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Black Water of Dee Gravel Project and Monitoring – Year Two

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Summary

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Keywords

BWoD; Restoration; fish; invertebrates; monitoring; gravel.

Background

The Galloway Fisheries Trust (GFT) managed the Black Water of Dee (BWoD) Restoration Project (phase1). This work is supported by funding from SPEN and Galloway Glens Landscape Partnership. This project includes the addition of substrate (referred to as gravel in the report) to the river. This report details year two monitoring surveys undertaken following the initial gravel addition.

This project began in 2021. Baseline monitoring surveys were undertaken in early summer 2021 prior to gravel being added at the end of August 2021. Details of the baseline monitirong results can be found in the Black Water of Dee Baseline Monitoring Report. Post-monitoring began immediately following the gravel addition works. Further monitoring surveys were carried out in the summer of 2022. The gravel addition work was repeated in late June 2022. Year two monitoring surveys were conducted in spring/summer 2023.

Main findings of the 2023 surveys

- Juvenile trout densities improved at the three gravel addition sites.
- Macroinvertebrate surveys improved at the gravel addition sites.
- Electrofishing habitat surveys showed a significant improvement in substrate compositions at the gravel addition monitoring sites.
- Geomorphological surveys showed a significant improvement in substrate compositions following gravel addition works.

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1. INTRODUCTION

The overall project aims to restore the Black Water of Dee, a major tributary of the Kirkcudbrightshire Dee, through the completion of a range of environmental works delivered in partnership with a range of organisations. The works include a range of riparian and instream works. The project will take a number of years to complete, the present work programme is considered as phase 1. Phase 1 of the project is now completed as of 2023 with plans for a phase 2 in development.

A key part of this project involved the addition of gravel and pebbles to create improved instream habitat. Natural sediment transportation down the BWoD has been halted for the last 85 years due to the Clatteringshaws Dam which was installed as part of the Galloway Hydro Scheme in the 1930s. As the smaller substrates over time were washed downstream and not replenished it left the Black Water of Dee with a river bed of only large substrates and bedrock. Salmonids require a mix of smaller substrates for spawning and younger ages classes to live in. While the Black Water of Dee was once a prime spawning river for Atlantic salmon and trout, currently only low densities of Brown trout populations are found and salmon are absent.

The project started in the summer of 2021 with around 460 tonnes of gravel / pebble mix added between five sites in accessible locations on the Black Water of Dee to provide improved spawning habitats for salmon and trout. Baseline monitoring surveys were undertaken prior to the gravel being added. Details from the 2021 gravel works can be found in the Black Water of Dee Baseline Monitoring Report. Monitoring works began immediately after the gravel addition works. The next part of the project was carried out in June 2022 with an additional 440 tonnes of gravel added and with monitoring works ongoing. No gravel was added in early 2023 but project monitoring surveys continued. Details on the gravel addition sites and work methodology can be found in the previous reports (Black Water of Dee Baseline Monitoring report and Black Water of Dee Year 1 Monitoring report).

The gravel and pebble mix was collected from further up the Dee catchment by an intake for a hydro dam on the Water of Deugh, where gravels regularly need to be moved as part of a maintenance programme. This material is usually removed and deposited back just downstream of the dam but for this project some of the substrate was transported to the Black Water of Dee. Both the Black Water of Dee and the Water of Deugh are within the same river catchment (Kirkcudbrightshire Dee) and exhibit similar characteristics and the gravels within the Water of Deugh are similar to gravels that would be naturally found in the Black Water of Dee. The gravel was deposited into selected areas of the Black Water of Dee where river flows are adequate to create natural sediment movement and distribute the gravel downstream into more natural features suitable for spawning.

The project design and source of substrate for introduction was guided and agreed with SEPA following site visits and detailed discussion.

The gravel is being closely observed to monitor downstream transportation. There were previously time-lapse and motion capture cameras in operation at selected sites along the Black Water of Dee to monitor progress. The gravel is also checked visually to monitor any changes. Geomorphological surveys looking at substrate compositions were undertaken at selected sites before the gravel was deposited and have been repeated to further monitor gravel movements. Invertebrate samples were taken in April 2021 prior to gravel addition and were repeated in April 2022 and early May 2023 following the gravel addition.

Ongoing plans for the project (phase 2) include continuing to monitor and add gravel to each site on a regular basis to achieve and maintain an adequate volume of spawning substrates within the river. The project includes further habitat enhancement work including mapping natural conifer regeneration in the riparian zones and cutting where it causes impacts. Areas where there is a lack of riparian deciduous trees are being identified to direct planting work.

The project is being managed by Galloway Fisheries Trust (GFT) with funding for phase 1 from Galloway Glens Landscape Partnership and a donation via SPEN up until early 2023. Monitoring of phase 1 works will continue (funded by GFT) and applications for funding for a phase 2 work program have been made. The overall project is supported by a steering group which involves various organisations and stakeholders including SEPA, DRAX, Forestry and Land Scotland, Dee District Salmon Fishery Board, NatureScot, Galloway Glens Landscape Partnership and GFT.

2. AIMS

The aims of this work were as follows:

2.1 Undertake quantitative electrofishing surveys to gather information on fish species at three monitoring sites and three control sites on the BWoD.

2.2 Carry out a detailed bankside and habitat survey at all six electrofishing sites.

2.3 Complete macroinvertebrate surveys at three gravel addition sites and one control site.

2.4 Undertake geomorphological surveys downstream of two gravel addition sites and two control sites.

2.5 Analyse and present results from electrofishing, geomorphological, and invertebrate surveys to provide monitoring data for this project.

3. METHODOLOGY

3.1 Data recording

The GFT is a partner in the Scottish Fisheries Co-ordination Centre (SFCC)[1], an initiative involving twenty six Scottish Fishery Trusts and others, including Marine Directorate (Scottish Government), the Tweed Foundation, the Spey Research Trust, the Tay Foundation and the Cromarty Firth Fisheries Trust.

This group has, in partnership, developed a set of agreed survey and data collection methodologies for electrofishing surveys and an associated database in which to record information gathered from such surveys. The electrofishing surveys undertaken by GFT for this study have been completed to the high standards that are required by the SFCC and recorded using the agreed methodologies.

3.2 Electrofishing surveys

To assess those fish populations present within a section of river, various techniques have been developed in recent decades. The main method of determining the status of a juvenile salmonid population is through employing the use of electrofishing equipment.

Electrofishing involves the 'stunning' of fish using an electric current which overpowers the nervous system of the fish and enables the operator to remove them from the water. Once captured, the fish recover in a holding container. They are then anaesthetised using a specific fish anaesthetic, identified to species level, measured and recorded. Once recovered, they are then returned unharmed to the area from which they were captured. This method of fishing involves the anode operator drawing stunned fish downstream to a net held against the current by an assistant. A hand net operator completes the three-man team. Captured fish are then transferred to a water-filled recovery container. The fishing team works its way across the survey section and upstream, thereby thoroughly fishing all the water in the chosen survey area.

To obtain fully quantitative information on the fish populations (primarily juvenile salmonids – see Section 3.2.1) within an area of interest, each survey site is fished through up to four times consecutively to allow the calculation of a more accurate estimate of the fish population present. A Zippin estimation of a fish population is a common calculation carried out using data derived from the depletion method of fishing (i.e. multiple-run fishing)[2]. The result provides an estimate of the fish population density per 100 m^2 of water, including the 95% confidence limits. When the calculation of a Zippin estimate of the population is not possible, a minimum estimate of the fish population is calculated for that section of river.

For this study, electrofishing was undertaken by three trained GFT staff at all survey sites. After the electrofishing exercise has been completed, a targeted and detailed SFCC habitat survey is completed of the actual fishing site. Results are provided in Section 4.1.1.

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1 http://www.sfcc.co.uk/

2 Zippin, C. (1958). The Removal Method of Population Estimation. Journal of Wildlife Management, 22. Pp 82-90.

3.2.1 *Limitations of electrofishing surveys*

The SFCC method of electrofishing was primarily developed to survey juvenile salmonids in relatively shallow running water. Non-salmonid fish species may be present and caught during these surveys, but their populations may not be properly determined using this method of electrofishing. Any non-salmonid fish species are therefore counted and measured (eels only) but no population estimate is made.

Electrofishing will never capture all the fish in a survey site, therefore densities presented in this report are an estimate - either a minimum estimate, or, where possible, the calculation of a Zippin estimate of the juvenile salmonid population residing within the site has been presented (see Section 4.1.1). The absence of fish cannot be ascertained with certainty using electrofishing techniques so a density of zero does not always guarantee fish are altogether absent from the surveyed section of watercourse. Finally, although a low density of fish can be assessed with electrofishing techniques, low and patchy distributions of fish may make drawing conclusions from the data more difficult.

The juvenile salmonid density classification scheme (see Section 3.2.3) is based solely on data from surveyed sites containing fish in 1997 to 2002 and refers to regional conditions at that time [(3)]; it must only be used as a very relative guide and not be used to draw conclusions. Moreover, the figures for juvenile trout are less reliable for various reasons (e.g. some surveyed populations of trout are isolated; sea trout contributing to stock in some areas etc.) and so can only be used as a relative indication of numbers.

3.2.2 *Electrofishing equipment*

The location of all the electrofishing survey sites selected for this study required the use of a mobile backpack electrofishing kit. The battery powered E-fish backpack electrofishing kit consists of an electronic controller unit with a linked cathode of braided copper (placed instream) and a linked, mobile, single anode, consisting of a pole-mounted stainless-steel ring and trigger switch, which is used instream to capture the fish. Smooth direct current was used in all survey sites.

3.2.3 *Age determination and density*

For this study the electrofishing survey concentrated on assessing the status of juvenile salmonid species, namely salmon and trout. In the majority of cases age determination can be made by assessment of the length of fish present. However, with older fish it is often more difficult to clarify age classes. In these cases, a small number of scale samples can be taken from fish, in addition to taking length assessments, to verify the ages of fish whose age cannot be determined with certainty from the length.

In this study, juvenile salmonids are differentiated into fry (age 0+) and parr (age 1++) age groups, as well as species (Table 1).

Table 1: Salmonid age classifications referred to in this report

Salmonid Fry (0+):	Young fish less than one year old resulting from spawning at the end of 2022
Salmonid Parr (1+ and older (1++)):	Young fish of greater than one year and greater than two years old (where present) from spawning in 2021 or

[3] Godfrey, J. D. (2006), Site Condition Monitoring of Atlantic Salmon SACs: Report by the SFCC to Scottish Natural Heritage, Contract F02AC608 https://www2.gov.scot/resource/doc/295194/0096508.pdf

	previously. Salmonids of up to three or four years old are also included in this category

Juvenile salmonids numbers recorded have also been classified into several ‘density’ categories. A classification scheme for densities of salmonids was previously generated by the SFCC using data collected from 1,638 Scottish electrofishing survey sites covering the period 1997 to 2002(3). From this, regional figures were created to allow more accurate local ‘density ranges’ (Table 2). The categories referred to in this report are based on quintile ranges for one-run electrofishing events in the Solway region (Solway Salmon Fishery Statistical Region), within which Kirkcudbrightshire Dee catchment lies.

Table 2: Quintile ranges for juvenile salmonids (per 100 m^2 of water; see Table 1 for age classifications) based on one-run electrofishing events, calculated on densities >0 over 291 sites in the Solway Statistical Region

	Salmon 0+	Salmon 1++	Trout 0+	Trout 1++
Minimum (Very Low)	0.22	0.38	0.38	0.35
20th Percentile (Low)	5.21	2.86	4.14	2.27
40th Percentile (Moderate)	12.68	5.87	12.09	4.71
60th Percentile (High)	25.28	9.12	26.63	8.25
80th Percentile (Very High)	46.53	15.03	56.49	16.28

3.2.4 Non-salmonid fish species

At each survey site the presence of non-salmonid fish species is noted. Population densities for these species are not calculated (see Section 3.2.1) but numbers of individuals are counted. In the case of any eels that are captured, a measurement to the nearest 5 mm is taken.

3.2.5 Site measurement

At each survey site a total site length was recorded, and average wet and channel widths calculated. The average wet width is calculated from five or more individual widths recorded at equidistant intervals from the bottom of the site (0 m) to the top. At each site the final width is noted at the upper limit of the surveyed water. From these site measurements the total area fished can be calculated.

3.2.6 Bankside/instream electrofishing site habitat assessment

At each electrofishing site a detailed habitat assessment using SFCC protocol is made of the instream habitat available for older (parr (1++) aged) fish. This assessment grades the instream ‘cover’ available to salmonids as none, poor, moderate, good or excellent. This grading provides an index of instream cover where diverse substrate compositions will score more favorably than areas of uniform substrate which provides lower levels of cover for individuals.

In accordance with SFCC protocols, percentage estimates of depths, substrate type and flow type are made at each electrofishing site. Additionally, percentage estimates of the quantity of the bankside cover features such as undercut banks, draped vegetation, bare banks and marginal vegetation are made. When any reference to left or right bank is made, it is always classed as left and right bank when facing downstream.

3.2.7 Survey areas and site selection

Sites were selected by GFT.

3.3 Macroinvertebrate surveys

Macroinvertebrate surveys were conducted to gain an understanding of the health of the river at each survey site. This was achieved by using macroinvertebrate communities as an indicator for changes in water quality and health as a result of fine sediment loading. This report will summarise and provide key information from the macroinvertebrate surveys conducted. Baseline samples were taken on 15th April 2021 with the surveys repeated 15th April 2022 and 3rd May 2023. This was to ensure no seasonal fluctuations would affect the samples.

Macroinvertebrate samples were collected from four survey sites. The macroinvertebrate samples were collected using a standard 25 cm frame kick sampling net with 1 mm spacing. The sampling methodology used was the standard macroinvertebrate sampling method of three minutes of kick sampling followed by one minute of manual sampling. As with the standard methodology the three minute kick sampling was split proportionally based on the invertebrate habitats present within the sample sites whilst the manual search focused on the surface layer, bankside vegetation/undercuts and stone washing. The resultant material collected during the kick sample and hand search was placed into a labelled container and preserved in 70% isopropanol. Samples were sorted at the GFT office with all individuals being counted and identified to family level in acordance with sampling for biotic assessment. Identification was completed using a low powered microscope with x10 to x40 variable magnification and using the Freshwater Biological Association Guide to British Freshwater Macroinvertebrates for Biotic Assessment identification guide.

In the previous monitoring reports, three Biotic Indices have been used to analyse the results and give an indication of the condition of the BWoD invertebrate communites at the time of sampling. The Indices used were the Biological Monitoring Works Party (BMWP) Index, the Proportion of Sediment-sensitive Invertebrate Index (PSI) and the Acid Water Indicator Community (AWIC) Index. The BMWP Index has now been replaced by the use of WHTP scoring system, which scores different invertebrate families based on their general water quality requirements, and analysed using the River Invertebrate Classification Tool (RICT) Model 44 software. Model 44 is still in development but is expected to replace the current Model 1 software. Based on environmental variables recorded at sample sites and predicted by DEFRA Model 44 Input Variable software the RICT software predicts the invertebrate communities that should be found and compares the predicted values with those recorded during invertebrate sampling. This gives a score which can be used to assess general water quality based on the scoring shown in Table 3.

Table 3: RICT overall score and Average Score per Taxon (ASPT) ratings

Overall Score	ASPT	Water Quality
0.97+	0.8+	High
0.86 – 0.96	0.68 – 0.79	Good
0.72 – 0.85	0.56 – 0.67	Moderate
0.59 – 0.71	0.47 – 0.55	Poor
<0.59	<0.47	Bad

ASPT (Average Score per Taxon) represents the average WHPT water quality score for the invertebrate families recorded within a sample. NTAXA is the number of different invertebrate families recorded within a sample. The previous years of invertebrate data has been re-analysed using WHPT and RICT software to replace the BMWP index and the results have been detailed in this report. Two additional Biotic Indices have been used to analyse the results and give an indication of the condition of the invertebrate communities at each sample site at the time of sampling (both of which can also be calculated by the RICT Software). The two Indices used are The Proportion of Sediment-sensitive Invertebrate Index (PSI) and the Acid

Water Indicator Community (AWIC) Index. Whilst the RICT Software gives an overall indication of water quality/invertebrate community health, the PSI Index assesses the levels of sedimentation within watercourses by looking at the proportion of sediment sensitive invertebrate families within an invertebrate sample. Drainage, land erosion, and works such as the gravel addition can result in high levels of sediment input from the surrounding land, which can "smother" riverbeds resulting in the death of buried fish eggs and some sediment intolerant invertebrate species. In a similar manor to the RICT and PSI Indices the AWIC Index uses the pH tolerance of different families of invertebrates to estimate the mean pH within a watercourse based on the invertebrates recorded. The scoring systems for both Indices are shown in Tables 4 and 5.

Table 4: PSI score ratings

PSI Score	River Bed Condition
81 to 100	Minimally Sedimented/Unsedimented
61 to 80	Slightly Sedimented
41 to 60	Moderately Sedimented
21 to 40	Sedimented
0 to 20	Heavily Sedimented

Table 5: AWIC score ratings

AWIC Score	Mean pH	Low 95 Percentile	Upp 95 Percentile
2	5.46	4.55	6.37
2.5	5.84	4.93	6.75
3	6.22	5.31	7.12
3.5	6.6	5.69	7.5
4	6.98	6.07	7.88
4.5	7.36	6.45	8.27
5	7.74	6.83	8.65
5.5	8.12	7.21	9.03
6	8.5	7.59	9.41

3.4 Geomorphological surveys

3.4.1 Quadrat surveys

Geomorphological surveys involve using a 1 m^2 quadrat to survey the composition of substrates (see Figure 1). This is repeated three times at random areas of each selected site. The percentages of each substrate type within the quadrat are estimated to the nearest 10%. This was first carried out prior to the gravel addition and was then repeated after gravel addition. Sites were selected downstream of two gravel addition sites with two control sites. It is expected that the percentage of gravel will gradually increase at the monitoring sites downstream of the gravel addition sites and will show progress of gravel movements.

Figure 1: Using a quadrat placed at random to estimate the percentage of substrate type composition

3.4.2 Boulder surveys

Certain large boulders were selected at both the monitoring and control sites as another method of geomorphological surveys. A flat stick is used to extend from the middle of the boulder until it hovers over the water and the distance between the stick and the river bed is measured (see Figure 2). It is expected that as gravel moves downstream and settles around these large boulders, the distances between the stick and the substrate will decrease as the smaller substrates build up.

Figure 2: Measuring the distance between the top of a solid structure to the river bed using a flat stick and measuring tape

4. RESULTS

4.1 Electrofishing surveys

The results of the electrofishing surveys are outlined in this section and presented in detail in Table 6. Site code, watercourse, site location, O.S. Grid reference, survey date and non-salmonid species are also shown in Table 6. Electrofishing and habitat information for all electrofishing survey sites surveyed are discussed in Section 4.1.1.

4.1.1 Electrofishing summary

All electrofishing sites on Black Water of Dee are summarised below in Table 6.

Table 6: Results from the 2021, 2022 and 2023 electrofishing surveys on the Black Water of Dee. Trout fry are classed as 0+ and trout parr are classed at 1++. In these cases, the number represents a minimum estimate of fish density per 100 m²

Site Code	Watercourse /River Order	Grid Ref	Survey Date	Area Fished (m^2)	Density per 100 m^2 Atlantic Salmon	Density per 100 m^2 Brown Trout
DB20	Black Water of Dee	259094 573671	27/07/2021	86.9	0	0+ 2.301 1++ 2.301
			13/07/2022	138.8	0	0+ 0.721 1++ 0.721
			10/07/2023	64	0	0+ 9.382 1++ 0
DB10	Black Water of Dee	261064 573001	22/07/2021	98.6	0	0+ 1.015 1++ 3.044
			13/07/2022	126.4	0	0+ 0 1++ 0.791
			10/07/2023	59.7	0	0+ 8.377 1++ 1.675
DB23	Black Water of Dee	258423 573430	22/07/2021	78.5	0	0+ 0 1++ 2.547
			13/07/2022	163.2	0	0+ 1.838 1++ 0
			10/07/2023	58	0	0+ 0 1++ 6.897
DB24	Black Water of Dee (CONTROL)	254987 574880	10/08/2021	146.6	0	0+ 0 1++ 4.094
			13/07/2022	141.4	0	0+ 0.707 1++ 0
			10/07/2023	130.1	0	0+ 0 1++ 0
DB14	Black Water of Dee (CONTROL)	261905 571442	22/07/2021	126.9	0	0+ 0 1++ 0.788
			13/07/2022	109.1	0+ 0 1++ 0.917	0+ 0.917 1++ 1.834

			04/08/2023	140.4	0	0+ 0.712 1++ 1.425
DB25	Black Water of Dee (CONTROL)	249514 579455	10/08/2021	101.4	0	0+ 2.958 1++ 3.944
			18/08/2022	79.5	0	0+ 3.774 1++ 3.774
			11/08/2023	100.5	0	0+ 2.984 1++ 2.984

The electrofishing results in 2023 appear positive with increases in fish densities at the gravel addition sites particularly this years fry. The conductivity within the BWoD is low and makes electrofishing difficult so some fish are always missed. Due to high flows this year, only accessible parts of the channel could be electrofished at all of the gravel addition sites but this is addressed in the results being provided for a standardised area i.e. 100 m^2 of water. The area fished at the control sites stayed the same as they were selected due to being accessible. The area fished for the control sites however can vary depending on water flows increasing water widths despite the same site being fished.

4.1.2 Electrofishing, habitat and macroinvertebrate survey results

A comparison of the substrate compositions observed in the habitat surveys between 2021-2023 can be found in Table 7. Detailed habitat surveys from 2023's electrofishing surveys are found below.

- DB20, BWoD

This site was located at gravel addition site 3. Instream cover was good at this site and depths ranged from 0 – 50 cm. Substrates were primarily small and consisted of gravel (40%), pebbles (30%), cobbles (20%), boulders (10%). Flows were mostly fast and consisted of run (70%) with areas of riffle (20%), and shallow glide (10%). The right bank had 50% of cover from areas of undercut and draped vegetation, but the left bank was bare due to the gravel banking created during this project. There is good cover upstream and downstream of the electrofishing site.

Brown trout fry were found in low density. The fry caught at this site was found within the added gravel.

Figure 3: DB20, BWoD

- DB10, BWoD

This site was located at the ford, gravel addition site 5. Instream cover was good and depths ranged from 0 – 50 cm. Substrates consisted of gravel (30%), pebbles (30%), cobbles (25%), and boulders (15%). Flows at this site were fast and consisted of run (50%) and riffle (30%) with some areas of shallow glide (20%). The left bank had no cover and the right bank had 90% of cover from areas of undercut and draped vegetation. The added gravel created a new left bank which took away the bankside cover previously provided.

Brown trout fry were found in low density and Brown trout parr were found in very low density.

Figure 4: DB10, BWoD

- DB23, BWoD

This site was situated at gravel addition site 2, across from the forestry track. Instream cover was good and depths ranged from 0 – 40 cm. Substrates consisted of gravel (40%), pebbles (20%), cobbles (10%), boulders (10%) and bedrock (20%). Flows consisted primarily of run (50%) and riffle (30%) with areas of deep pool (10%), and some torrent due to high water (10%). The left bank had no cover and the right bank had 20% of cover from areas of undercut and draped vegetation. The right bank had conifer trees in very close proximity to the watercourse.

Brown trout parr were present in low density. Brown trout fry were absent from this site.

Figure 5: DB23, BWoD

- DB24, BWoD (CONTROL)

This site was located at the top of the BWoD, just below Clatteringshaws Dam. It was the highest control site within the BWoD. Instream cover was good and depths ranged from 10 – >50 cm. Substrates were primarily large and consisted of pebbles (15%), cobbles (20%), boulders (30%), and bedrock (40%). Flows consisted of run (80%) and deep pool (20%). The left bank had no cover and the right bank had 20% cover from undercuts and draped vegetation. The surrounding landscape was conifer plantations.

Fish were absent from this site.

Figure 6: DB24, BWoD

- DB14, BWoD (CONTROL)

This site was located downstream of Barney Bridge. It was the lowest control site within the BWoD. Instream cover was good and depths ranged from 10 - >50 cm. Substrates were primarily large and consisted of boulders (50%), cobbles (30%), bedrock (10%), with some small areas of pebbles (5%) and gravel (5%). Flows were primarily fast but mixed between run (40%), riffle (30%) with areas of deep glide (20%) and some deep pools (10%). The left bank had 10% cover from draped vegetation and the right bank had 25% cover from draped vegetation and rocks embedded in the banking. The surrounding landscape was broadleaf trees and conifer plantation.

Brown trout fry and parr were both found in very low densities.

Figure 7: DB14, BWoD

- DB25, BWoD (CONTROL)

This site was located upstream of Clatteringshaws dam, and was the only control site complete outwith any potential influence from the gravel addition. Instream cover was good and depths ranged from <10 - >50 cm. Substrates were mixed and consisted of boulders (30%), cobbles (30%), pebbles (20%), gravel (15%), and sand (5%). Flows were fast and consisted of riffle (50%), run (40%) with some shallow glide (10%). The left bank had 40% cover provided by rocks embedded in the banking while the right bank had no cover. The surrounding landscape was tall herbs and conifer plantations, which had a good buffer zone between the river and the forestry line.

Brown trout fry were found in very low density and Brown trout parr were found in low density.

Figure 8: DB25, BWoD

Table 7: Substrate compositions at all electrofishing sites between 2021-2023

Site	Substrate Composition 2021	Substrate Composition 2022	Substrate Composition 2023
DB20	40% Bedrock 20% Boulders 30% Cobbles 10% Pebbles 0% Gravel	10% Bedrock 10% Boulders 20% Cobbles 30% Pebbles 30% Gravel	10% Boulders 20% Cobbles 30% Pebbles 40% Gravel
DB10	20% Boulders 50% Cobbles 20% Pebbles 10% Gravel	10% Boulders 20% Cobbles 20% Pebbles 40% Gravel 10% Sand	15% Boulders 25% Cobbles 30% Pebbles 30% Gravel
DB23	40% Bedrock 20% Boulders 30% Cobbles 10% Pebbles 0% Gravel	10% Bedrock 20% Boulders 20% Cobbles 20% Pebbles 30% Gravel	20% Bedrock 10% Boulders 10% Cobbles 20% Pebbles 40% Gravel
DB24 (CONTROL)	40% Bedrock 30% Boulders 20% Cobbles 5% Pebbles 5% Gravel	30% Bedrock 30% Boulders 20% Cobbles 15% Pebbles 5% Gravel	40% Bedrock 20% Boulders 20% Cobbles 15% Pebbles 5% Gravel
DB14 (CONTROL)	0% Bedrock 30% Boulders 50% Cobbles 15% Pebbles 5% Gravel	20% Bedrock 30% Boulders 30% Cobbles 15% Pebbles 5% Gravel	

DB25 (CONTROL)	30% Boulders 30% Cobbles 20% Pebbles 20% Gravel	40% Boulders 30% Cobbles 10% Pebbles 10% Gravel 10% Sand	

The habitat surveys at each gravel addition site show significant improvement in spawning substrates. All gravel addition sites showed a distinct lack of small substrates suitable for spawning in 2021 prior to gravel being added. The surveys in 2022 and 2023 following the addition of gravel showed a huge improvement in the substrate compositions with the majority of substrate composition being pebbles and gravel. The control sites remain largely unchanged which is to be expected. The lowest control site may eventually show slight increases in small substrate composition as gravel transports down the river system. The results show a significant improvement in spawning substrate availability for fish within the BWoD.

4.2 Macroinvertebrate surveys

Macroinvertebrate samples were taken at three of the gravel addition sites and one control site. The invertebrate sample sites are also included in the electrofishing surveys with the habitat recorded for the electrofishing surveys being representatitve of the habitat within the invertebrate sampling sites. The results for the RICT ASPT and NTaxa, PSI and AWIC indices are shown in Table 8, and the ranking/ratings are shown in Table 9.

The full result table for the invertebrate samples is listed in Appendix 1.

Table 8: Biotic Index Scores for the BWoD 2021-2023 invertebrate sampling sites

Index	Year	DB20	DB10	DB23	DB25 (CONTROL)
RICT ASPT	2021 2022 2023	0.994 0.896 0.876	0.901 0.928 0.916	1.048 0.982 0.873	1.039 1.016 0.883
RICT NTaxa	2021 2022 2023	0.928 0.869 0.987	0.977 0.97 1.039	0.675 1.079 1.137	1.161 1.043 1.043
PSI	2021 2022 2023	80 83 65.5	74 86.7 70.4	85 83.3 65.6	87 92.86 61.5
AWIC	2021 2022 2023	3.5 3.4 3.8	3.6 3.2 3.6	3.5 3.7 4.2	4.1 3.9 4.3

Table 9: Biotic index ratings for the Black Water of Dee 2021-2023 invertebrate sampling sites

Index	Year	DB20	DB10	DB23	DB25 (CONTROL)
RICT ASPT	2021 2022 2023	High Good Good	High Good Good	High High Good	High High Good
RICT NTaxa	2021 2022 2023	High High High	High High High	Moderate High High	High High High
PSI	2021	Slightly Sedimented	Slightly Sedimented	Minimally Sedimented / Unsedimented	Minimally Sedimented / Unsedimented

	2022	Minimally Sedimented / Unsedimented	Minimally Sedimented / Unsedimented	Minimally Sedimented / Unsedimented	Minimally Sedimented / Unsedimented
	2023	Slightly Sedimented	Slightly Sedimented	Slightly Sedimented	Slightly Sedimented
AWIC	2021 2022 2023	Mean pH 6.6 Mean pH 6.6 Mean pH 6.6	Mean pH 6.6 Mean pH 6.22 Mean pH 6.6	Mean pH 6.6 Mean pH 6.6 Mean pH 6.98	Mean pH 6.98 Mean pH 6.98 Mean pH 6.98
Number of Taxa	2021 2022 2023	15 13 15	14 11 15	10 17 19	17 16 16

The results show general water quality to be "Good" to "High" with results close to those predicted by the RICT software. The RICT ASPT results appear to have decreased in water quality at all sites. However, the NTaxa at all gravel addition sites have increased since 2021 prior to the gravel addition works. In 2023, all sites bar DB20 exceeded the RICT software predictions suggesting the diversity of invertebrate communites have improved following the addition of gravel. However, the control site (DB25) has exceeded RICT predictions for NTaxa during all years of surveys suggesting perhaps the software is underestimating the biodiversity of invertebrates that should be present within the sites.

The PSI results for all sites indicated slight levels of sedimentation in 2023 compared to minimally sedimented/unsedimented in 2021 and 2022. The control site outwith the effect of the gravel works also showed an increase in sedimentation in 2023 which suggests there was an external cause. It may indicate the sedimentation throughout the Black Water of Dee is due to land use practices within the surrounding commercial forestry or from the severe flooding events that happened over the previous winter.

The final indice (AWIC) shows all sites having a pH below 7 which indicates that, on average, the pH from each site is slightly acidic. This has remained largely unchanged during the three years of sampling, with only one site (DB23) showing a slight improvement from a mean pH of 6.6 in 2021 and 2022 to 6.98 in 2023.

4.3 Geomorphological surveys

Baseline geomorphological surveys were undertaken on 30th July 2021 prior to gravel being added to the BWoD. These surveys were repeated on 8th November 2021, 15th April 2022, and 4th July 2023. Tables 10 and 11 detail the results from these surveys.

Table 10: Results from the 2021-2023 quadrat surveys

Site	River	**Substrate Composition** **30/07/2021 (before gravel works)**	**Substrate Composition** **08/11/2021 (after gravel works)**	**Substrate Composition** **15/04/2022 (after gravel works)**	**Substrate Composition** **04/07/2023 (after gravel works)**
D/S Ford	Black Water of Dee	Boulders 60% Cobbles 30% Pebbles 10%	Boulders 30% Cobbles 10% Pebbles 20% Gravel 40%	Boulders 30% Cobbles 20% Pebbles 20% Gravel 30%	Boulders 20% Cobbles 30% Pebbles 25% Gravel 25%

D/S Gravel Site 3	Black Water of Dee	Bedrock 80% Boulders 20%	Boulders 20% Coubbles 20% Pebbles 20% Gravel 40%	Boulders 20% Cobbles 20% Pebbles 30% Gravel 30%	Boulders 10% Cobbles 20% Pebbles 40% Gravel 30%
U/S Gravel Site 3 (CONTROL)	Black Water of Dee	Bedrock 100%	Bedrock 100%	Bedrock 100%	Bedrock 100%
U/S Clatteringshaws Dam (CONTROL)	Black Water of Dee	Boulders 20% Cobbles 10% Pebbles 10% Gravels 50% Sand 10%	Boulders 10% Cobbles 10% Pebbles 20% Gravel 50% Sand 10%	Boulders 20% Cobbles 20% Pebbles 10% Gravel 40% Sand 10%	Boulders 20% Cobbles 10% Pebbles 10% Gravel 50% Sand 10%

Table 11: Results from the 2021-2023 boulder surveys

Site	**River**	**Distance from top of boulder to river bed (cm)** **30/07/2021 (before gravel works)**	**Distance from top of boulder to river bed (cm)** **08/11/2021 (after gravel works)**	**Distance from top of boulder to river bed (cm)** **15/04/2022 (after gravel works)**	**Distance from top of boulder to river bed (cm** **14/07/2023 (after gravel works)**	**Difference in gravel depth (cm)**
D/S Ford	Black Water of Dee	Boulder 1: 101 Boulder 2: 90	Boulder 1: 93 Boulder 2: 79	Boulder 1: 92 Boulder 2: 77	Boulder 1: 89 Boulder 2: 76	Boulder 1: -12 Boulder 2: -14
D/S Gravel Site 3	Black Water of Dee	Boulder 1: 74 Boulder 2: 79	Boulder 1: 65 Boulder 2: 79	Boulder 1: 63 Boulder 2: 79	Boulder 1: 61 Boulder 2: 72	Boulder 1: -13 Boulder 2: -7
U/S Gravel Site 3 (CONTROL)	Black Water of Dee	Boulder 1: 53 Boulder 2: 60	Boulder 1: 53 Boulder 2: 60	Boulder 1: 53 Boulder 2: 60	Boulder 1: 53 Boulder 2: 60	Boulder 1: 0 Boulder 2: 0
U/S Clatteringshaws Dam (CONTROL)	Black Water of Dee	Boulder 1: 103 Boulder 2: 113	Boulder 1: 103 Boulder 2: 112	Boulder 1: 103 Boulder 2: 112	Boulder 1: 102 Boulder 2: 113	Boulder 1: 0 Boulder 2: +1

The geomorphological surveys show a huge improvement in substrate composition and substrate depth between 2021 prior to the gravel being added and 2022-2023. The quadrat surveys show the gravel addition sites went from being primarily composed of large substrates (bedrock, boulders and cobbles) in 2021, to being composed primarily of small substrates (pebbles, gravel) in 2022 and 2023. The boulder surveys show that downstream of the gravel addition sites, there has been a significant amount of gravel settling around large instream structures (large boulders). The control sites in both quadrat and boulder surveys have remained largely unchanged.

5. DISCUSSION

5.1 Discussion outline

This report outlines the year 2 monitoring surveys undertaken in 2023 for the Black Water of Dee Habitat Restoration Project. These surveys followed the 2021 baseline surveys which were carried out prior to any gravel being added into the system and the 2022 surveys which involved both monitoring and the addition of more gravel.

5.1.1 Electrofishing surveys discussion

Baseline electrofishing surveys showed that prior to gravel addition there were only Brown trout present within the Black Water of Dee. Salmon were once abundant in the BWoD but have since disappeared from the river believed to be partly due to a consistent decrease of spawning substrates following the construction of Clatteringshaws Dam in the 1930s. Three electrofishing sites are monitoring sites and three are control sites. Two of these control sites are within the BWoD below Clatteringshaws Dam where gravel addition works took place meaning they may be influenced by the gravel addition works in the future. One control site is above Clatteringshaws Dam where no fish can migrate to making it an external control site that cannot be influenced by the gravel addition works.

Overall brown trout densities increased at all three gravel addition sites. At DB10, in 2022 only one trout fry was caught whereas in 2023 there were six fry and one parr. At DB20, in 2022 only two trout fry were caught and in 2023 there were six trout fry. At DB23, in 2022 there were three trout fry and in 2023 there were no fry but four trout parr. This can be expected as the habitat within DB23 is now much more suitable for parr aged fish over fry due to the larger substrates providing good instream cover. Although numbers are still very low across all sites, they are improving and show that the gravel is being utilised by resident trout in the BWoD. Small improvements are expected to begin with in any restoration project as it takes several years to recover populations, therefor increases of only a few fish are still a promising success.

The control sites have had minor fluctuations in fish densities throughout all three years of baseling and monitoring surveys. The control sites within the BWoD are unlikely to be affected by the gravel addition works, and the control site above Clatteringshaws dam is completely outwith potential influence from the gravel works. Any changes observed within the control sites can be attributed to external influences and can give insight into other factors affecting fish populations within the BWoD. The control sites remain the same each year but depending on water flows can have higher or lower areas fished which in turn affects the densities. The same number of fish may be caught however if the area fished changes then the density will change too. It should also be noted that the control sites tend to be better habitat for parr aged fish, which naturally move around watercourses more readily meaning they do not stay in the same site for long periods of time which can also cause density fluctuations.

Electrofishing in the Black Water of Dee is also unlikely to represent the total number of fish within a site due the the low conductivity meaning fish are more likely to escape the electricity and not be caught. It is not possible to catch all fish within an electrofishing site and the low conductivity, high flows, and dark cloudy water make this more of a challenge within the BWoD. There was likely more fish at all survey sites which escaped capture. However, the improvements in numbers between 2021-2023 are very promising and show the added gravel is being used as intended by fish within the Black Water of Dee.

5.1.2 Invertebrate surveys discussion

Overall, the macroinvertebrate surveys at the gravel addition sites have improved in 2023. Colonisation and diversity can take several years to show significant changes, however this project is already seeing an increase in benthic invertebrate families which have the preference of small substrates such as gravel.

It should be noted that macroinvertebrate surveys were undertaken in the first week of May in 2023, whereas they were taken in mid April in both 2021 and 2022. This may have caused a slight variation in the results compared to if the samples were taken at the same time in 2023. Invertebrate communities have seasonal fluctuations meaning a few weeks difference may have altered a small amount of the invertebrates within the sites. However, this is unlikely to have had an adverse affect on the overall results as any possible differences would have been very minor.

The RICT software predictions were introduced to the project monitoring this year, and the previous survey results were also put through the software to be compared to the 2023 results. The RICT software was introduced to replace the BMWP monitoring discussed in the previous reports. Comparisons can now be made using the results from the RICT software from the 2021 survey prior to the gravel being added and from the 2022 and 2023 post-monitoring surveys. The RICT software has replaced BMWP because it is used in the Water Framework Directive and is thought to give a more accurate representation of water quality than BMWP.

Overall, the RICT ASPT scores indicated all sites were of "Good" water quality in 2023, which was a decrease from the "High" water quality observed at all sites in 2021 prior to the gravel addition works, and at sites DB23 and DB25 (control) in 2022. ASPT (Average Score per Taxon) represents the average WHPT water quality score for the invertebrate families recorded within a sample. WHPT scores determine the level of tolerance to organic pollution by each invertebrate family. Therefor, a decrease in ASPT does not necessarily mean that the number of invertebrate families are decreasing, but can indicate that the composition of families within a site is changing to include families which are more pollution tolerant. In the event of pollution, more pollution tolerant families will thrive and produce a prediction of poorer water quality. In the case of this project, there was a slight increase in sedimentation levels and a decrease in RICT ASPT scores across all sites in 2023 which may be the reason for more pollution tolerant families being present.

RICT NTaxa predicts the number of invertebrate families that should be present within a site using geographical data and predictions. The RICT NTaxa predictions have increased at all sites between 2021 and 2023. All gravel addition sites suffered a slight reduction in predictions between 2021 and 2022, which is likely due to the disturbance in the habitats caused directly by the gravel addition works. By the 2023 surveys, the gravel had time to settle and allowed for some colonisation of invertebrates which is most likely why the NTaxa predictions improved. The results from DB10 and DB23 in 2023 suggest there is now a higher diversity of invertebrates within the sites than was predicted by RICT software, suggesting the habitat has improved greatly for invertebrate communities. However, the control site (DB25) has exceeded RICT NTaxa predictions across all survey years which suggests the software may have some inaccuracies and is underestimating the number of invertebrate families that should be present at the sites. Regardless, the number of invertebrate families within all gravel addition sites has improved since 2021 suggesting the addition of gravel has allowed for colonisation and an increase in diversity of invertebrates which prefer smaller substrates and faster flowing water.

PSI scores represent the levels of siltation within a river. High levels of siltation can cause problems for salmonids and smother eggs buried in gravel. In 2021, the PSI scores from the Black Water of Dee showed slightly sedimented in two sites (DB20 and DB10); and minimally sedimented/unsedimented in the other two sites (DB23 and DB25 which was the control site). In 2022, all four sites were classed as minimally sedimented/unsedimented which is the best class of water quality in this scoring system. In 2023, all four sites were classed as slightly sedimented. This was also observed at the control site which is above Clatteringshaws Dam and isolated from the project area. This suggests the cause of this across all sites was external and outwith the effect of the gravel addition works. The Black Water of Dee runs through several kilometres of commercial forestry where works such as felling, planting, and transporting of timber happen often. All land use practices run the risk of impacting nearby watercourses by the addition of silt or other pollutants. There were also particularly severe floods over winter of 2022 which could also have impacted the Black Water of Dee. However, the increase in sedimentation at all sites has not appeared to have severely impacted the macroinvertebrate or fish communites.

AWIC scores represent levels of acidification within a river. All four sites had a mean pH of below 7 meaning all sites are on average slightly acidic. The pH of a river fluctuates naturally however rivers can become more acidic following heavy rainfall when surrounded by conifer plantations and/or damaged peatlands. The highest mean pH during all years has been found at the control site above Clatteringshaws Dam (DB25) at 6.98 with all other sites estimated to be around 6.6 pH. The control site has an ideal buffer zone from the river to the beginning of the conifer plantations (> 20 m). Whereas conifers being in close proximity are a distinct issue in the section of the Black Water of Dee below Clatteringshaws Dam. Coniferous woodlands and the associated ground works can cause issues with acidification in poorly buffered waters in Galloway. Individual conifer trees and conifer plantations should be at least 20 m away from the edge of any watercourse to help reduce impact. However, along the BWoD there are several areas where the trees are within this 20 m zone which is a concern. In 2023, site DB23 also had a mean pH of 6.98 and is the only site to have shown improvement during the three years of monitoring this project. During the gravel addition works, a large gravel bed and banking was created at this site which slightly increased the buffer zone between the riverbed and the surrounding conifer plantations which may have helped to reduce the acidity at this site.

Overall, the invertebrate samples show good – high levels of water quality, with some improvements in the diversity of families within the gravel addition sites. All sites including the control site observed a decrease in RICT ASPT scores and an increase in sedimentation, likely due to an external cause. The diversity of invertebrates, however, has improved with the number of families increasing at each site in 2023. Future surveys should continue to show an improvement in macroinvertebrate diversity to being composed of families which prefer small substrates and faster flows which will in turn provide more food for fish.

5.1.3 Geomorphological surveys discussion

The 2021 baseline geomorphological surveys showed a distinct lack of spawning substrates throughout the BWoD below Clatteringshaws Dam. The control site upstream of Clatteringshaws Dam has a good mix of substrates which is the goal for the BWoD downstream of the dam. The control site within within the BWoD is above the highest site of gravel addition within the BWoD and should not change with gravel movements further downstream. 2022 and 2023 geomorphological surveys showed significant improvements in substrate compositions downstream of the gravel addition sites. This shows that the gravel has moved downstream and settled naturally into the system. No issues with blockages or flooding has been observed.

5.1.4 Gravel addition discussion

A total of 900 tonnes of gravel has been added into the BWoD system - 460 tonnes were added in 2021 and 440 tonnes in 2022. The monitoring results show that this has vastly improved the spawning habitat within the BWoD and that the added gravel has already been utilised by salmonids residing in the BWoD. Further monitoring is required to see the benefits for the ecology and to guide future gravel addition.

6. APPENDIX

Table 13: Results from the 2021, 2022, and 2023 Black Water of Dee invertebrate samples

Family	DB23 2021	DB23 2022	DB23 2023	DB20 2021	DB20 2022	DB20 2023	DB10 2021	DB10 2022	DB10 2023	DB25 2021	DB25 2022	DB25 2023
Baetidae										26	13	1
Capniidae												
Chironomidae	49	147	38	11	69	18	12	58	70	11	5	5
Chloroperlidae	10	115	28	14	38	27	18	34	36	14		13
Coegrionidae		1	12	1								
Cordulegastridae				1					3			
Corixidae		1	19	3								
Dytiscidae			11	4		1	2			6		4
Elmidae	162	22	1	52	1	19	2		22	80	75	31
Ephemerellidae			9							1		
Gyrinidae		13		3	25		1	1	1	5		
Heptageniidae			6							65	87	9
Hydropshychidae		38	1	1	2	1			3	5		2
Leptoplebiidae	64	130	35			54	62	8	49	4		13
Leuctridae	9	19		1	9	4	2			3		
Limnephilidae	19	9		5		2	8	4	4	16	5	4
Nemouridae	261	128	2	95	44	33	46		64	20	15	7
Oligochaeta	24	23	9	12	46	35	13	21	13	10	69	
Perlodidae	113	441	56	19	149	47	19	63	38	3	41	
Pediciidae												6
Phryganeidae			25			8						
Polycentropodidae		28	8	3	14		11	19	49			
Rhyacophilidae	4	5	15	7	10					2	13	3
Salmonid fry		4						1				
Sialidae					4		1		3			
Simuliidae			12		4	10		4	194	8	3	1
Siphlonuridae		8										
Taeniopterygidae										1		
Tipulidae		4					1	1			12	
Veliidae			1	4					4		1	