.2
	Glossiphoniidae		3.4	3.4		3.4
	Erpobdellidae	2	3.6	3.6		2
Crustacea (crayfish, slaters and shrimps)	Asellidae		2.3	4		4
	Gammaridae		4.2	4.5	4.6	4.6
Ephemeroptera (mayflies)	Baetidae	7.2	5.9	7.2	5.9	7.2
	Heptageniidae		10.3	8.5	10.3	10.3
	Leptophlebiidae				8.8	8.8
	Ephemeridae		8.3			8.3
	Ephemerellidae	7.9	9	8.5		
	Caenidae		6.5	6.5		6.5
Plecoptera (stoneflies)	Taeniopterygidae		11			11
	Nemouridae			8.7		8.7
	Leuctridae					10.6
	Perlodidae		10.5			10.5
	Pertidae		0			12.6
	Chloroperlidae		12.2			
Odonata Zygoptera (damselflies)	Calopterygidae				5.9	
Hemiptera (bugs)	Veliidae		4.5			
	Gerridae					5.2
Coleoptera (beetles)	Halipidae		3.6			
	Dytiscidae		4.5	4.5	4.5	4.5
	Gyrinidae					8.1
	Hydraenidae				8.5	8.5
	Scirtidae		6.9			
	Elmidae		5.3	7.4	7.4	7.4
Trichoptera (caddisflies)	Rhyacophilidae		9.2	9.2	8.1	9.2
	Glossosomatidae			7.8	7.6	7.8
	Hydroptilidae		6.5	6.5		6.1
	Psychomyiidae			5.8		5.8
	Polycentropodidae					8.1
	Hydropsychidae	7.2	7.2	7.2	7.2	7.2
	Lepidostomatidae		9.9	9.9		9.9
	Limnephilidae		5.9			5.9
	Sericostomatidae					9.4
	Odontoceridae		11.1			
Diptera (true flies)	Leptoceridae		6.7	6.7	6.7	6.7
	Tipulidae		5.4	5.4	5.4	5.4
	Psychodidae		4.5	4.5		4.5
	Ceratopogonidae		5.4	5.5		5.5
	Simuliidae		5.5	6.1	5.5	6.1
	Chironomidae	-0.9	1.3	-0.9	1.3	1.3
	Stratiomyidae		3.6	3.6	3.6	
	Rhagionidae		9.6			
	Tabanidae		7.1			
	Athericidae					9.3
	Empididae	7	7	7	7	7
	Muscidae	0	4	4		4

Figure 18 WHPT scores for each present scoring family at the Abercynon Site

Major group	Taxon	Abundance Value				
		1970	1990	2000	2010	2020
Triclada (flatworms)	Planariidae		13	1		
	Dendrocoelidae		3			2
Mollusca (snails, limpets and mussels)	Hydrobiidae	7	46	8	1	
	Bithyniidae			6	1	
	Physidae		13	1		2
	Lymnaeidae	10	25	55	1	21
	Planorbidae		3	5		1
	Ancylus group	109	24	7		1
	Sphaeriidae		13	4		3
Oligochaeta (worms)	Oligochaeta	3942	108	73	54	25
Hirudinea (leeches)	Piscicolidae			1		1
	Glossiphoniidae		7	2		1
	Erpobdellidae	25	3	2		22
Crustacea (crayfish, slaters and shrimps)	Asellidae		41	4		2
	Gammaridae		8	22	283	643
Ephemeroptera (mayflies)	Baetidae	692	28	193	58	156
	Heptageniidae		12	5	27	57
	Leptophlebiidae				2	1
	Ephemeridae		3			1
	Ephemerellidae	1	213	10		
	Caenidae		128	102		24
Plecoptera (stoneflies)	Taeniopterygidae		3			1
	Nemouridae			1		1
	Leuctridae					33
	Perlodidae		3			4
	Perlidae					1
	Chloroperlidae		33			
Odonata Zygoptera (damselflies)	Calopterygidae				1	
Hemiptera (bugs)	Veliidae		3			
	Gerridae					1
Coleoptera (beetles)	Haliplidae		3			
	Dytiscidae		3	1	6	6
	Gyrinidae					6
	Hydraenidae				1	3
	Scirtidae		3			
	Elmidae		6	14	27	81
Trichoptera (caddisflies)	Rhyacophilidae		13	10	3	14
	Glossosomatidae			1	22	3
	Hydroptilidae		21	26		5
	Psychomyiidae			1		1
	Polycentropodidae					11
	Hydropsychidae	26	12	15	22	57
	Lepidostomatidae		3	1		2
	Limnephilidae		3			3
	Sericostomatidae					21
	Odontoceridae		3			
	Leptoceridae		3	2	1	9
Diptera (true flies)	Tipulidae		3	7	9	5
	Psychodidae		3	3		1
	Ceratopogonidae		3	38		13
	Simuliidae		3	85	2	66
	Chironomidae	685	24	310	29	91
	Stratiomyidae		3	1	1	
	Rhagionidae		3			
	Tabanidae		3			
	Athericidae					2
	Empididae	2	3	9	2	2
	Muscidae		3	1		3

Figure 19 Abundance of scoring families at the Abercynon site

pH levels in Abercynon have been remained fairly linear according to the data with the first reading being 7.9 in 1970 and the most recent reading in 2025 being 8.02. These pH results have also varied with the range of pH reading being 0.58. Similarly with the BOD results for Cwmpennar, Abercynon saw a large decrease in the BOD scores from a relatively high score of 4.5 in 1970. The BOD scores then stayed between 1.11 and 2.03 between 2000 and 2013. Levels of DO gradually increase over the time frame between 1970 and 2025 (Figure 20).

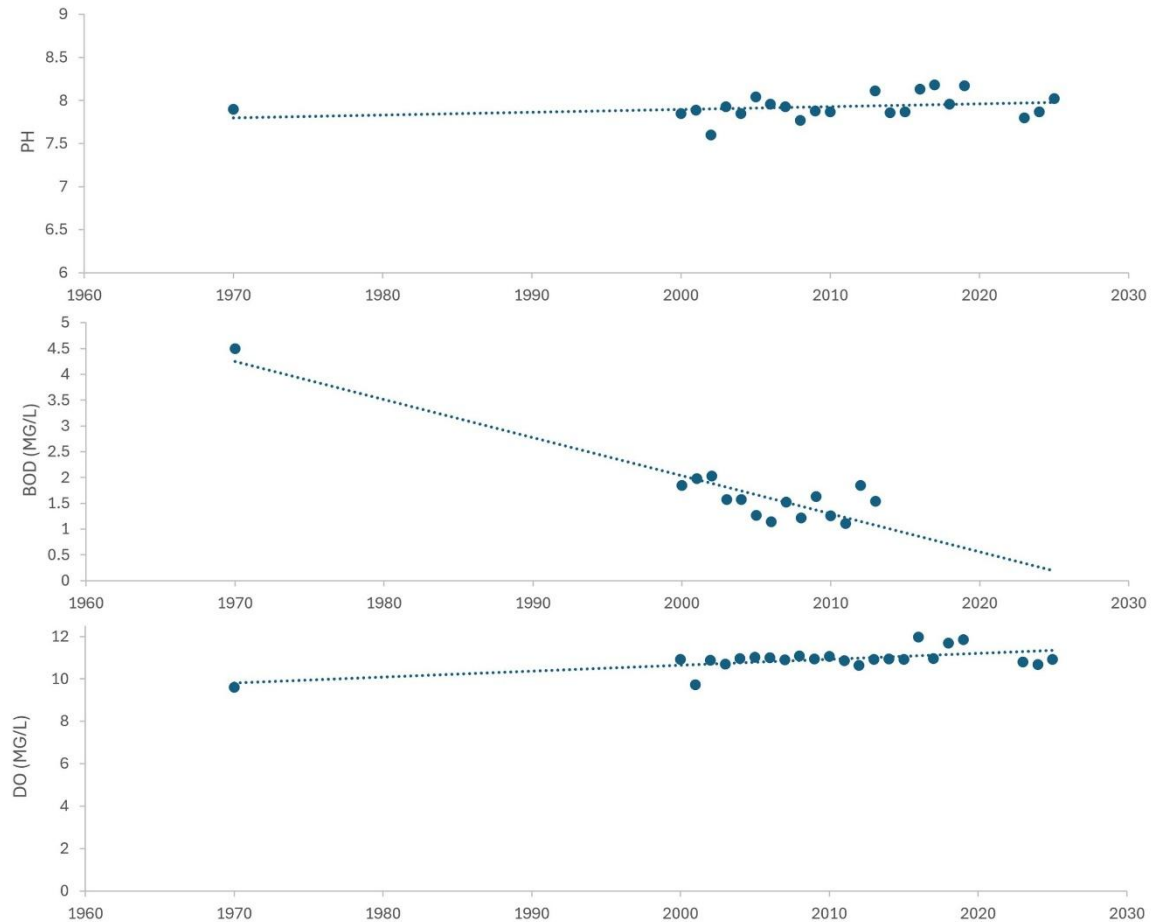


Figure 20 Chemical data including pH BOD and DO found at the Abercynon site sourced from the 1970 study and NRW

5. Discussion

5.1. Lower sections of the Afon Cynon

5.1.1. Quality and abundance of present families

Although there are some limitations with the 1970s data including a potential for error in the family abundance due to differing sampling methods, there is still some limited uses of abundance from this study. Using abundance levels and scores, general trends can still be assigned. For example, while specific abundances levels and scores may not be exactly accurate, excessively high levels of abundance of individual families or groups can be assumed that there were a relatively high number of individuals present in comparison with other species from the same sample such as Oligochaeta. The identification of families and whether their present or absent from the site allow for the analysis of trends of when these absent high scoring families returned to the sites.

A number of high scoring groups such as Ephemeroptera, Plecoptera and Trichoptera (EPT) returned to the sites between 1970 and 1990. It has been well documented in literature that the return of pollution sensitive groups such as EPT are consistent with ecological recovery (England et al., 2021). Based on the diversity of EPT families identified, both sites saw reduced level of Ephemeroptera in the 1970s and almost no Plecoptera and Trichoptera aside from a single scoring family in Abercynon. During the first sampling conducted in 1990, levels of ETP rose significantly (Table 7). Similar results were found by J.G Smith (2003) in which a stream effected by fly ash discharge, a byproduct of coal power production, saw a complete extirpation of Plecoptera and Trichoptera and a reduced level of Ephemeroptera. The stream in this study also saw recovery of these groups after the fly ash discharges ceased. This case study shares many parallels with the Afon Cynon including the pollution type and EPT return pattern.

Table 7 Average Ephemeroptera, Plecoptera and Trichoptera family abundances in Cwmpennar and Abercynon in 1970 and 1990 (Appendix C/D)

	Cwmpennar		Abercynon	
	1970	1990	1970	1990
Ephemeroptera	2	5	2	5
Plecoptera	0	4	0	3
Trichoptera	0	6	1	7

As discussed in the literature review, Oligochaeta are resilient and can thrive in areas affected by heavy pollution as these species are adapted to low oxygen environments (Glasby, Erséus and Martin, 2021). In the cases of heavy pollution where DO levels are low, these organisms can easily become the dominant species which was seen in the Cwmpennar and Abercynon sites during the 1970s sampling. However, as pollution reduces and the DO levels rise, Oligochaeta will often see a decline as other species recolonise the area (Golubkov, Balushkina and Golubkov, 2020). This was also apparent in Cwmpennar and Abercynon as during the periods of heavy pollution, Oligochaeta was dominant with thousands of individuals present which later decreased as water quality improved and other species returned to the sites. Further supporting the idea of a transition from a polluted, low-quality environment to a recovering stream.

Based on the WHPT ASPT scores for each year between 1990 and 2025 (Figure 13 and 17), there is a continuous rise in the number and variety of high scoring taxa present in the lower Afon Cynon. Cwmpennar reached its highest average ASPT score in 2013 with a score of 5.8. It then saw decline in the following years with its most recent score being 5.58. With the PIVPACS prediction model being 6.44, the Cwmpennar site fell just short of the predicted model. Abercynon saw a trend of more continual improvement with a final ASPT score of 6.33 which when compared with the RIVPACS prediction being 6.77, shows it came closest to achieving this score in 2025,

5.1.2. Family and group diversity

Based on trends for the WHPT NTAXA scores for Cwmpennar and Abercynon (Figure 13 and 17), the diversity of scoring families saw a large increase with the scores almost doubling between 1970 and 1990 from 10 to 18. The idea that diversity at the family level increases in the period after water pollution is common in the literature (Vaughan and Ormerod, 2012).

The lower sections of the Afon Cynon have seen a recolonisation of species between the year 1970 and 1990. The speed at which species can return to an area is highly dependent on local conditions around the river (Langford and Shaw, 2009). One of the key factors that may have led to its quick recolonisation of extirpated species is the fact that the upper sections of the river remained relatively unaffected by the industrial pollution of the river. A similar study conducted on 3 rivers in England discussed how despite greatly improving water quality, recolonisation of extirpated species remained slow for 2 of these rivers, taking up to 4 decades for these rivers to regain lost species while the other river recovered within a few years. Similar to the Afon Cynon, this river had a

largely unpolluted upper section, allowing a much faster colonisation rate. This could indicate the reason for the Afon Cynon rapid recovery of its lower sections. Based on the results in Cwmpennar and Abercynon, the recolonisation of many of the families took place at some point between 1970 and 1990 meaning that the return of many of these families took place over a maximum period of 20 years. This in itself can be seen as a quick recovery when compared to sites described by Langford and Shaw (2009) but it may have recovered prior to the 1990s. It's impossible to narrow down the exact time of when these families returned to the sites. It could potentially have been a gradual return starting prior to 1970 but without more data, it is impossible to conclude definitively.

After 1990, the levels of family diversity continued to increase overall up until the most recent samples collected by SEWRT in 2025. The Cwmpennar site has a predicted NTAXA score of 28.26. Of the lower Afon Cynon, this site came closest to achieving the RIVPACS predicted number of scoring families in 2007 with an of NTAXA of 27.5/28.26. Cwmpennar then saw a decline in the following years with the most recent sampling achieving a score of 22/28.26. The NTAXA scores for this site varied throughout the time period with a rise in species throughout the 2000s followed by a decline in the 2010s.

At the Abercynon site, the latest sample in 2025 was the closest to achieving its predicted score with an NTAXA score of 25.5/27.31. This site followed a similar trend to Cwmpennar with a rise in the diversity of scoring taxa throughout the 2000s followed by a decrease in the 2010s. Chemical results for both sites may indicate a potential reason for this decline in family diversity.

5.1.3. Chemical results

During the early 2010s there was a decrease in the family diversity, there was a slight decrease in levels of DO and an increase in BOD at both sites (Figure 16 and 20). While these were not dramatic changes in the average DO levels, even a slight change can have an effect on sensitive species and overall family diversity (Croijmans, de Jong and Prins, 2020). DO scores shown in the chemical data graphs are an average of each year with some DO scores dropping considerably lower for single samples. In June 2010, DO levels in Cwmpennar were measured as low as 7.65 which was followed by a low NTAXA score. Changes in DO oxygen effecting macroinvertebrate diversity levels is well documented in literature (Galic, Hawkins and Forbes, 2019). This could indicate a potential period of pollution, possibly of organic nature as the levels of BOD in Abercynon were elevated.

Based on the long-term trends in the chemical results, it is clear that the water quality has greatly improved between 1970 and the 2000s with a sharp drop in BOD levels at both the Cwmpennar and Abercynon sites. It was discussed in the 1971 study that there were plans to redirect all sewage and industrial effluents to a waste treatment plant near Pontypridd. When comparing the location of the sample sites alongside known sewage effluent release points highlighted in the 1971 study (Figure 21), the poor water quality and reduced macroinvertebrate communities at the lower catchment sites coincide with these locations. The absence of consistent sewage effluent and industrial waste could be one of the reasons for the decrease in BOD alongside the increase in macroinvertebrate populations within the Afon Cynon but without chemical data between the 1970 study and the 2000s, it's hard to know exactly when the water quality saw a recovery.

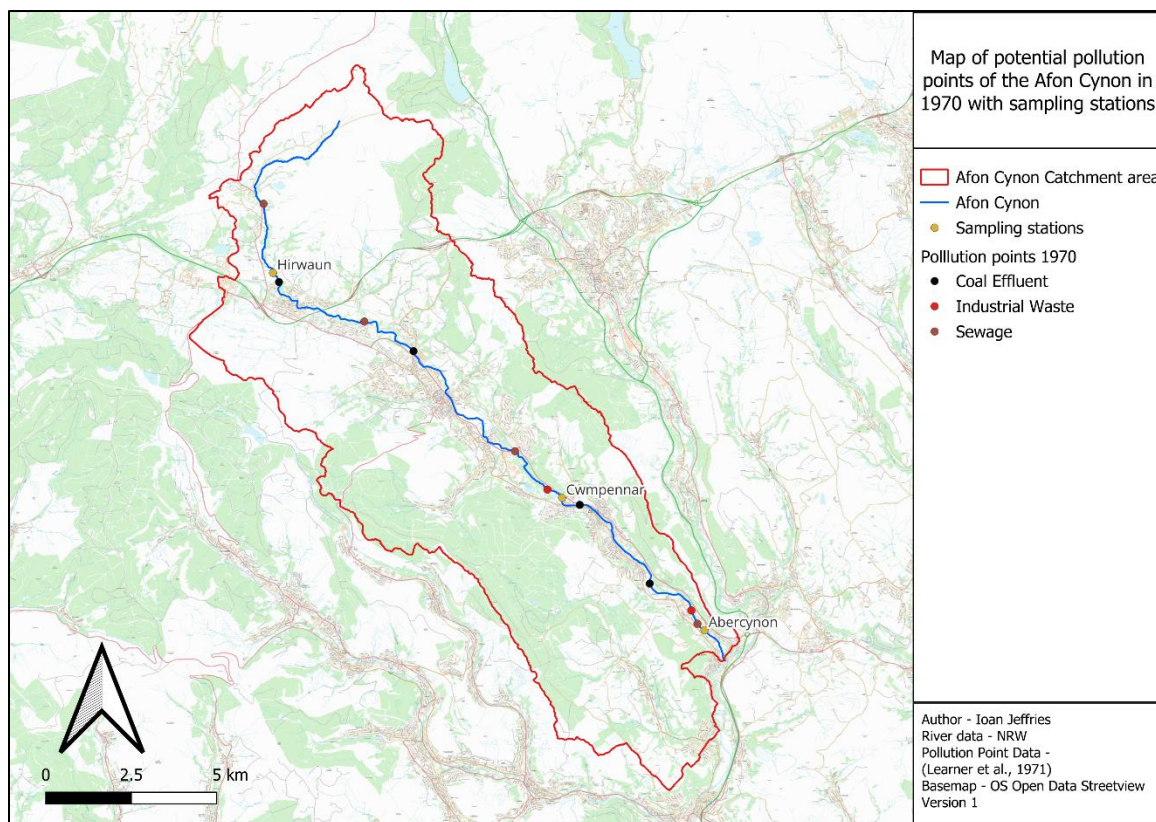


Figure 21 Map of sampling stations along with potential pollution points in 1970 identified by Learner et al (1971)

5.2. Upper sections of the Afon Cynon

While the lower sections of the Afon Cynon show a trend of ecological recovery, the upper sections show a different trend. Metrics such as BOD have had a gradual increase while ASPT and DO have shown signs of decline. While it's not been a drastic decline, in certain metrics there has been a noticeable and steady decline in both chemical and sensitive invertebrate communities.

5.2.1. Chemical Data

It is important that upper sections of a river are to a clean standard as this will have a drastic effect on water quality downstream. Any pollutants that are present in the upper areas of a river will be carried downstream and will affect the waterbody as a whole (Alexander et al., 2007).

As previously discussed in the literature review, BOD is used to measure organic matter such as sewage within a water body. The BOD measures the amount of oxygen required by microorganisms to decompose the organic matter within the water body. This means that as the water gets further downstream to the lower catchments, bacteria will use up more oxygen within the water, overall decreasing the amount of DO available (Pan, 2026). This is made worse when effluent is released upstream such as in the case of the Afon Cynon as the low DO levels caused by the aerobic bacteria breaking down the organic matter will have an effect on lower sections of the river before it reaches the mouth and enters the sea (Vigiak et al., 2019).

The high BOD score indicates an increase in organic pollution which potentially indicates sewage from storm overflow points. There are several of these located along the length of the river including above the Hirwaun site (DWR Cymru, 2025). Historical release data does not go back as far as 2014 and so is hard to determine the exact source of this pollution, but it is more than likely from one of these sources.

5.2.2. Taxa diversity and abundance

Even discounting the ASPT score for the 1970s results which as previously mentioned might not be completely accurate, there was still a noticeable overall decline in high scoring families present at the Hirwaun site (DWR Cymru, 2025). Unfortunatley, no NRW invertebrate sampling was conducted throughout the 2010s and so the effects of this high BOD had on the diversity and abundance of macroinvertebrates cannot be analysed between 2008 and 2021. This does

demonstrate the need for frequent and continuous monitoring of river systems in order to monitor effects of potential pollution events.

6. Conclusions and Recommendations

Based on the findings in this study, the Afon Cynon has undergone a substantial ecological and environmental recovery over the past 60 years. The aims of this study were to use previously published data and compare this with more current data sets to confirm and assess the rate at which the Afon Cynon has recovered using macroinvertebrate communities as the indicator. Overall, the results indicate that macroinvertebrates are an effective method of determining the rate of recovery in the Afon Cynon.

Recovery was most apparent within the lower catchments of the river at Cwmpennar and Abercynon which was most heavily affected by the heavy pollution of the 20th century. The 1970s data indicated a minimal presence of pollution sensitive taxa such as Ephemeroptera, Plecoptera and Trichoptera at these lower catchment sites. By the 1990s and beyond these families had recolonised the area both in abundance and diversity which increased the WHPT ASPT and NTAXA scores. A potential reason for this fast recovery time is the relatively unaffected upper sections of the river which allowed for a faster recolonisation rate than if the whole river was affected, which otherwise may have taken decades to fully recover.

Species such as Oligochaeta which are indicators of poor water quality when they are the dominant species showed a considerable decline since the 1970 sampling and continued to decline up until the most recent sampling, indicating that other more pollution sensitive species were able to return to the site, reducing Oligochaeta abundance.

Fluctuations in DO levels may have caused a decline in the number of scoring families present throughout the 2010s at both Cwmpennar and Abercynon. This shows the importance of consistent and continual monitoring to assess any potential degradation in water quality.

The baseline set out by the RIVPACS prediction models for ASPT and NTAXA show that Cwmpennar and especially Abercynon have almost completely recovered from this historic pollution with recent sampling indicating that the scores are just falling short of achieving the targets. However, with some reductions in ASPT rates in Cwmpennar in the 2020s, monitoring is important to ensure the pollution sensitive species don't reduce any further.

The relatively unaffected site of Hirwaun showed signs of degradation in a few metrics such as an increasing BOD as well as a slowly decreasing DO and diversity of high scoring macroinvertebrate families. Due to the elevated BOD at the site, it is more than likely the result of organic pollution

entering the river. This may indicate decreasing quality which must be monitored to prevent further degradation and potentially degrading areas downstream. Further research should be undertaken to identify potential pollution sources and the reason for this degradation.

The difference in sampling methods between the 1970s study and more recent sampling methods should be acknowledged as this does affect the abundance of species reported. While efforts were taken to correct these alternative sampling metrics, there are still uncertainties when calculating abundance scores such as the ASPT. The lack of data between 1970 and 1990 as well as the lack of chemical data prior to the 2000s means that identifying the exact time periods of improvements became impossible. The best that could be estimated was that the improvements occurred prior to 1990 and continued to improve beyond into the 2020s. More recent gaps in sampling also meant that certain important time periods such as the 2010s, especially in the Hirwaun site were missed. More consistent monitoring could have filled in this missing data which could have been used to assess trends.

Further research should focus on the continued monitoring of the river with consistent and standardised sampling procedures. Work being done by the South East Wales Rivers Trust to monitor the Afon Cynon and neighbouring catchments is incredibly important in assessing whether these trends are fluctuations in water quality or if there is a larger deterioration in progress.

7. References

- Abubakr, A., Gojar, A.A., Balkhi, M.H. and Malik, R. (2017). Macro-Invertebrates (Annelida; Oligochaeta) As Bio-Indicator of Water Quality under Temperate Climatic Conditions. *International Journal of Pure and Applied Science*, [online] 6(1). doi:<http://dx.doi.org/10.18782/2320-7051.5903>.
- Alexander, R.B., Boyer, E.W., Smith, R.A., Schwarz, G.E. and Moore, R.B. (2007). The Role of Headwater Streams in Downstream Water Quality1. *JAWRA Journal of the American Water Resources Association*, [online] 43(1), pp.41–59. doi:<https://doi.org/10.1111/j.1752-1688.2007.00005.x>.
- Alison, I. (1985). The Evolution of an Industrial Site: The Llwydcoed Brickworks. In: *Environmental Studies in the Cynon Valley*. pp.132–142.
- Andersen, M.M., Rigét, F.F. and Sparholt, H. (2003). A modification of the Trent Index for use in Denmark. *Water Research*, [online] 18(2), pp.145–151. doi:[https://doi.org/10.1016/0043-1354\(84\)90062-9](https://doi.org/10.1016/0043-1354(84)90062-9).
- Bartram, J., Ballance, R., United Nations Environment Programme and World Health Organization (1996). *Water quality monitoring : a practical guide to the design and implementation of freshwater quality studies and monitoring programmes*. London ; New York: E & Fn Spon.
- Bonada, N., Prat, N., Resh, V.H. and Statzner, B. (2006). DEVELOPMENTS IN AQUATIC INSECT BIOMONITORING: A Comparative Analysis of Recent Approaches. *Annual Review of Entomology*, [online] 51(1), pp.495–523. doi:<https://doi.org/10.1146/annurev.ento.51.110104.151124>.
- Carpenter, K.E. (1926). THE LEAD MINE AS AN ACTIVE AGENT IN RIVER POLLUTION. *Annals of Applied Biology*, [online] 13(3), pp.395–401. doi:<https://doi.org/10.1111/j.1744-7348.1926.tb04285.x>.
- Cereghetti, E. (2024). *Stream Ecosystems and Terrestrial Resources: a Temporal Perspective on Detritus Cycling and Keystone Shredders*. [online] Available at: <https://www.zora.uzh.ch/entities/publication/73ef7816-1681-42a4-b2c2-0324b079c0c3> [Accessed 11 Nov. 2025].

Clarke, R.T., Wright, J.F. and Furse, M.T. (2003). RIVPACS models for predicting the expected macroinvertebrate fauna and assessing the ecological quality of rivers. *Ecological Modelling*, 160(3), pp.219–233. doi:[https://doi.org/10.1016/s0304-3800\(02\)00255-7](https://doi.org/10.1016/s0304-3800(02)00255-7).

Clements, W.H. (1994). Benthic Invertebrate Community Responses to Heavy Metals in the Upper Arkansas River Basin, Colorado. *Journal of the North American Benthological Society*, [online] 13(1), pp.30–44. doi:<https://doi.org/10.2307/1467263>.

Croijmans, L., de Jong, J.F. and Prins, H.H.T. (2020). Oxygen is a better predictor of macroinvertebrate richness than temperature – a systematic review. *Environmental Research Letters*, [online] 16(2). doi:<https://doi.org/10.1088/1748-9326/ab9b42>.

Cummins, K.W. (2021). The Use of Macroinvertebrate Functional Feeding Group Analysis to Evaluate, Monitor and Restore Stream Ecosystem Condition. *Reports on Global Health Research*. [online] doi:<https://doi.org/10.29011/2690-9480.100129>.

CVHS (2013). *Cynon Valley History Society: a history society for Aberdare and district*. [online] Cynon Valley Historic Society. Available at: <https://www.cvhs.org.uk/timeline/chron.html>.

Dalu, T., Masese, F., Iteba, J. and Wanderi, E. (2024). *Afrotropical Streams and Rivers*. [online] Elsevier. Available at: <https://www.sciencedirect.com/science/chapter/edited-volume/abs/pii/B9780443238987000270>.

Dobson, M., Pawley, S., Fletcher, M. and Powell, A. (2012). *Guide to freshwater invertebrates*. Ambleside: Freshwater Biological Association.

Dodds, W.K. and Whiles, M.R. (2020). *Freshwater ecology : concepts and environmental applications of limnology*. London ; San Diego, Ca: Academic Press Is An Imprint Of Elsevier.

Earle, S. (2019). *13.3 Stream Erosion and Deposition*. [online] Opentextbc.ca. Available at: <https://opentextbc.ca/physicalgeology2ed/chapter/13-3-stream-erosion-and-deposition/> [Accessed 11 Nov. 2025].

England, J., Hayes, C., White, J. and Johns, T. (2021). Evidence of Taxonomic and Functional Recovery of Macroinvertebrate Communities Following River Restoration. *Water*, 13(16), p.2239. doi:<https://doi.org/10.3390/w13162239>.

Environmental Audit Committee (2022). *Water Quality in Rivers - Environmental Audit Committee*. [online] Parliament.uk. Available at: <https://publications.parliament.uk/pa/cm5802/cmselect/cmenvaud/74/report.html>.

Eriksen, T.E., Jacobsen, D., Demars, B.O.L., Brittain, J.E., Søli, G. and Friberg, N. (2022). Effects of pollution-induced changes in oxygen conditions scaling up from individuals to ecosystems in a tropical river network. *Science of The Total Environment*, [online] 814, p.151958. doi:<https://doi.org/10.1016/j.scitotenv.2021.151958>.

Evans, T., Messenger, M., Rowson, S., Wakelin, P. and Williams, R. (2003). <https://industrial-archaeology.org/wp-content/uploads/2017/05/2003-Industrial-Archaeology-of-South-East-Wales.pdf>. [online] Association for Industrial Archaeology. Available at: <https://industrial-archaeology.org/wp-content/uploads/2017/05/2003-Industrial-Archaeology-of-South-East-Wales.pdf>.

FBA (2025). *RICT User Guide*. [online] Github.io. Available at: <https://aquametrics.github.io/RICT/articles/user-guide.html>.

Fornaroli, R., Ippolito, A., Tolkkinen, M.J., Mykrä, H., Muotka, T., Balistrieri, L.S. and Schmidt, T.S. (2018). Disentangling the effects of low pH and metal mixture toxicity on macroinvertebrate diversity. *Environmental Pollution*, [online] 235, pp.889–898. doi:<https://doi.org/10.1016/j.envpol.2017.12.097>.

Galic, N., Hawkins, T. and Forbes, V.E. (2019). Adverse impacts of hypoxia on aquatic invertebrates: A meta-analysis. *Science of The Total Environment*, [online] 652, pp.736–743. doi:<https://doi.org/10.1016/j.scitotenv.2018.10.225>.

Gholizadeh, M. and Heydarzadeh, M. (2017). *Functional feeding groups of macroinvertebrates and their relationship with environmental parameters , case study: in Zarin -Gol River*. [online] Available at: https://jifro.ir/browse.php?a_id=2858&sid=1&slc_lang=en&ftxt=1.

Glasby, C.J., Erséus, C. and Martin, P. (2021). Annelids in Extreme Aquatic Environments: Diversity, Adaptations and Evolution. *Diversity*, [online] 13(2), p.98. doi:<https://doi.org/10.3390/d13020098>.

Gmeiner, I., Vitecek, S., Wassenaar, L.I., Kainz, M.J. and Pilecky, M. (2025). Selective Retention of Long-Chain Polyunsaturated Fatty Acids in Heptageniidae (Ephemeroptera) of Subalpine Streams. *Freshwater Biology*, [online] 70(6). doi:<https://doi.org/10.1111/fwb.70052>.

Golubkov, S.M., Balushkina, E.V. and Golubkov, M.S. (2020). Restoration of Zoobenthic Communities and Water Quality in the River Ecosystem after a Decrease in the Level of Organic Pollution. *Contemporary Problems of Ecology*, 13(2), pp.146–155. doi:<https://doi.org/10.1134/s1995425520020031>.

Gore, J.A. (2006). Methods in stream ecology. In: *Methods In Stream Ecology*. Amsterdam ; Boston: Academic Press/Elsevier.

Gray, N.F. (2017). *Water science and technology : an introduction*. Boca Raton, Fl: Crc Press.

Green, S. and Everall, N. (2023). *We need to be cautious with family-level assessments of freshwater invertebrate biodiversity* | *Wildfish*. [online] Wildfish. Available at: <https://wildfish.org/latest-news/we-need-to-be-cautious-with-family-level-assessments-of-freshwater-invertebrate-biodiversity/>.

Harrison, R.M. (2001). *Pollution : causes, effects and control*. Cambridge, England: Royal Society Of Chemistry.

Hauer, R. and Resh, V. (2006). Macroinvertebrates. In: R. Hauer and G. Lamberti, eds., *Methods in Stream Ecology*. Elsevier.

Hawkes, A.H. (1998). Origin and development of the biological monitoring working party score system. *Water Research*, [online] 32(3), pp.964–968. doi:[https://doi.org/10.1016/s0043-1354\(97\)00275-3](https://doi.org/10.1016/s0043-1354(97)00275-3).

Hoover, T.M. and Ackerman, J.D. (2011). Microdistribution of a torrential stream invertebrate: Are bottom-up, top-down, or hydrodynamic controls most important? *Limnology and oceanography, fluids and environments*, [online] 1(1), pp.147–162. doi:<https://doi.org/10.1215/21573698-1498042>.

Humphrys, G. (1972). *Industrial Britain - South Wales*. David and Charles.

Hutchings, A.M., Vries, C., Hayes, N.R. and Orr, H.G. (2024). Temperature and dissolved oxygen trends in English estuaries over the past 30 years. *Estuarine Coastal and Shelf Science*, [online] 306, pp.108892–108892. doi:<https://doi.org/10.1016/j.ecss.2024.108892>.

Ince, L. (1993). *The South Wales Iron Industry, 1750-1885*. Ferric, pp.33–46.

Johnston, R.K. and Wiederholm, T. (1993). *Freshwater Biomonitoring Using Individual Organisms, Populations, and Species Assemblages of Benthic Macroinvertebrates I*. [online] Available at: https://www.researchgate.net/profile/Richard-Johnson-17/publication/312777214_Freshwater_biomonitoring_using_individual_organisms_populations_and_species_assemblages_of_benthic_macroinvertebrates/links/588f049392851cef1363be5f/Freshwater-biomonitoring-using-individual-organisms-populations-and-species-assemblages-of-benthic-macroinvertebrates.pdf.

Kellner, E. and Hubbart, J. (2017). Advancing Understanding of the Surface Water Quality Regime of Contemporary Mixed-Land-Use Watersheds: An Application of the Experimental Watershed Method. *Hydrology*, [online] 4(2), p.31. doi:<https://doi.org/10.3390/hydrology4020031>.

Kral, F., Robertson, O., Fry, M. and Laize, C. (2017). *RICT Database and Delivery System River Invertebrate Classification Tool Database and Delivery System River Invertebrate Classification Tool Database and Delivery System*. [online] UKCEH. Available at: <https://nora.nerc.ac.uk/id/eprint/517305/7/N517305CR.pdf>.

Kumar, A., Anand, K. and Iqbal, A. (2015). *Characteristics and impact of different industrial effluents from coal mines with a biotechnological approach of using green algae for waste water treatment-an appraisal*. [online] Available at: https://www.researchgate.net/publication/314104382_Characteristics_and_impact_of_different_industrial_effluents_from_coal_mines_with_a_biotechnological_approach_of_using_green_algae_for_waste_water_treatment-an_appraisal_Kumar_Anand_MdIqbal_Ansari_MdI [Accessed 21 Oct. 2025].

Langford, T. and Shaw, P. (2009). *Long-term ecological recovery in a river polluted to its sources: the River Tame in the English midlands*.

Lawrence, R. (2012). *The Coal Mines of South Wales*. Bradwell Books.

- Learner, M.A., Williams, R., Harcup, H. and Hughes, B.D. (1971). *A survey of the macro-fauna of the River Cynon, a polluted tributary of the River Taff (South Wales)*.
- Lester, C., Smith, K., Temple, M., Taf, B. and Authority, H. (2003). *Health Impact Assessment of Land Remediation Options: Site of the former Phurnacite Factory at Abercwmboi I*. [online] National Public Health Services for Wales. Available at: <https://phwwhocc.co.uk/whiasu/wp-content/uploads/sites/3/2021/05/abercwmboiremediation.pdf>.
- Liu, M., Han, G., Li, X., Zhang, S., Zhou, W. and Zhang, Q. (2020). Effects of Soil Properties on K Factor in the Granite and Limestone Regions of China. *International Journal of Environmental Research and Public Health*, [online] 17(3), p.801. doi:<https://doi.org/10.3390/ijerph17030801>.
- Longstaffe, O., Apanasonok, A., Bates, P., Rippon, L., Sarremejane, S. and Stubbington, R. (2024). *Kick sampling aquatic macroinvertebrate communities in small streams: is 3 minutes too long, too short, or just right?* [online] Freshwater Biological Association. Available at: <https://www.fba.org.uk/articles/kick-sampling-aquatic-macroinvertebrate-communities-in-small-streams-is-3-minutes-too-long-too-short-or-just-right>.
- Magallón Ortega, G., Escalera Gallardo, C., López-López, E., Sedeño-Díaz, J.E., López Hernández, M., Arroyo-Damián, M. and Moncayo-Estrada, R. (2021). Water Quality Analysis in a Subtropical River with an Adapted Biomonitoring Working Party (BMWP) Index. *Diversity*, [online] 13(11), p.606. doi:<https://doi.org/10.3390/d13110606>.
- Malison, R.L., DelVecchia, A.G., Woods, H.A., Hand, B.K., Luikart, G. and Stanford, J.A. (2020). Tolerance of aquifer stoneflies to repeated hypoxia exposure and oxygen dynamics in an alluvial aquifer. *Journal of Experimental Biology*. [online] doi:<https://doi.org/10.1242/jeb.225623>.
- Mear, J.F. (2001). *Cynon Coal*. Cynon Valley Historic Society.
- Merritt, R.W. and Cummins, K.W. (2006). Trophic Relationships of Macroinvertebrates. In: R. Hauer and G. Lamberti, eds., *Methods In Stream Ecology*. Elsevier.
- Metcalf, J.L. (1989). Biological water quality assessment of running waters based on macroinvertebrate communities: History and present status in Europe. *Environmental Pollution*, [online] 60(1-2), pp.101–139. doi:[https://doi.org/10.1016/0269-7491\(89\)90223-6](https://doi.org/10.1016/0269-7491(89)90223-6).

NRW (2015). *South East Valleys Management Catchment Summary*. [online] Available at: https://cdn.cyfoethnaturiol.cymru/679387/2016_updated-south-east_valleys_catchment_summary_nrw.pdf.

NRW (2024). *River Macroinvertebrates Site Details | DataMapWales*. [online] Gov.wales. Available at: https://datamap.gov.wales/layers/geonode:nrw_river_macroinvert_site_detail.

NRW (2025). *NRW Freshwater River Macroinvertebrates | DataMapWales*. [online] Gov.wales. Available at: https://datamap.gov.wales/layergroups/geonode:nrw_river_macroinvertebrates.

NRW (2026). *Water Framework Directive (WFD) Regulations Cycle 3 Classification*. [online] Datamap Wales. Available at: https://datamap.gov.wales/maps/new?layergroup=geonode:nrw_wfd_cycle_3_classifications#/.

O'keeffe, I. (2021). *The River Cynon: a SmartRivers Case Study*. [online] Wildfish. Available at: <https://wildfish.org/latest-news/river-cynon-case-study/>.

Paisley, M.F., Trigg, D.J. and Walley, W.J. (2014). Revision of the Biological Monitoring Working Party (BMWP) Score system: Derivation of present-only and abundance-related Scores from Field Data. *River Research and Applications*, [online] 30(7), pp.887–904. doi:<https://doi.org/10.1002/rra.2686>.

Pan, S. (2026). *BOD Test (Biological Oxygen Demand) - Principle, Procedure, Calculation - Biology Notes Online*. [online] Biology Notes Online. Available at: <https://biologynotesonline.com/biological-oxygen-demand-test/>.

Pawley, S., Dobson, M. and Fletcher, M. (2011). *Guide to British freshwater macroinvertebrates for biotic assessment*. Far Sawrey, Ambleside: Freshwater Biological Association.

Prommi, T.O., Seetapan, K. and Vitheepradit, A. (2025). Diversity of caddisflies (Trichoptera), water quality factors, and microplastics in a northern Thai stream. *Ecologica Montenegrina*, [online] 89, pp.140–160. doi:<https://doi.org/10.37828/em.2025.89.8>.

RICT Steering Group (2025). *River Invertebrate Classification Tool (RICT) Functional Specification*. [online] Github.io. Available at: <https://aquametrics.github.io/RICT/articles/functional-specification.html#acceptance-and-validation-of-input-data>.

- Roberts, D.E. (2026). *Cynon Valley History Society: 600 Million Years of Cynon Valley Geological History*. [online] Cvhs.org.uk. Available at: <https://cvhs.org.uk/DERoberts/contents.html> [Accessed 4 Jun. 2026].
- Royal Commission on Sewage Disposal (1915). *Treating and Disposal of Sewage*. [online] Internet Archive. Available at: <https://archive.org/details/cu31924003641929/page/n19/mode/2up>.
- SIM (2021). *Slums and suburbs: Water and Sanitation in the First Industrial City*. [online] Science and Industry Museum. Available at: <https://www.scienceandindustrymuseum.org.uk/objects-and-stories/water-and-sanitation>.
- Smith, J.G. (2003). Recovery of the Benthic Macroinvertebrate Community in a Small Stream After Long-Term Discharges of Fly Ash. *Environmental Management*, [online] 32(1), pp.77–92. doi:<https://doi.org/10.1007/s00267-003-2962-1>.
- Stanford, J.A. (2006). Landscapes and Riverscapes. In: *Methods In Stream Ecology*. Amsterdam ; Boston: Academic Press/Elsevier.
- Strangeways, I. (2007). *Measuring the natural environment*. Cambridge, U.K. ; New York: Cambridge University Press, Lavergne, Tn, . 15 July.
- Szałkiewicz, E., Kałuża, T. and Grygoruk, M. (2022). Detailed analysis of habitat suitability curves for macroinvertebrates and functional feeding groups. *Scientific Reports*, 12(1). doi:<https://doi.org/10.1038/s41598-022-15096-8>.
- Thorp, J.H. and Covich, A.P. (2008). *Ecology and classification of North American freshwater invertebrates*. San Diego Etc.: Academic Press, pp.661–731.
- Timm, H. and Haldna, M. (2019). Do abundance and percentage of dipteran larvae and Oligochaeta indicate low water quality in streams and lake littoral? *Oceanological and Hydrobiological Studies*, [online] 48(4), pp.415–429. Available at: <https://czasopisma.bg.ug.edu.pl/index.php/oandhs/article/view/7975> [Accessed 11 Nov. 2025].
- UK Government (2017). *The Water Environment (Water Framework Directive) (England and Wales) Regulations 2017*. [online] Legislation.gov.uk. Available at: <https://www.legislation.gov.uk/uksi/2017/407/contents>.

- Vaughan, I.P. and Ormerod, S.J. (2012). Large-scale, long-term trends in British river macroinvertebrates. *Global Change Biology*, [online] 18(7), pp.2184–2194. doi:<https://doi.org/10.1111/j.1365-2486.2012.02662.x>.
- Veach, A.M., Troia, M.J., Jumpponen, A. and Dodds, W.K. (2018). Top–down effects of a grazing, omnivorous minnow (*Campostoma anomalum*) on stream microbial communities. *Freshwater Science*, [online] 37(1), pp.121–133. doi:<https://doi.org/10.1086/696292>.
- Vigiak, O., Grizzetti, B., Udias-Moinelo, A., Zanni, M., Dorati, C., Bouraoui, F. and Pistocchi, A. (2019). Predicting biochemical oxygen demand in European freshwater bodies. *Science of The Total Environment*, [online] 666, pp.1089–1105. doi:<https://doi.org/10.1016/j.scitotenv.2019.02.252>.
- Vilenica, M., Kerovec, M., Pozojević, I. and Mihaljević, Z. (2020). Mayfly response to different stress types in small and mid-sized lowland rivers. *ZooKeys*, [online] 980, pp.57–77. doi:<https://doi.org/10.3897/zookeys.980.54805>.
- Water on the Web (2017). *Water on the Web | Understanding | Water Quality | Parameters*. [online] Waterontheweb.org. Available at: <https://www.waterontheweb.org/under/waterquality/oxygen.html>.
- Welsh Government (2024). *LiDAR Data download | DataMapWales*. [online] Gov.wales. Available at: <https://datamap.gov.wales/maps/lidar-data-download/>.
- WFD UKTAG (2023). *UKTAG River Assessment Method Benthic Invertebrate Fauna Invertebrates (General Degradation): Walley, Hawkes, Paisley & Trigg (WHPT) metric in River Invertebrate Classification Tool (RICT)*. [online] Water Framework Directive – United Kingdom Advisory Group. Available at: <https://wfd.uk.org/sites/default/files/River%20Invertebrates%20WHPT%20UKTAG%20Method%20Statement%20-%20updated%20July%202023.pdf>.
- Whelan, M.J., Linstead, C., Worrall, F., Ormerod, S.J., Durance, I., Johnson, A.C., Johnson, D., Owen, M., Wiik, E., Howden, N.J.K., Burt, T.P., Boxall, A., Brown, C.D., Oliver, D.M. and Tickner, D. (2022). Is Water Quality in British Rivers ‘better than at Any Time since the End of the Industrial Revolution’?. *Science of The Total Environment*, [online] 843(157014), p.157014. doi:<https://doi.org/10.1016/j.scitotenv.2022.157014>.

Wolkersdorfer, C. (2022). *Mine Water Treatment – Active and Passive Methods*. Springer.

Woodiwiss, F.S., 1960. Trent Biotic Index Pollution. *2nd. Quinquennial Abstracts of Statistics Relating to the Trent Watershed*.

Appendix A: WHPT scoring index (FBA, 2025)

Taxon	WHPT for abundance category 1 (1-9)	WHPT for abundance category 2 (10-99)	WHPT for abundance category 3 (100-999)	WHPT for abundance category 4+ (1000 +)
Triclada (flatworms)				
Planariidae	4.7	5.4	5.4	5.4
Dugesidae	2.8	3.1	3.1	3.1
Dendrocoelidae	3.0	2.6	2.6	2.6
Mollusca (snails, limpets and mussels)				
Neritidae	6.4	6.5	6.9	6.9
Viviparidae	5.2	6.7	6.7	6.7
Valvatidae	3.3	3.1	2.7	2.7
Hydrobiidae	4.1	4.2	4.6	3.7
Bithyniidae	3.6	3.8	3.3	3.3
Physidae	2.7	2.0 ✓	0.4	0.4
Lymnaeidae	3.6	2.5	1.2	1.2
Planorbidae (excl. <i>Ancylus</i> group)	3.2	3.0	2.4	2.4
<i>Ancylus</i> group (= Ancyliidae)	5.8	5.5	5.5	5.5
Acroloxidae	3.6	3.8	3.8	3.8
Unionidae	5.2	6.9	6.9	6.9
Sphaeriidae (Pea mussels)	4.4	3.5	3.4	2.3
Dreissenidae	3.7	3.7	3.7	3.7
Oligochaeta (worms)				
Oligochaeta	3.6	2.3	1.4	-0.6 ✓
Hirudinea (leeches)				
Piscicolidae	5.2	4.9	4.9	4.9
Glossiphoniidae	3.4 ✓	2.5	0.8	0.8
Hirudinidae	-0.8	-0.8	-0.8	-0.8
Erpobdellidae	3.6	2.0 ✓	-0.8	-0.8
Crustacea (crayfish, slaters and shrimps)				
Astacidae (incl. non-native species)	7.9	7.9	7.9	7.9
Asellidae	4.0 ✓	2.3	0.8	-1.6
Corophiidae	5.7	5.8	5.8	5.8
Crangonyctidae	3.8	4.0	3.6	3.6
Gammaridae	4.2	4.5	4.6	3.9
Niphargidae	6.3	6.3	6.3	6.3
Ephemeroptera (mayflies)				
Siphonuridae (incl. Ameletidae)	11.3	12.2	12.2	12.2
Baetidae	3.6	5.9	7.2 ✓	7.5
Heptageniidae (incl. Arthropleiidae)	8.5	10.3	11.1	11.1
Leptophlebiidae	8.8	9.1	9.2	9.2
Potamanthidae	9.8	10.4	10.4	10.4
Ephemeridae	8.3	8.8	9.4	9.4
Ephemerellidae	7.9 ✓	8.5	9.0	9.0
Caenidae	6.5 ✓	6.5	6.5	6.5
Plecoptera (stoneflies)				
Taeniopterygidae	11.0	11.9	12.1	12.1
Nemouridae	8.7	10.7	10.7	10.7
Leuctridae	9.3	10.6	10.6	10.6
Capniidae	9.7	9.4	9.4	9.4
Perlodidae	10.5	11.5	11.5	11.5
Perlidae	12.6	13.0	13.0	13.0
Chloroperlidae	11.4	12.2	12.2	12.2
Odonata Zygoptera (damselflies)				
Platycnemididae	6.0	6.0	6.0	6.0
Coenagrionidae (= Coenagriidae)	3.4	3.8	3.8	3.8
Lestidae				
Calopterygidae (= Agriidae)	5.9	6.2	6.2	6.2
Odonata Anisoptera (dragonflies)				
Cordulegasteridae	9.8	9.8	9.8	9.8
Aeshnidae	4.7	4.7	4.7	4.7
Corduliidae				
Gomphidae				
Libellulidae	4.1	4.1	4.1	4.1

Appendix A: (Continued)

Hemiptera (bugs)				
Mesoveliidae	4.7	4.7	4.7	4.7
Hydrometridae	4.3	4.3	4.3	4.3
Veliidae	4.5	3.9	3.9	3.9
Gerridae	5.2	5.5	5.5	5.5
Nepidae	2.9	2.9	2.9	2.9
Naucoridae	3.7	3.7	3.7	3.7
Aphelocheiridae	8.6	8.5	8.0	8.0
Notonectidae	3.4	3.9	3.9	3.9
Pleidae	3.3	3.3	3.3	3.3
Corixidae	3.7	3.9	3.7	3.7
Coleoptera (beetles)				
Halipidae	3.6	3.4	3.4	3.4
Paelobiidae (= Hygrobiidae)	3.8	3.8	3.8	3.8
Noteridae	3.2	3.2	3.2	3.2
Dytiscidae	4.5	4.8	4.8	4.8
Gyrinidae	8.1	9.0	9.0	9.0
Hydrophilidae (incl. Georissidae, Helophoridae & Hydrochidae)	5.8	8.8	8.8	8.8
Hydraenidae	8.5	10.5	10.5	10.5
Scirtidae (= Helododae)	6.9	6.8	6.8	6.8
Dryopidae	6.0	6.0	6.0	6.0
Elmidae	5.3	7.4	8.3	8.3
Megaloptera (alderflies)				
Sialidae	4.2	4.4	4.4	4.4
Neuroptera Planipennia (lacewings)				
Sisyridae	5.7	5.7	5.7	5.7
Trichoptera (caddisflies)				
Rhyacophiliidae	8.1	9.2 ✓	8.3	8.3
Glossosomatidae	7.8	7.6	7.2	7.2
Hydroptilidae	6.1	6.5	6.8	6.8
Philopotamidae	11.2	11.1	11.1	11.1
Psychomyiidae	5.8	5.7	5.7	5.7
Polycentropodidae	8.2	8.1	8.1	8.1
Hydropsychidae	5.8	7.2	7.4	7.4
Phryganeidae	5.5	5.5	5.5	5.5
Brachycentridae	9.6	9.5	8.9	8.9
Lepidostomatidae	9.9	10.3	10.2	10.2
Limnephilidae (including Apataniidae)	5.9	6.9	6.9	6.9
Goeridae	8.8	8.8	9.4	9.4
Beraeidae	8.8	7.3	7.3	7.3
Sericostomatidae	8.9	9.4	9.5	9.5
Odontoceridae	11.1	10.3	10.3	10.3
Molannidae	6.5	7.6	7.6	7.6
Leptoceridae	6.7	6.9	7.1	7.1
Diptera (true flies)				
Tipulidae (including Cylindrotomidae, Limoniidae & Pedicidae)	5.4	6.9	6.9	7.10
Psychodidae	4.5	3.0	3.0	3.00
Ptychopteridae	6.4	6.4	6.4	6.40
Dixidae	7.0	7.0	7.0	7.00
Chaoboridae	3.0	3.0	3.0	3.00
Cuticidae	2.0	1.9	1.9	1.90
Ceratopogonidae	5.4 ✓	5.5	5.5	5.50
Simuliidae	5.5	6.1	5.8	3.90
Chironomidae	1.2	1.3	-0.9	-0.90 ✓
Stratiomyidae	3.6	3.6	3.6	3.60
Rhagionidae	9.6	9.6	9.6	9.60
Tabanidae	7.1	7.3	7.3	7.30
Athericidae	9.3	9.5	9.5	9.50
Empididae	7.0 ✓	7.6	7.6	7.60
Dolichopodidae	4.9	4.9	4.9	4.90
Syrphidae	1.9	1.9	1.9	1.90
Sciomyzidae	3.4	3.4	3.4	3.40
Ephydriidae	4.4	4.4	4.4	4.40
Muscidae	4.0	2.6	2.6	2.60

Appendix B: NRW Macroinvertebrate data for the Hirwaun site 1990 – 2008

Major group	Taxon	17/04/1990	03/09/1990	11/10/1990	11/04/1991	01/08/1991	23/11/1991	22/04/1992	28/07/1992	21/04/1993	20/08/1993	29/03/1995	01/09/1995	10/10/1995	09/03/2000	22/09/2000	16/04/2002	09/09/2002	04/04/2005	09/09/2005	03/04/2008	06/09/2008		
Trachea (flavornis)	Planariidae	33	3	3	3	3	3	3	3	33	3	3					1	10	1					
	Dugesitidae																							
Mollusca (snails, limpets and mussels)	Hydrulidae	3				3					33	3							1	6	3	20	1	
	Physidae																		1	1			1	
	Lymnaeidae	3	3	33	3	3	3	3	3					33				1	39	4	40		1	
	Panorbidae	3																					1	
Oligochaeta (worms)	Sphaeriidae	3					3																1	
	Oligochaeta	3					3	3			3												1	
Hirudinea (leeches)	Pleurodidae																							
	Glossophoridae																							
Crustacea (cyclops, slaters and shrimps)	Epidictidae									3														
	Asellidae																							
Ephemeroptera (mayflies)	Gammaridae	3	3	33	33	3	3	33	3	33	33	33	3	33	33	33	33	33	33	700	260	400	60	14
	Baetidae	33	3	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
	Heptageniidae	3	3	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
	Leptophlebiidae																							1
	Pteronarcys	3																						1
	Ephemeroptera	3																						1
Plecoptera (stoneflies)	Ephemeroptera	33	3																					1
	Caridae	33				3					33	33	3	3	3	3	3	3	3	3	3	3	3	3
	Tamodryphidae					3						3												4
	Neuroptera	3		33	33		32	33	3	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
	Leuctridae	3	3			33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
	Freudiidae	3		3		3		3																3
	Chironomidae																							1
	Dytiscidae	3	3	3				33	3	33	33	33	3	3	3	3	3	3	3	3	3	3	3	3
Coleoptera (beetles)	Hydrophilidae	3				3						3											1	
	Hydrophilidae	3																					1	
	Euridae	3	3	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
	Rhyacophoridae	3	3	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	
Trichoptera (caddisflies)	Glossosomatidae																							
	Hydroptilidae																							
	Psychomyiidae	3																						
	Psychomyiidae	3																						
	Hydroptilidae																							
	Hydroptilidae																							
	Limnephilidae	3	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
	Sarcophagidae	33	3	33	3	33	3	33	3	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
	Odonatidae																							
	Lepidoptera																							
Diptera (true flies)	Trichidae	3																						
	Psychodidae																							
	Ceratopogonidae																							
	Simuliidae	3	3	3	3	3	3	3	3	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
	Chironomidae	33	3	3	3	3	3	3	3	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
	Tanidae																							
	Empididae																							
	Musculidae																							

Appendix C: NRW Macroinvertebrate for the Cwmpennar Site 1990 - 2013

Major group	Taxon	Site name or code	01/05/1990	09/08/1990	07/11/1990	11/04/1991	01/08/1991	21/11/1991	22/04/1992	03/07/1992	21/04/1993	25/08/1993	30/03/1995	01/08/1995	10/10/1995	06/10/1996	03/03/2000	07/09/2000	28/04/2004	08/09/2004	29/10/2007	10/09/2007	08/04/2010	15/10/2010	08/02/2013	26/09/2013
Triclad (flatworm)	Planorbidae		3	33	3	3	3	33	3	33	3	3	3	3	3					11	1	2				3
	Dugesiidae																									
	Hydrobiidae		33	33	3	3	33	3	33	3	33	33	33	3	33	3					2	2				
	Hydrobiidae		33	33	3	3	33	3	33	3	33	33	33	3	33	3					400	200	8	7	1	2
	Hydrobiidae		33	33	3	33	3	33	3	33	3	33	33	3	33	3					11	3	1			1
Mollusca (snails, limpets and mussels)	Hydrobiidae		33	33	3	33	3	33	3	33	3	33	33	3	33	3					3	2				
	Hydrobiidae		33	33	3	33	3	33	3	33	3	33	33	3	33	3					3	2				
	Hydrobiidae		33	33	3	33	3	33	3	33	3	33	33	3	33	3					3	2				
	Hydrobiidae		33	33	3	33	3	33	3	33	3	33	33	3	33	3					3	2				
	Hydrobiidae		33	33	3	33	3	33	3	33	3	33	33	3	33	3					3	2				
Oligochaeta (worms)	Oligochaeta		33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	200	90	50	10	40	80	20
	Oligochaeta		33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	200	90	50	10	40	80	20
	Oligochaeta		33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	200	90	50	10	40	80	20
	Oligochaeta		33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	200	90	50	10	40	80	20
	Oligochaeta		33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	200	90	50	10	40	80	20
Pelecypoda (bivalves)	Pelecypoda		3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	3	2	4			4
	Pelecypoda		3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	3	2	4			4
	Pelecypoda		3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	3	2	4			4
	Pelecypoda		3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	3	2	4			4
	Pelecypoda		3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	3	2	4			4
Gastropoda (snails, slugs and limpets)	Gastropoda		3	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	40	50	10	2	2		4
	Gastropoda		3	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	40	50	10	2	2		4
	Gastropoda		3	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	40	50	10	2	2		4
	Gastropoda		3	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	40	50	10	2	2		4
	Gastropoda		3	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	40	50	10	2	2		4
Ephemeroptera (may flies)	Ephemeroptera		33	33	3	3	3	3	3	3	3	33	33	3	3	3	3	3	3	20	20	20	300	4	4	28
	Ephemeroptera		33	33	3	3	3	3	3	3	3	33	33	3	3	3	3	3	3	20	20	20	300	4	4	28
	Ephemeroptera		33	33	3	3	3	3	3	3	3	33	33	3	3	3	3	3	3	20	20	20	300	4	4	28
	Ephemeroptera		33	33	3	3	3	3	3	3	3	33	33	3	3	3	3	3	3	20	20	20	300	4	4	28
	Ephemeroptera		33	33	3	3	3	3	3	3	3	33	33	3	3	3	3	3	3	20	20	20	300	4	4	28
Plecoptera (stoneflies)	Plecoptera		33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	10	5	30	3	30	1	4
	Plecoptera		33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	10	5	30	3	30	1	4
	Plecoptera		33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	10	5	30	3	30	1	4
	Plecoptera		33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	10	5	30	3	30	1	4
	Plecoptera		33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	10	5	30	3	30	1	4
Coleoptera (beetles)	Coleoptera																									
	Coleoptera																									
	Coleoptera																									
	Coleoptera																									
	Coleoptera																									
Trichoptera (caddisflies)	Trichoptera		3	3	3	3	3	3	3	3	3	33	33	3	3	3	3	3	3	6	4	20	250	6	1	3
	Trichoptera		3	3	3	3	3	3	3	3	3	33	33	3	3	3	3	3	3	6	4	20	250	6	1	3
	Trichoptera		3	3	3	3	3	3	3	3	3	33	33	3	3	3	3	3	3	6	4	20	250	6	1	3
	Trichoptera		3	3	3	3	3	3	3	3	3	33	33	3	3	3	3	3	3	6	4	20	250	6	1	3
	Trichoptera		3	3	3	3	3	3	3	3	3	33	33	3	3	3	3	3	3	6	4	20	250	6	1	3

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[illegible]