ECOLOGICAL RECOVERY OF THE RIVER PELENNA (SOUTH WALES) FOLLOWING THE PASSIVE TREATMENT OF ABANDONED MINE DRAINAGE[1]

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Abstract. From the 1960s to the late 1990s, the River Pelenna in South Wales was impacted for a distance of 7 km by five significant discharges from abandoned coal mines. Elevated iron and low pH caused significant orange staining and had detrimental effects on the river ecology. The River Pelenna Minewater Project constructed a series of passive wetland treatment systems to treat these discharges. Monitoring of the performance and environmental benefits of these has been undertaken as part of an ongoing Environment Agency R&D project. This project has assessed the changes in water quality as well as monitoring populations of invertebrates, fish and birds between 1993 and 2001.

Performance data from the wetlands show that on average the three systems are removing between 82 and 95% of the iron loading from the minewaters. Downstream in the rivers the dissolved iron concentration has dropped to below the Environmental Quality Standard (EQS) of 1 mg/l for the majority of the time. Increases in pH downstream of the discharges have also been demonstrated.

Trout (*Salmo trutta)* recovered quickly following minewater treatment, returning the next year to areas that previously had no fish. Intermittent problems with overflows from the treatment systems temporarily depleted the numbers, but the latest data indicate a thriving population. The overflow problems and also background episodes of acidity have affected the recovery of the riverine invertebrates. However there have been gradual improvements in the catchment, and in the summer of 2001 most sites held faunas, which approached unpolluted controls. Recovery of the invertebrate fauna is reflected in marked increases in the breeding success of riverine birds between 1996 and 2001.

This study has shown that constructed wetlands can be an effective, low cost and sustainable solution to ecological damage caused by abandoned mine drainage.

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Introduction

In South Wales, former coal industries have left an obvious environmental and social legacy. Little is now left in the way of active coal mining operations but the settlements that developed with the industry still remain. Most mining infrastructure has been demolished and spoil heaps have been reclaimed but the environmental impacts of mine drainage are a persistent legacy in many areas.

Tonmawr, a village situated in the Pelenna valley, near the towns of Neath and Port Talbot, developed around the coal industry. The earliest records of coal mining relate to a level opened in 1823 (Reynolds 1985). Over the next 100 or so years many drift mines and one deep mine were opened in the vicinity. By the early 1960s, mining had ceased in the valley.

Following the closure of these mines, the workings flooded and mine drainage discharged into the Gwenffrwd and Blaenpelenna, tributaries of the River Pelenna. These stained the two tributaries and the River Pelenna orange and caused elevated iron concentrations for approximately 7km, as far downstream as the confluence with the River Afan (Edwards *et al.* 1997). Assessments of the ecological status of the polluted rivers showed that juvenile trout (*Salmo trutta*) populations and macroinvertebrate assemblages were impoverished both upstream and downstream of the minewater discharges on the Gwenffrwd and Blaenpelenna, and to a lesser extent on the River Pelenna (Edwards, 1995). Macroinvertebrate assemblages in the headwaters of the catchment were typical of acidified streams, while communities downstream of the major minewater discharges were even more impoverished. Poor survival rates of trout eggs, alevins and parr were observed in the Blaenpelenna and Gwenffrwd, particularly downstream of the minewater discharges. The toxic effects of metals and acidity in the minewaters and episodic surface-water acidification, coupled with the smothering effects of ochre on the substrate, were thought to be responsible for the impoverishment of the aquatic fauna.

Research elsewhere has investigated the effect minewater discharges have on invertebrates and fish. A reduction in the invertebrate taxonomic richness at sites impacted by minewaters has been found by Amisah and Cowx (2000), Malmqvist and Hoffsten (1999), Mori *el al.* (1999) and Soucek *et. al.* (2000). Restrictions on fish reproduction and egg survival leading to poor juvenile populations have been identified at other sites impacted by minewater in the UK by Amisah and Cowx (2000) and Scullion and Edwards (1980).

The Pelenna minewaters are generally net-acidic with iron as the main contaminant, while levels of other metals are generally no higher than background levels in the rivers. Five main discharges were identified as requiring treatment in order to lower the dissolved iron concentration in the rivers to below the Environmental Quality Standard (EQS) of 1 mg/l. The characteristics of each discharge are shown in Table 1.

Table 1. Characteristics of the Pelenna minewaters.

	Mean Flow (l/s)	Mean pH	Mean Total Iron (mg/l)	Mean Iron Loading (kg/day)	Mean Alkalinity (mg/l $CaCO_3$)
Whitworth A[1]	9.3	6.0	61.3	41.9	31.6
Whitworth B[2]	18.0	5.9	5.5	7.3	6.8
Gwenffrwd[2]	5.0	5.3	0.7	0.9	14.4
Whitworth No 1[3]	4.7	6.3	24.1	9.5	42.0
Garth Tonmawr[4]	20.0	5.8	28.6	47.2	14.6

Notes; [1]Data from 1993 to 2001
[2]Whitworth B and Gwenffrwd minewater data is post 10/98 only following an underground diversion of the minewater flow regimes.
[3]Data from 1995 to 2001
[4]Data from 1991 to 2001

A project was initiated by Neath Port Talbot County Borough Council (NPTCBC) and The Environment Agency Wales (EAW) to construct a series of passive wetland treatment systems for these discharges. Funding was obtained from the European Union LIFE fund (a European financial instrument for the environment) and the Welsh Development Agency's (WDA) Land Reclamation Programme. The schemes were constructed in three phases from 1995 to 1999. The design and size of each scheme is outlined below:

- Phase I-Whitworth No 1 wetlands were constructed in 1995 with four cells in parallel covering 900m^2. Bark mulch and mushroom compost were used as substrates and the systems were planted with Cat's-tail (*Typha latifolia)* and Soft Rush (*Juncus effusus)*.
- Phase II-Garth Tonmawr wetlands contain five cells covering 6370m^2 and were constructed in 1998/99. There are three aerobic cells and two Reducing and Alkalinity Producing System (RAPS) cells that incorporate downward flow compost substrates with limestone bases for alkalinity generation. This system was left to colonise naturally.

- Phase III-Whitworth A, Whitworth B and Gwenffrwd wetlands were constructed in 1998. The wetlands operate in two legs, Whitworth A and Gwenffrwd. The Whitworth A leg has a RAPS of 1825m^2 followed by an aerobic wetland of 4500m^2 The Gwenffrwd leg of the system consists of a RAPS cell of 2425m^2 followed by a settlement pond of 850m^2 and then an aerobic cell of 2000m^2. This leg was modified in 2001 after a natural underground diversion of the minewater in the winter of 1998 resulted in it bypassing the system. It now captures the flow from both the Gwenffrwd and Whitworth B minewaters.

The location of each phase of the treatment system is shown in Figure 1. A three-year R&D project funded by the Environment Agency is currently assessing the performance, environmental benefits and sustainability of these treatment systems. The results reported here are the latest assessment of the recovery of the ecology of the River Pelenna and the effectiveness of the constructed wetlands as a method for treating minewater discharges.

Methods

Water quality monitoring

Water quality samples were taken from the minewaters and the outlet from each cell of each treatment system. River water quality was monitored at a number of sites including up and downstream of each discharge (Figure 1). Monitoring has been undertaken by the EAW at all sites from 1993 to 2001 and at the wetland sites since construction. Samples were taken using standard Environment Agency (EA) methods (Environment Agency, 1998a). Field measurements for pH were taken on a YSI 600XL multi-parameter meter and alkalinity was measured using a Palintest photometer 5000. The Environment Agency National Laboratory Service in Llanelli analysed the samples. EAW Hydrometric Field Officers monitored wetland and river flows using standard EA techniques (Environment Agency, 1998b).

River water quality data was analysed for any significant step changes following minewater treatment. Two software packages were used (TAPIR and BADGER) to assess temporal trends. These were developed by the Water Research Council (WRc), specifically for improved environmental monitoring by the Environment Agency (Wyatt *et. al.* 1998).

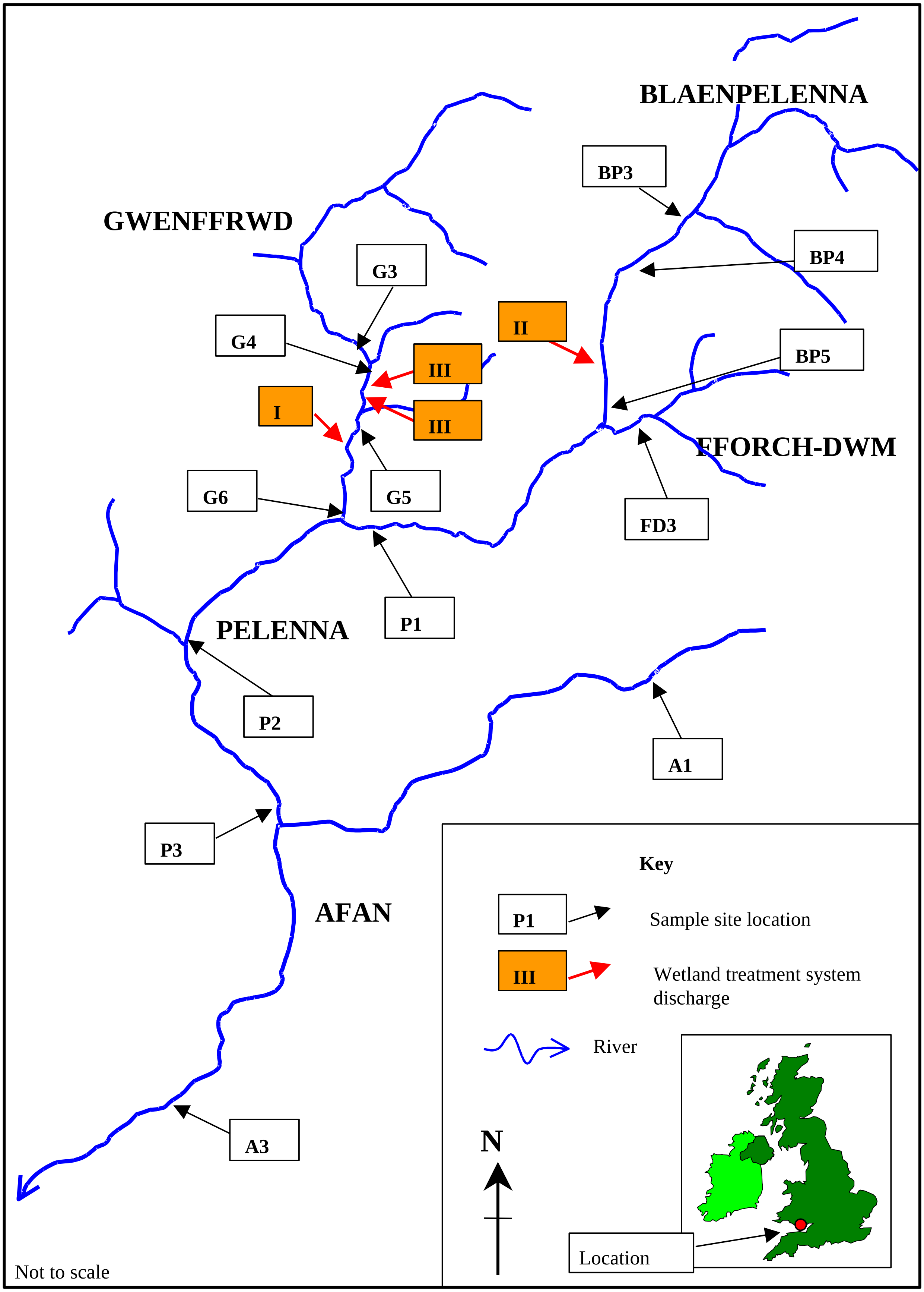

Figure 1. Wetland treatment system and sample point locations.

Ecological studies

Invertebrate populations were monitored yearly from 1993 until 2001. Sampling was undertaken in Spring and Autumn using a three-minute kick sample, followed by identification to species level in the laboratory. Standard EA methodology was followed (Environment Agency, 1999). The accuracy of sorting and identification was subject to in-house and external quality control. Data generated were analysed using a number of biotic indices including the Biological Monitoring Working Party (BMWP) Score, Average Score Per Taxon (ASPT) and total abundance. The BMWP score was designed to give a general indication of the biological conditions of rivers. Each macroinvertebrate family is given a score between one and ten, based upon its susceptibility to organic pollution (Metcalfe, 1989). The ASPT is calculated by dividing the BMWP score by the number of taxa.

The multivariate classification technique TWINSPAN (Two-Way INdicator SPecies ANalysis) was also employed. TWINSPAN splits sites into groups that are essentially similar in taxonomic composition (Gauch, 1982). Indicator species that show a preference for each split or group are identified and the relationships between the site groupings and environmental variables can be explored.

Fish population data were gathered in the summers of 1993, 1994, 1996 and 1999 to 2001. Stretches of 50 m were electrofished using a quantitative method. The stretches were isolated up and downstream using nets and then fished a minimum of three times. Standard EA methodology was observed (Environment Agency, 1998c). Results were converted into fish densities per $100m^2$ using the method of Carle and Strub (1978) for both fry (<1 year old) and parr (>1 year old). National Fisheries Classification Scores (NFCS) were calculated for the data (Mainstone, et. al. 1994). This system categorises the fish densities observed against a national dataset of fisheries of a similar type. The observed densities are then expressed as being within a certain percentage of sites for a given species group within the database. The system is classified in six parts as below:

- Grade A Excellent within top 20% of database
- Grade B Good 60-80%
- Grade C Fair 40-60%
- Grade D Fair 20-40%
- Grade E Poor Lower 20%
- Grade F Fishless

Predicted densities of fish were calculated using a habitat assessment scheme (HABSCORE) that measures and evaluates habitat features which influence salmonid distribution (WRc, 1999). Characteristics of each field sites are input into the system, which then returns a predicted fish density for such a habitat, assuming pristine water quality.

Riverine bird populations were assessed using the British Trust for Ornithology (BTO) Waterways Bird Survey (WBS) methodology (Taylor and Murray, 1982). Three river stretches were surveyed on six separate occasions with no three sequential visits spanning less than ten days. Species were identified and as much extra information as possible was noted, including sex, juvenile birds and nest sites. The location of each siting was made using a handheld Global Positioning System (GPS). Analysis of territories was done using the BTO WBS guidelines (Marchant, 1994). This identifies areas of the river that are occupied by separate specific groups of birds over a number of visits.

Results and Discussion

Wetland Treatment Performance

Iron is the only metal found in highly elevated concentrations in the Pelenna minewaters. The sizing of the schemes was designed around the iron loading of each minewater. Alkalinity-producing cells were utilised where minewater within the treatment systems was net-acidic. Use of alkalinity producing cells at Garth Tonmawr and Whitworth A resulted in significant pH increases (Table 2). At the Whitworth No.1 site there has been a smaller pH rise during treatment; this system has no cells designed to specifically increase alkalinity. The change in pH in Whitworth No.1 is therefore presumably due to bacterially generated alkalinity.

The mean total iron concentration and iron loading of the minewater and wetland outlets is shown in Table 2. From this the percent removal of the iron loading has been calculated. Whitworth No.1 wetland has the least loading and of this only 82% is being removed. This is the lowest performance of the three systems. The mean outlet iron concentration of 4.26 mg/l is still causing some staining downstream in the Gwenffrwd. This was the first system constructed and consisted of four cells in parallel. It frequently had flow distribution problems resulting in reduced residence time and lowered treatment efficiency.

Table 2. Summary performance data for the Pelenna wetlands.

Wetland[1]	pH in	pH out	Fe inlet[2]	Fe outlet[2]	Fe loading inlet[3]	Fe loading outlet	Percent removal[4]	Removal per m^2 (5)
Whitworth No.1	6.30	6.87	23.9	4.3	9.5	1.6	82.0	8.1
Garth Tonmawr	5.80	6.85	28.6	1.9	47.2	3.0	94.7	7.8
Whitworth A	5.95	7.36	60.8	2.2	41.5	1.2	95.7	6.1

Notes: [1] Wetland data averaged over the following timescales:
Whitworth No.1: 1995 to 2001
Garth Tonmawr: 1999 to 2001
Whitworth A: 1998 to 2001
[2] Fe as total iron in mg/l.
[3] Fe loading in kg/day
[4] Percent removal of incoming iron loading
[5] as $g/m^2/day$

The Garth Tonmawr and Whitworth A wetlands received a much higher iron loading and have both removed approximately 95% of the incoming iron since their construction. Figure 2 demonstrates the iron loading at Garth Tonmawr and percent removal of the loading. The system had a period of lower performance eight months after construction for approximately six months. Since then the performance has increased and is now steady at 97 to 99% removal. The wetland copes with the range of iron loading as demonstrated by the fact that there has been no iron staining at the outlet for the past year.

River Water Quality

A stated objective of the minewater treatment project was to reduce the mean dissolved iron content in all the receiving watercourses to below the Environmental Quality Standard (EQS) limit of 1 mg/l. Table 3 contains the mean dissolved iron and pH values for each river monitoring site pre- and post- commissioning of all three phases of treatment. The mean dissolved iron concentration is currently below the EQS standard at all the sample points. The largest change in concentration is at BP5, G4 and G5, the sites immediately below the minewater discharges. The dissolved iron concentration has been significantly lowered ($p < 0.01$) at all the sites downstream of the minewater discharges except for the very bottom of the Pelenna. The pH has been significantly raised at all the sites downstream of the discharges, again this is especially evident a short distance downstream of the minewater discharges.

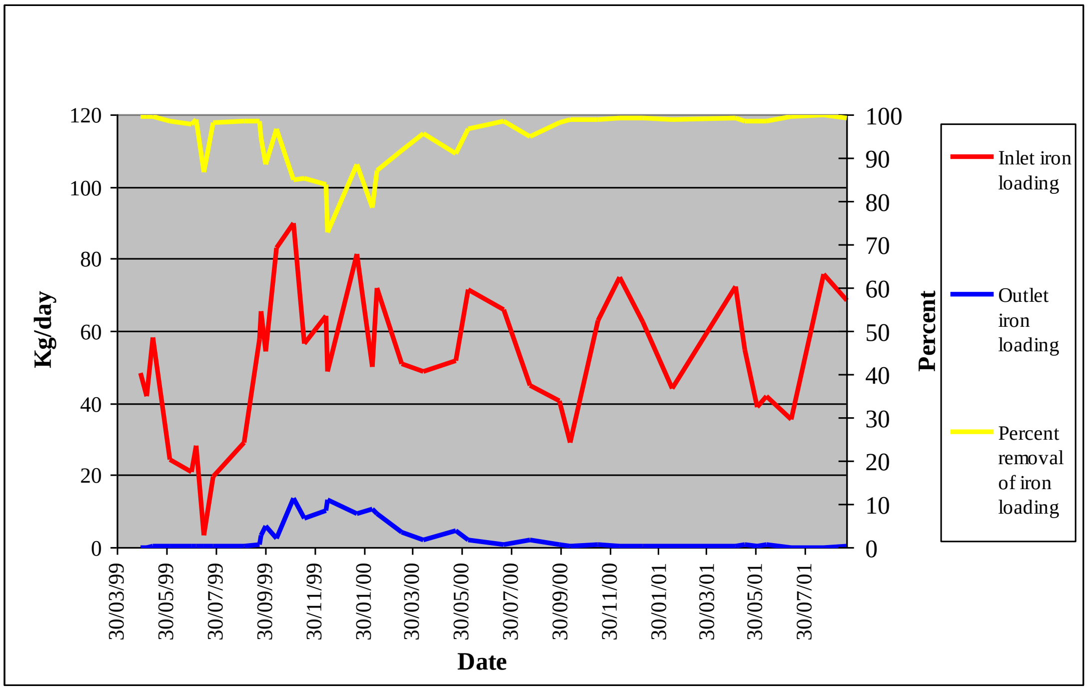

Figure 2. Iron loading and removal rate of the Garth Tonmawr wetland system.

Figures 3 to 5 demonstrate the changes in pH and dissolved iron at these sites following the construction of the treatment schemes. At site BP5 (Figure 3) immediately downstream of the Garth Tonmawr wetland system on the Blaenpelenna, the dissolved iron level in the watercourse has been below 1 mg/l on all the sampling occasions following treatment. The graphs for sites G4 and G5 (Figures 4 and 5) demonstrate the iron removal abilities of the wetlands. The two peaks in late 1998 and spring 2000 when the iron level was continuously above 1 mg/l were caused by ochre blocking the inlet pipes to the Whitworth A system. The minewater then discharged untreated into the Gwenffrwd at the original discharge point upstream of site G4. As it took a few months for the inlet pipes to be cleared this had an obvious detrimental effect on the watercourse. Iron peaks can be seen in the data as far downstream as site P2 at Efail Fach, approximately 3km downstream.

Site G4 shows a slight increase in pH once the minewater discharges were prevented from entering the Gwenffrwd without treatment (Figure 4). This was expected, as there is no longer the acidity production created by the oxidation of iron in the watercourse. Site G5 shows a much greater increase in pH following treatment (Figure 5). This site is downstream of the discharges from the Phase III wetlands, which contain two RAPS cells. The alkalinity generated from these RAPS cells raises the pH sufficiently to have a much greater buffering effect in the receiving water.

Table 3. Mean pH and dissolved iron concentrations in the rivers pre and post minewater treatment.

Site code	Location	pH (pre)[1]	pH (post)	Iron(mg/l) (pre)[2]	Iron(mg/l) (post)
BP3	U/S of minewater on Blaenpelenna	6.04	6.23	0.20	0.31
BP4	U/S of minewater on Blaenpelenna	6.37	6.65*	0.20	0.37*
BP5	100m D/S of Garth Tonmawr minewater on Blaenpelenna	6.07	6.66*	2.21	0.44*
FD3	Control stream	6.67	6.82	0.05	0.02
G3	U/S of minewater on Gwenffrwd	6.07	6.46	0.11	0.22
G4	20m D/S of Whitworth A minewater on Gwenffrwd	5.61	6.35*	10.71	0.92*
G5	400 m D/S of Whitworth A minewater on Gwenffrwd	5.51	6.70*	4.79	0.77*
G6	1 km D/S of Whitworth A minewater on Gwenffrwd	5.62	6.97*	2.56	0.50*
P1	2.5 km D/S of Garth Tonmawr minewater on Gwenffrwd	6.46	6.92*	0.30	0.17*
P2	1.8 km D/S of Gwenffrwd and Blaenpelenna confluence	6.40	6.84*	0.55	0.26*
P3	4km D/S of Gwenffrwd and Blaenpelenna confluence	6.76	7.09*	0.22	0.17

Notes: [1]pH pre and post construction of the three treatment phases.
[2]Dissolved iron in mg/l pre and post construction of the treatment scheme
*Denotes significance of change in post construction value at $P < 0.01$ based on temporal change analysis of step change in data.

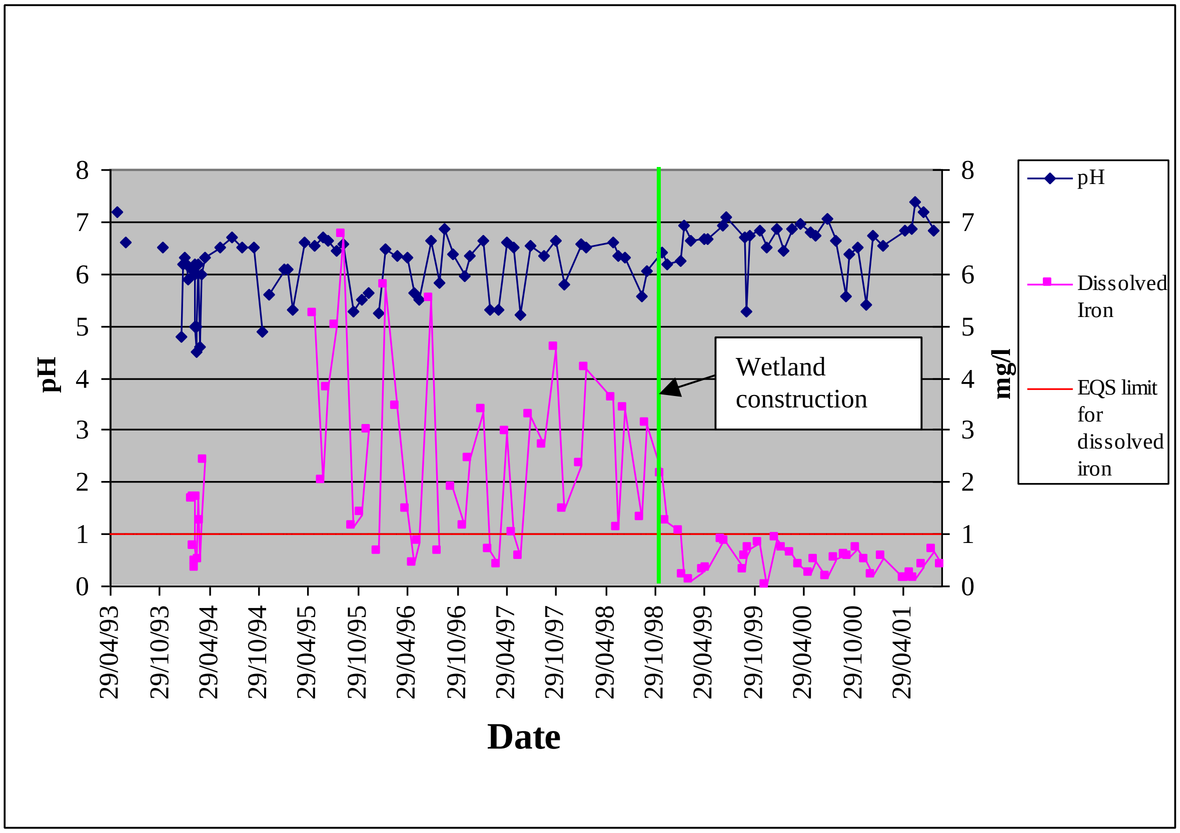

Figure 3. pH and dissolved iron at BP5, downstream of Garth Tonmawr treatment system

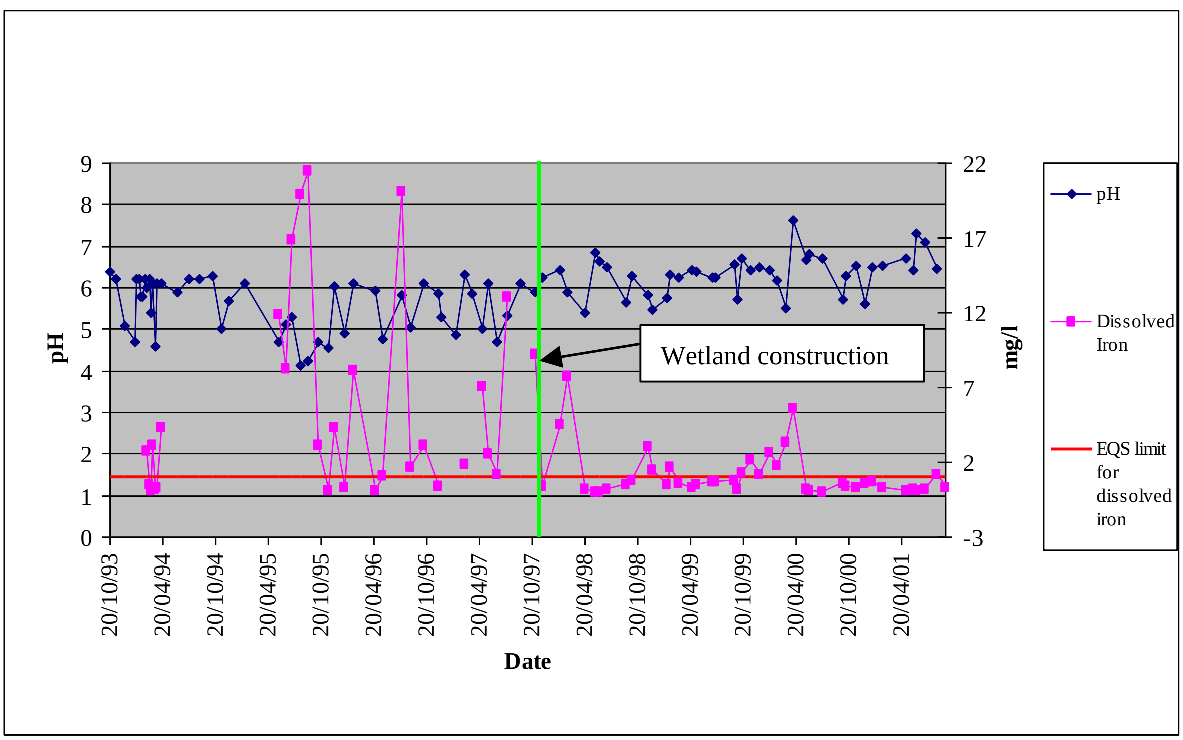

Figure 4. pH and dissolved iron at G4, downstream of Whitworth A minewater (original discharge and current overflow)

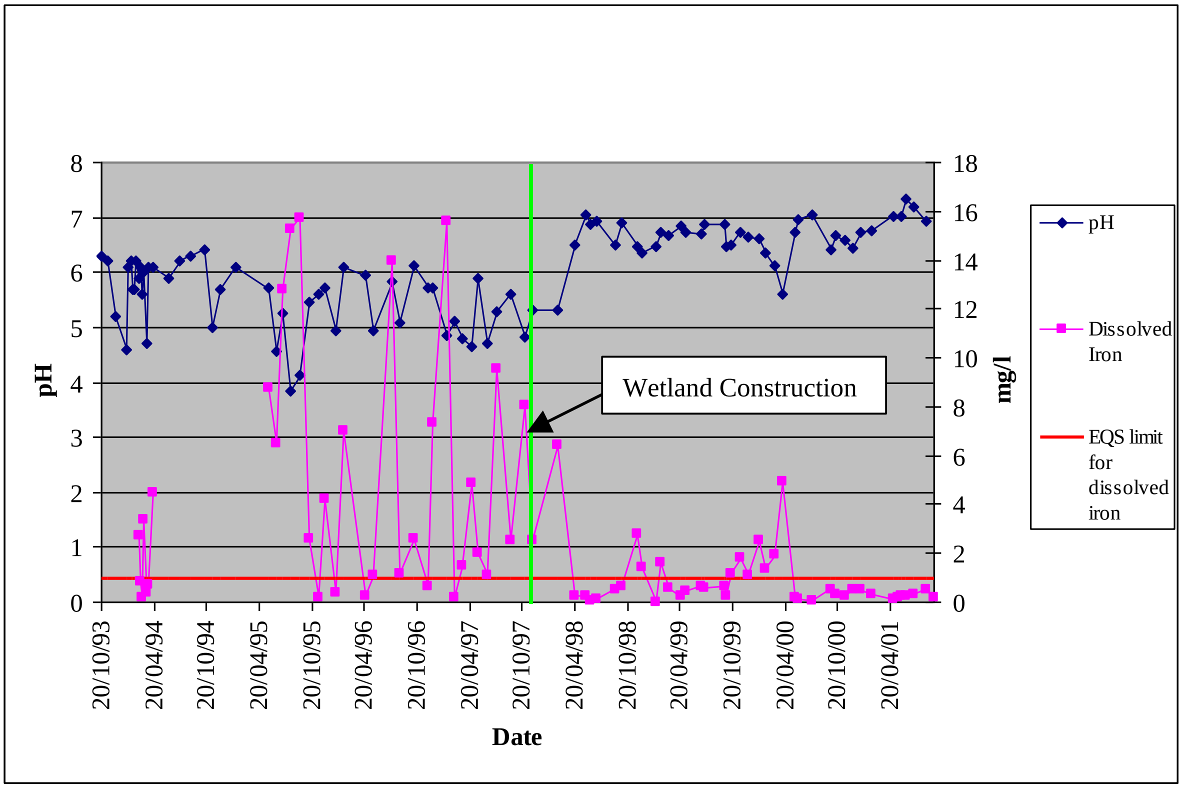

Figure 5. pH and dissolved iron at G5, downstream of the Phase III treatment scheme

Macroinvertebrate Populations

Macroinvertebrate assemblages were assessed in the spring and summer of each year. The total abundance of individuals at each site was used as a simple method of assessing the recovery of the population as a whole. The results from this method are similar to those shown by BMWP score and number of taxa. Variations in abundance over time and specifically following treatment were not obvious at some sites. Sites BP5 and G4 are immediately downstream of the minewaters, and respectively demonstrate the improvement in total abundance following minewater treatment (Figures 6 & 7).

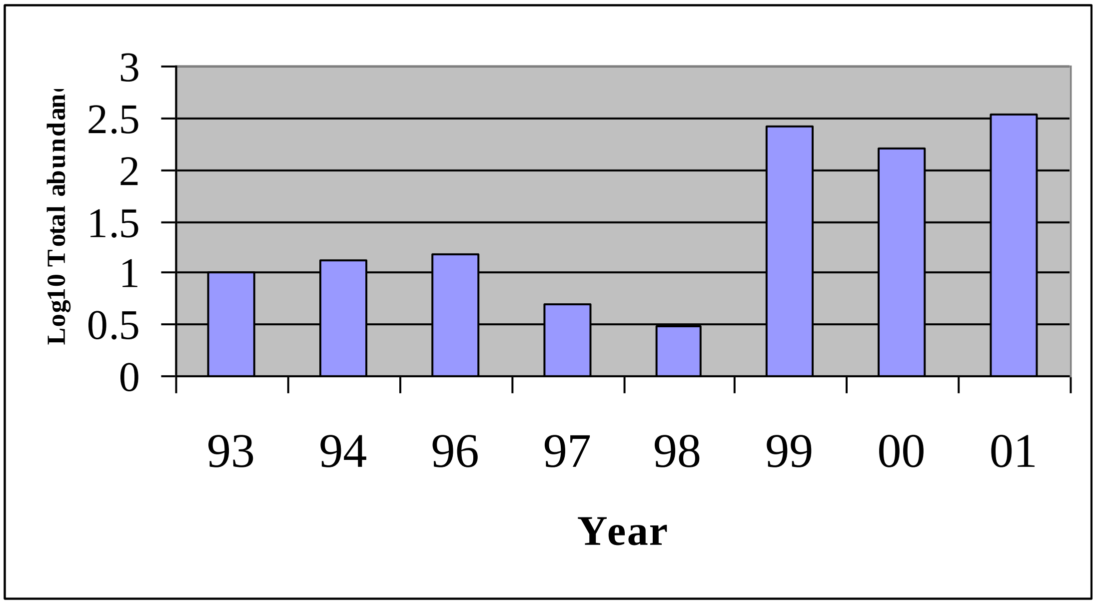

Figure 6. Summer total abundance data for site BP5

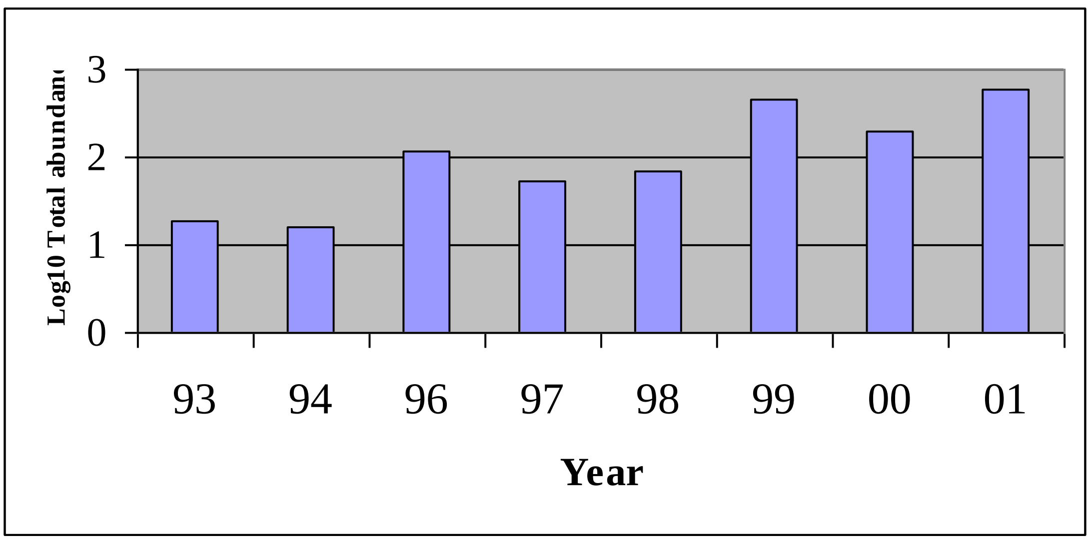

Figure 7. Summer total abundance data for site G4

The TWINSPAN classification was used to assign the sites into groups that are essentially similar in taxonomic composition. The groups identified can then be related to environmental variables, while specific indicator organisms are identified that govern membership of each group. Using this statistical tool, improvements over time can be assessed as the sites move from the high number groups to lower number. Table 4 shows the average values for the BMWP and ASPT scores, number of taxa and total abundance for the four groups (Von Reibnitz, 2001).

Table 4 Biotic indices data for the spring and summer TWINSPAN classification groups

	TWINSPAN group	BMWP[1]	ASPT[2]	Number of taxa[3]	Total abundance[4]
Spring	1	113.6	6.3	17.9	1013
	2	97.2	6.7	14.7	378
	3	58.0	6.3	9.3	167
	4	41.4	6.2	6.7	26
Summer	1	86.7	5.9	14.6	887
	2	82.0	6.0	13.5	810
	3	53.4	5.5	9.7	142
	4	24.5	4.7	5.1	16

Notes: [1]Mean Biological Monitoring Working Party (BMWP) score
[2]Mean Average Score per Taxon (ASPT)
[3]Mean number of taxa
[4]Mean Total abundance

Maps of the changes in TWINSPAN group are shown in figures 8 and 9. At the control sites FD3, A1 and A3 there have been few changes in group membership across the years. On the Blaenpelenna there has been a change from Group 4 to Group 3 at the upstream site in both spring and summer. In summer at BP5, downstream of the minewater, the improvements following treatment are obvious from 1999 onwards. However, the spring data do not show an improvement until 2001, possibly due to the increased environmental stress in spring caused by the more frequent acidic episodes. Furthermore, certain species that appear to return quickly in this catchment once the minewater pollution has been removed were abundant only in summer samples. This is due to the annual life cycle of these species and is likely to account for the more pronounced recovery seen in summer.

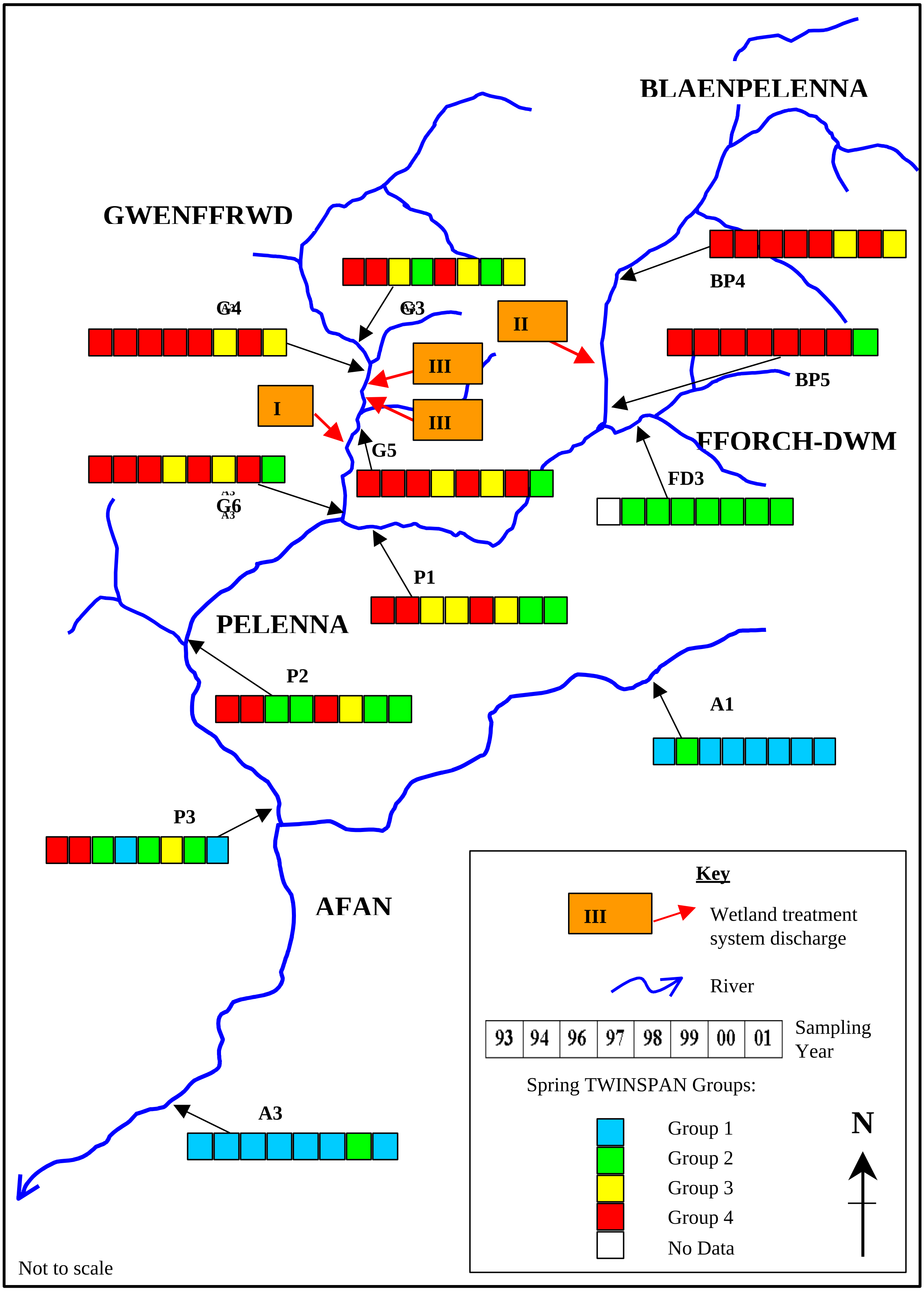

Figure 8. Spring TWINSPAN results

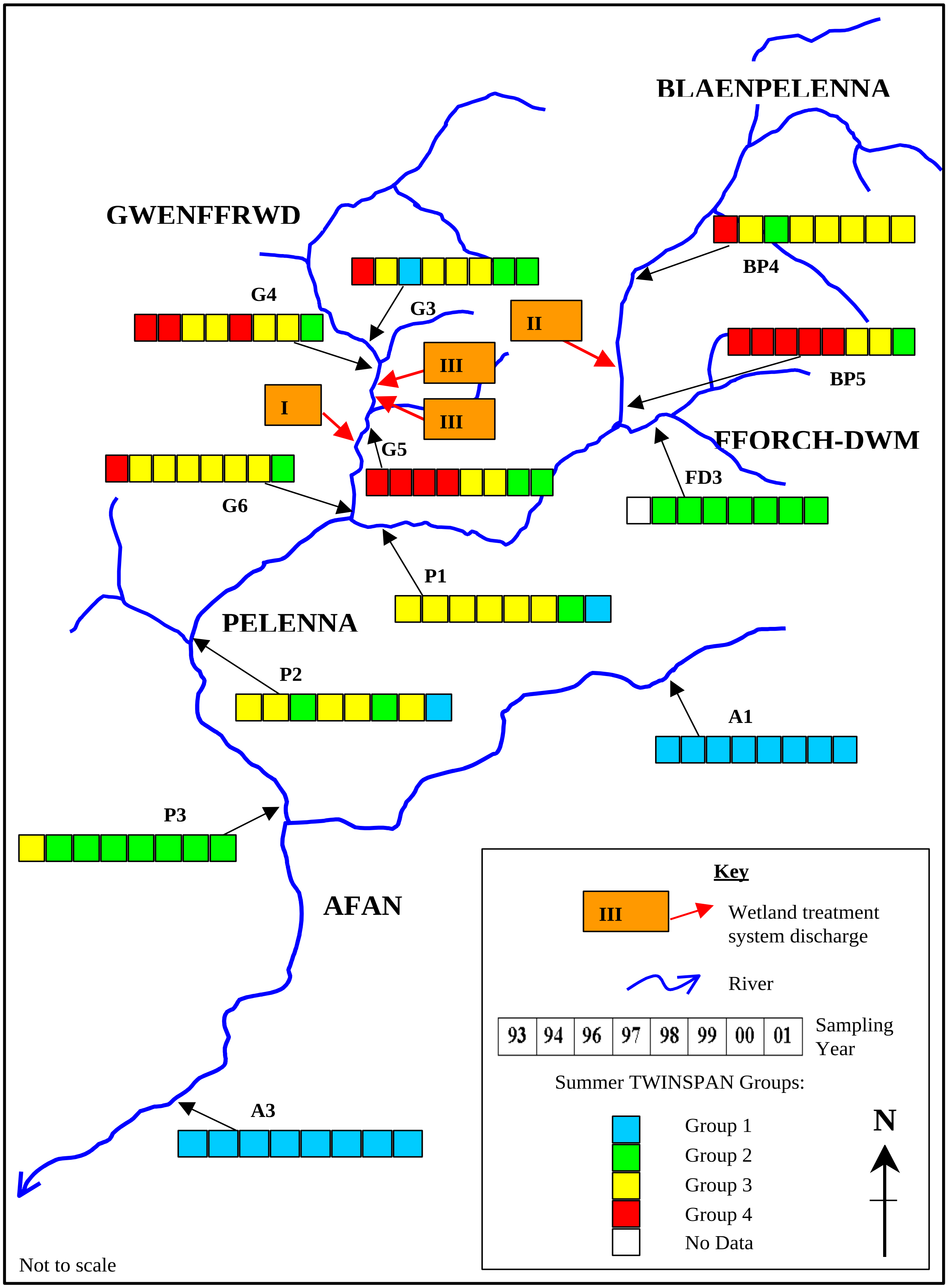

Figure 9. Summer TWINSPAN results

Ephemerella ignita, a species of mayfly, was the main species that characterised the recovery of this catchment. It exists in the control sites in fairly stable numbers but was not evident at any of the minewater-impacted sites. Following treatment of the minewaters, *Ephemerella ignita* were the first species to obviously recover. Nelson and Roline (1996) also found that the number of taxa in the Ephemeroptera order increased following minewater treatment along with Plecoptera and Trichoptera. Ephemeroptera were identified as being intolerant to elevated metal concentrations by Malmqvist and Hoffsten (1999) and Soucek *et al.* (2000). *Leuctra spp.* (stonefly) were also identified as indicators of the recovery of the Pelenna catchment, but the improvements were not as marked as those of *Ephemerella ignita.*

On the Gwenffrwd, a similar pattern emerges from the TWINSPAN analysis. Some recovery is seen upstream over the entire time period. A greater recovery is seen during both spring and summer below the minewater discharges following the main treatment in 1998. In spring 2000 the Whitworth A system, treating the most polluting minewater, became blocked with ochre for a period of a few months, discharging untreated minewater. This blockage, combined with the impacts of the natural underground diversion of the Gwenffrwd, caused a number of environmental stresses in the catchment. The iron levels in the watercourse, which were well above 1mg/l during this period (Figures 4 & 5), especially affected the invertebrates in spring. At all the Gwenffrwd sites during this period, the invertebrate population soon reverted to the pre treatment polluted conditions. In 2001, once these problems had been resolved, the invertebrates recovered quickly demonstrating the best improvements to date.

The TWINSPAN analysis also identified improvements in the macroinvertebrate populations further downstream, on the Pelenna. During both spring and summer improvement has been gradual over a number of years, as each minewater has been treated.

The TWINSPAN analysis and other biotic indices demonstrate the recovery of the invertebrate population in the catchment, although the recovery has been impaired by background episodic acidification. Nelson and Roline (1996) found that invertebrate populations recovered to comparable levels of upstream sites within two years. They suggested that aquatic communities impacted by metals, in the absence of degraded habitat and with nearby colonist pools, will recover quickly if low instream concentrations of toxicants are achieved. The limited upstream populations on the Pelenna are likely to slow down the recovery of the invertebrates, as they have to rely on recolonisation from downstream.

Fish Population

Figures 10 and 11 contain the observed and expected trout fry and parr densities in the catchment over the period of monitoring. Table 5 contains the National Fisheries Classification Scheme (NFCS) scores for 1993 and 2001 along with the expected score.

Table 5 Observed National Fisheries Classification Scores (NFCS).

Site	1993	2001	Predicted
P1	E	B	C
P2	D	A	D
P3	D	C	D
BP4	E	D	C
BP5	E	B	B
G3	F	F[2]	C
G4	F	B	B
G5	F	A	C
G6	F	B	C
FD3	A[1]	A	A

Notes: [1]Data for the Fforch Dwm (FD3) from 1994, as it was not sampled in 1993.
[2]Site G3 is inaccessible for fish due to a migratory barrier.

The Fforch Dwm (FD3), the control site for the catchment, has had a fairly stable fry and parr population except in 2000. This was most likely to have been caused by habitat loss due to erosion of a spoil tip. The site was ranked as grade A in the NFCS score throughout most of the years of sampling.

The Gwenffrwd and Blaenpelenna sites have all demonstrated significant improvements in the populations of fry and parr. Many sites have improved from having no fish or very few fish to having populations that meet or exceed the expected fish densities, in some cases within a year following minewater treatment. This improvement is also seen in the sites upstream of the minewater discharges, although the upstream Blaenpelenna site (BP4) is still below its expected NFCS population density. It has been noted that fish annually returned to the Pelenna and attempted to spawn (M.Brett, Fisheries Enforcement Officer, Personal Communication) but the water quality

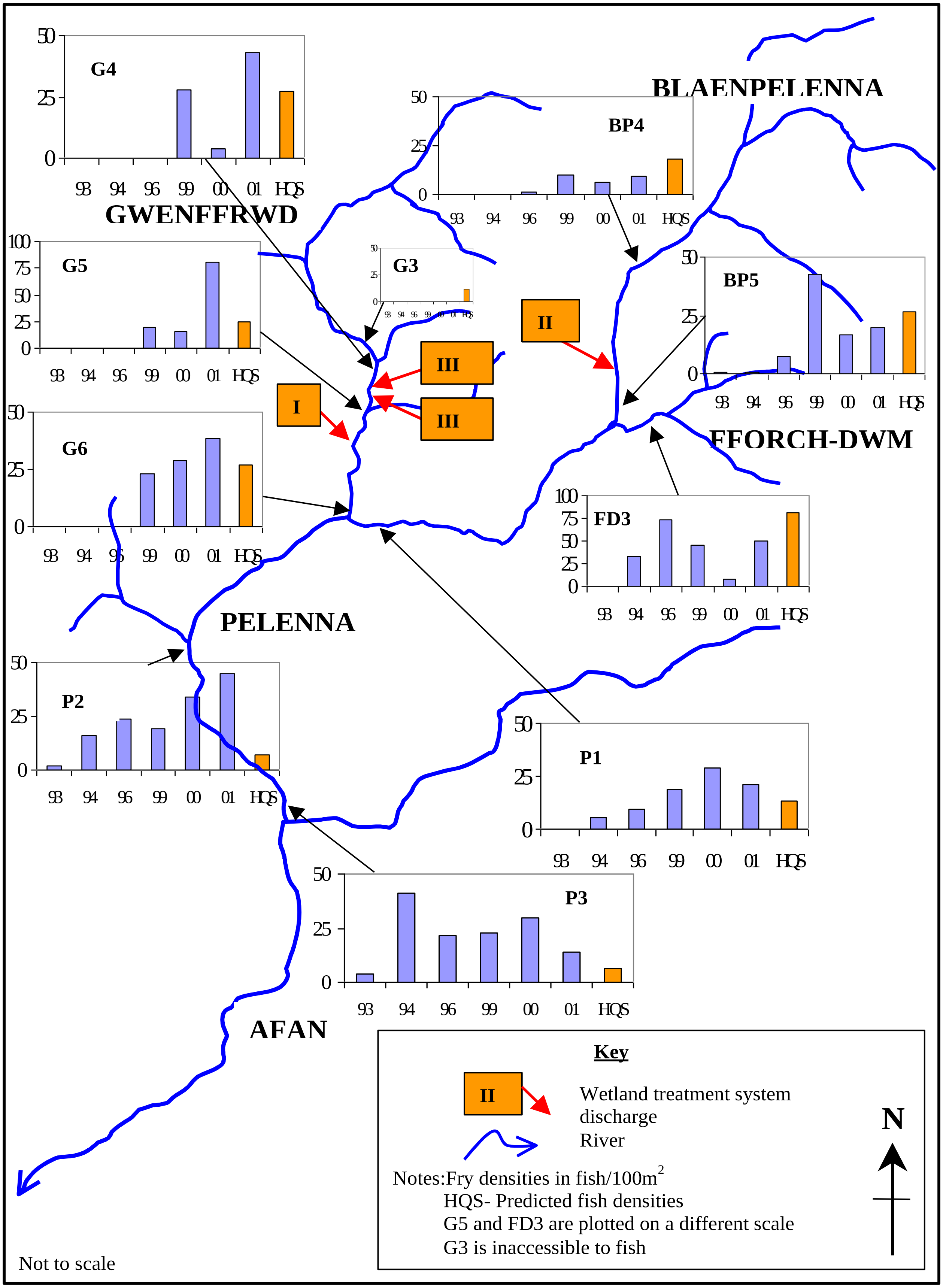

Figure 10. Observed and expected trout fry densities

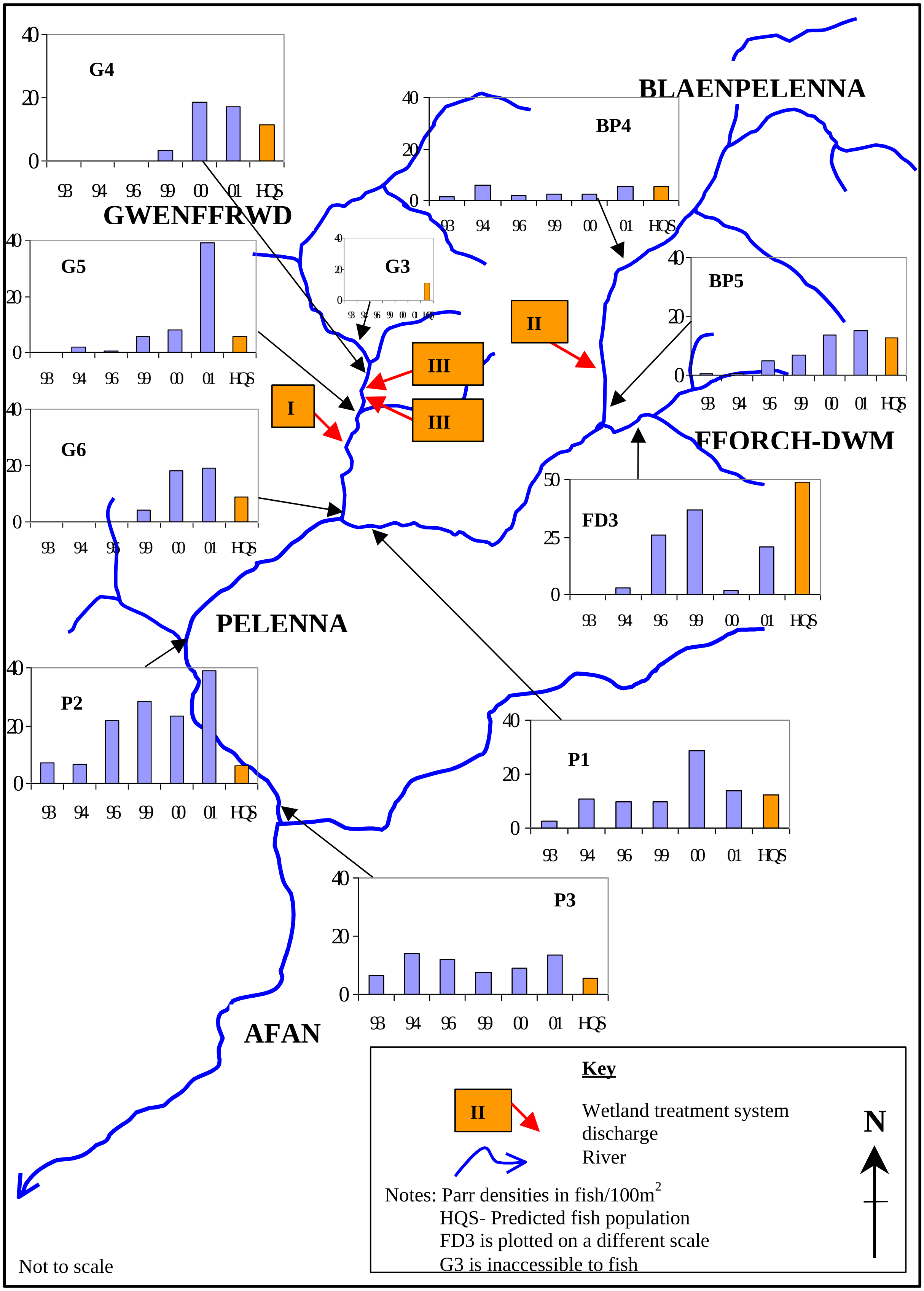

Figure 11. Observed and expected trout parr densities

impacts on the eggs and fry meant that few survived. Following the treatment of the minewaters the recovery of the fish has been quick as many more eggs and fry survive.

At site P2 on the Pelenna there was a large increase in the population of both fry and parr, again exceeding the expected densities. Further downstream at site P3 increases are again evident, but these are not so great as the existing populations were healthier due to the better water quality at this distance from the minewater discharges.

Riverine Birds

The riverine bird survey was undertaken in 1996 and 2001 to assess the effects higher up in the food chain, resulting from the improvements in water quality following minewater treatment. Table 6 shows the numbers of sightings of each bird species during the surveys. This does not represent the actual numbers of birds in the catchment, as the idea is to observe the birds more than once on separate visits.

The total number of sightings has markedly increased from 1996 to 2001. This is especially evident for the populations of dippers and grey wagtails. A territorial analysis was undertaken on the data and used to assess how many individual territories were held by each species. Grey wagtails (*Motacilla cinerea*) held 17 territories in 2001 compared to five in 1996. Five dipper (*Cinclus cinclus*) territories were identified in 2001 compared to none in 1996 (Wiseman, 2001). Due to their feeding habits, dippers are very good indicators of water quality as they feed exclusively within the watercourse on the invertebrate populations and occasional fish fry. Roberts (1996) estimated that the catchment could support five dipper territories if the water quality was improved. It now has this number of territories, indicating significant improvements in water quality.

Table 6. Riverine bird survey results

Stretch	Species	Total sightings 1996	Total sightings 2001
Pelenna	Dipper	4	27
	Grey Wagtail	15	46
	Pied Wagtail	-	3
	Mallard	3	3
	Grey Heron	1	4
	Kingfisher	1	-
Gwenffrwd	Dipper	-	8
	Grey Wagtail	1	23
	Pied Wagtail	2	1
	Mallard	2	6
Blaenpelenna	Dipper	-	8
	Grey Wagtail	13	66
	Pied Wagtail	5	9
	Mallard	2	13
Total sightings per survey year		49	217

Conclusions

The passive treatment of the minewater discharges on the Pelenna has been demonstrated to be very effective. The three phases of wetlands are removing the vast majority of the iron loading that they receive. The later two phases that treat the most polluting discharges are generally performing at a removal rate of around 95%. Significant increases in the pH of the discharges have also been achieved.

The river water quality changes observed as a result of this treatment performance are quite striking. A stated objective of the treatment project was to lower the mean dissolved iron concentration in the watercourses to below the EQS level of 1 mg/l. This has been achieved at all the monitoring points on the rivers.

Macroinvertebrate populations have started to recover, with increased total abundance and species diversity being observed at a number of the sites. The abundance of the mayfly *Ephemerella ignita* in particular has increased. Various biological indices have shown that this recovery is most obvious immediately below the minewater discharges. The recovery of invertebrates appears to be slower than that observed in studies elsewhere; this could be due to episodic surface-water acidification impoverishing upstream populations and therefore limiting recovery by downstream drift.

The trout populations have recovered more quickly. At some sites the numbers of fry and parr reached predicted densities within one or two years after minewater treatment. Prior to remediation, adult sea trout had attempted to spawn in the river but the ochre smothered gravels and poor water quality meant that few eggs or fry survived. Once the water and gravel quality improved, the populations were able to recover quickly.

With the increase in invertebrate populations a knock-on effect up the food chain to the riverine birds has been observed. Numbers and territories of grey wagtails and dippers have increased dramatically in the catchment. The dipper is especially important as an indicator species as it feeds exclusively in the aquatic environment and therefore requires clean water conditions.

The overflow problems experienced on the Gwenffrwd demonstrate how quickly the river water quality and macroinvertebrates could be impacted again by minewater. This indicates the need for the systems to be maintained in appropriate operating conditions.

The monitoring of the performance and environmental benefits of these passive constructed wetlands have demonstrated that they can be an effective, low cost and sustainable solution to ecological damage caused by abandoned mine drainage.

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