# The partial recovery of the metal polluted River Rheidol

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## Introduction

The fissures associated with the faults of the Lower Palaeozoic rocks of mid Wales have been infilled with quartz and baryte and in many areas this has been accompanied by ore minerals such as galena (lead sulphide) and sphalerite (zinc sulphide). These ores have been reputedly mined since pre-Roman times but the greatest mining activity was during the period 1750 to 1900. The industry had declined by the end of the last century due to foreign competition but some mines reopened for a short time during the 1914–18 war. The last mines to close in the Rheidol catchment were the Melindwr Mine and Rhiwfron Mine in 1922 (Carpenter 1924a) apart from some minor activity at Erw Tomau Mine which finished in 1927.

Lead mining in Wales has been described in detail by Lewis (1967) whereas the geology of the mining district is described by Jones (1922). The River Rheidol was in the area most affected by mining and about 43 mines were worked in the catchment. An outline map of the river with the locations of the mines is given in Fig. 1. Ore was separated from the crushed rock by water flotation and the water which contained dissolved metal salts and suspended solids were then discharged into streams. The degradation of the environment as a result of this mining activity can be summarized as outlined below.

1. Oxidation of the ore during extraction and weathering of spoil heaps produced lead sulphate and zinc sulphate which are soluble and toxic to many freshwater organisms (Carpenter 1924b).
2. The suspended solids of ore and rock produced by crushing and flotation were discharged into the river causing siltation which adversely affected the benthos. The spoil heaped on the banks of the streams was washed into the rivers resulting in an unstable river bed unsuitable for the establishment of vegetation (Rees 1937; Jones 1950).

3. There was an effect on the marine environment in the area effected by the freshwater discharge and zinc concentration, for example, of certain littoral organisms has been shown to be higher in this area (Ireland 1973).
4. Soils of the area were affected by deposition of ore particles by the river in the flood plain and by aerial pollution from smelting and windblown slime (sediment) in the vicinity of the mines. In such areas crops were adversely affected and there were occasional reports of poisoning of stock (Griffith 1918; Alloway & Davies 1971).

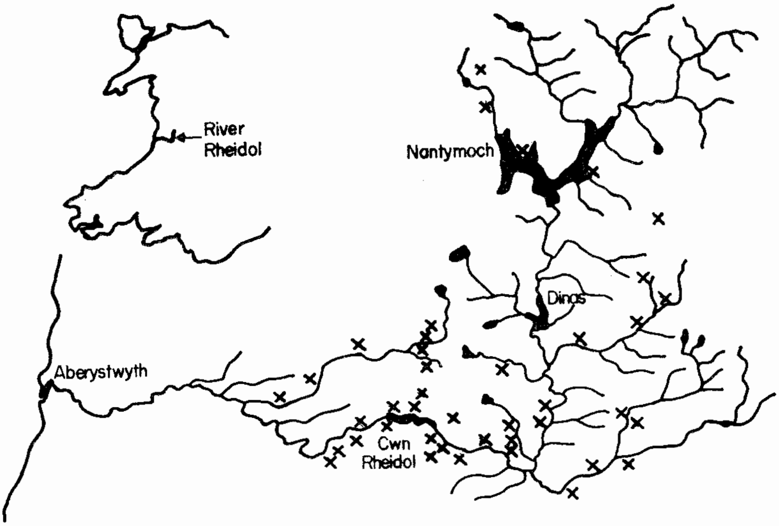


**Figure 1.** Outline map of River Rheidol showing location of mine workings (after Jones 1922 and Carpenter 1924).

5. When the mines were closed no attempt was made to landscape the area affected and they were left in a derelict condition. Because of the toxic nature and nutrient deficiency of the spoil heaps they did not become colonized with vegetation (Newton 1944).

Not all the legacy was on the debit side, however, and several lakes were created to supply water for the flotation process. These lakes are now used for angling and can be considered an asset to the environment.

The following account is primarily concerned with water pollution and its ecological effects. The recovery of the river since the decline of the mining industry is described to a stage where the fish population has virtually fully recovered yet the water quality is not yet regarded with confidence as entirely suitable for human consumption.

## Water quality

Grimble (1904) refers to the River Rheidol and the neighbouring Ystwyth as 'two sewers used almost solely for the lawless and selfish benefit of industries which could well afford to take proper means to effectually prevent the poisoning of the waters'. The only treatment known at that time, however, was settlement which could not have affected the metal salts in solution. Settlement lagoons were installed at some mines but these 'slime beds' were probably intended more for the reclamation of ore than the prevention of pollution.

There appears to be no record of water quality for the period when mining was at its peak. The first analyses are quoted by Carpenter (1924b) for the period when the mining industry was in its final stage of decline. She records a lead level of 0·2 to 0·5 mg/l in the lower reaches and after 1922 there was an apparent improvement with the lead not normally determinable, and even in times of flood not exceeding 0·1 mg/l apart from one occasion in March 1924 when a lead level of 0·4 mg/l was recorded. This was the last record of so high a degree of pollution. James *et al.* (1932) using more 'critical' methods of analysis found lead levels of 0·02 to 0·17 mg/l and zinc levels of nil to 0·3 mg/l in the main river. No records of water quality are known from 1932 until 1955 when preliminary work started on a hydro-electric scheme. Since then analytical work has been undertaken on a large scale by the Central Electricity Generating Board and the South West Wales River Authority (formerly the River Board). A comparison of lead and zinc content for the lower reaches only is given in Table 1. This tends to show

**Table 1.** Historical comparison of lead and zinc estimates for the lower reaches of the River Rheidol.

| | | Range in mg/l | |
|---|---|---|---|
| | | Pb | Zn |
| 1919–21 | (Carpenter 1924b) | 0·2 –0·5 | |
| 1922–23 | (Carpenter 1924b) | nil–0·1* | |
| 1931–32 | (James *et al.* 1932) | 0·02–0·1 | 0·14–0·30 |
| 1971–72 | (River Authority) | nil–0·04 | 0·20–0·83 |

* Plus one record of 0·4 mg/l in a flood in 1924.

that there was a pronounced improvement in lead content after the final closure of the mines in 1922 and that there has been an apparent further improvement since 1931–2, so that nowadays lead is not often detectable in the main river. Methods for zinc analysis were not developed at the time of the study made by Carpenter (1924b) and all that can be said about the zinc content is that there has apparently been no improvement from 1931–2 to the present day. Lead was the main metal extracted by the mining industry and whereas sphalerite is commonly found on the spoil heaps at the present time galena is only rarely found.

Direct comparisons in the quality of water in the catchment between one year and another are, however, of doubtful validity. Very low levels of these metals are being measured and the results of a sampling programme can be affected by a number of factors, e.g. the weather conditions, the location of the sampling station, the river flow, the form in which the trace metal may exist in the water, the nature of the sampling devices and containers and the stability of the samples. It is clear that a good deal more work requires to be done to standardize sampling techniques. Comparison of today's results with those published forty years ago should be made with great caution, particularly as analytical methods have changed. The current method is atomic absorption spectrophotometry.

The results of water analysis of the lower reaches of the River Rheidol are given in Table 2. As in all Cardiganshire rivers the water is slightly acid

**Table 2.** Water analysis for the lower reaches of the River Rheidol (at Penybont Bridge) based on seven samples taken in 1971–2.

| | Mean | Range |
|---|---|---|
| pH | — | 6·4–7·0 |
| Conductivity (μmho/cm) | 60 | 49–76 |
| Biochemical Oxygen Demand | 1·2 | 0·6–1·9 |
| Dissolved Oxygen | 11·5 | 10·3–13·6 |
| Hardness as $CaCO_3$ | 24·8 | 13–36 |
| Chlorides | 6·3 | 5–9 |
| Nitrates | 0·47 | 0·38–0·64 |
| Nitrites | — | nil–0·005 |
| Ammoniacal Nitrogen | — | nil–0·17 |
| Albuminoid Ammonia | — | nil–0·13 |
| Iron (total) | 0·95 | 0·46–1·90 |

(results expressed as mg/l except pH and Conductivity)

and very soft. This softness is a disadvantage as far as metal toxicity is concerned. The river shows no sign of organic pollution, the ammonia levels are normally low and the water is always well saturated with oxygen. The only town in the catchment is Aberystwyth which discharges its effluent to the sea near the estuary.

Levels of lead and zinc in the catchment are relatively low and results of sampling in 1971–2 are given in Table 3. The main sources of pollution in the middle and lower reaches are the Llywernog Mine on the Nant Llywernog, the Ystymtuen Mine on the Afon Tuen and the Goginan Mine on the Afon

Melindwr. The Cwm Rheidol Mine on the main river remains a very serious source of pollution and some deterioration in water quality downstream of the mine is thought to have taken place in recent years due to prospecting activities.

**Table 3.** Heavy metal content of River Rheidol at routine sampling stations based on seven samples taken in 1971–2.

| | pH | Hardness as $CaCO_3$ | | Zn | | Pb |
|---|---|---|---|---|---|---|
| | range | mean | range | mean | range | range |
| *Main river* | | | | | | |
| 1. Ponterwyd Bridge | 6·3–7·3 | 28 | 8–45 | 0·10 | 0·02–0·21 | nil–0·04 |
| 2. Below Cwm Rheidol Mine | 6·5–7·2 | 27 | 16–33 | 0·45 | 0·15–0·81 | nil–0·04 |
| 3. Below Capel Bangor | 6·4–7·5 | 34 | 20–72 | 0·41 | 0·20–0·83 | nil–0.04 |
| *Tributaries* | | | | | | |
| 4. Nant Llywernog | 6·6–7·7 | 37 | 19–53 | 1·08 | 0·40–1·28 | nil–0·04 |
| 5. Afon Tuen | 6·4–7·7 | 38 | 16–48 | 0·14 | 0·04–0·35 | nil–0·04 |
| 6. Afon Mynach | 5·4–7·2 | 41 | 13–68 | 0·21 | 0·05–0·43 | nil–0·10 |
| 7. Afon Melindwr | 6·6–7·0 | 44 | 36–52 | 0·81 | 0·60–1·10 | nil–0·10 |

(results expressed as mg/l except pH)

## The biological recovery

### BENTHOS

Studies of the benthos provide one of the earliest examples of the value of invertebrates as indicators of pollution. Carpenter (1924b) started her pioneer work after the First World War and between 1919 and 1921 she was only able to find 14 species consisting almost entirely of insect larvae and a few crustacean species. In 1922 there was an apparent improvement and 29 species were found including trichopteran larvae and a planarian species. Laurie & Jones (1938) surveyed the river in 1931 and 1932 and recorded 103 species—a considerable improvement, including molluscs and fish which had previously been absent. They noted no further change in 1936. Jones (1949) made a further study of the Rheidol in 1947 and 1948 and recorded 191 species but only 130 of these occurred in the main stream. Thus the recovery of the benthos and increase in species diversity has been comprehensively documented in this series of papers by workers at the University College of Wales, Aberystwyth. A comprehensive review of the early work including botanical work and work on neighbouring rivers is provided by Newton (1944).

A survey by A. Jenkins (unpublished) in 1965–6 indicated that the most abundant species were as follows:

PLECOPTERA
*Amphinemura sulcicollis* (Stephens)
*Leuctra inermis* (Kempny)
*Leuctra hippopus* (Kempny)

EPHEMEROPTERA
*Rithrogena semicoloratea* (Curt.)
*Baetis rhodani* (Pict.)

DIPTERA
*Simulium reptans* L. (local)

TRICHOPTERA
*Hydropsyche instabilis* (Curt.)
*Rhyacophila dorsalis* (Curt.)

Only one species was found which had not previously been recorded namely the trichopteran *Glossosoma conformis* Neboiss. This suggests that there has been little, if any, change since 1947–8. Indeed the main recovery appears to have been prior to 1931–2 and some of the apparent later improvement may well be due to a more thorough examination and better identification to species.

## FISH

Royal Commissions on River Pollution in 1874 and 1900 established that early in the nineteenth century the River Rheidol had been a healthy river abounding in fish. The destruction of the fishery appeared to have coincided with the introduction of fine grinding machinery by the mining industry. When Carpenter (1924b) surveyed the river in 1919 to 1921 she found the main river devoid of fish except for the occasional stray brown trout *Salmo trutta fario* from unpolluted tributaries or sewin (migratory trout) *Salmo trutta trutta* from the sea, and apparently these neither survived nor bred.

The first fish to become established in the main river were sticklebacks *Gasterosteus aculeatus* L. recorded by Carpenter (1925). An angling club called the Rheidol Protection Society was formed in 1930 when the trout fishery first showed signs of recovery and Laurie & Jones (1938) recorded that in 1932 brown trout were found as high up as Aberffrwd. Jones (1949) described the fish fauna in 1947–8 as decidedly poor and recorded stickleback, brown trout, sewin, eels *Anguilla anguilla* (L.) and some uncertain records of salmon *Salmo salar* L. In 1949 some minnows *Phoxinus phoxinus* (L.) made an appearance probably from introductions a few years previously from the River Dyfi (Jones 1950) but these fish have not survived. During this period the run of sewin was increasing each year but the salmon were much slower to colonize the river. Salmon were first established as present in 1952 when Mr R. L. Marston of the *Fishing Gazette* confirmed that a fish specimen from the River Rheidol was a salmon parr.

Restocking of the River Rheidol was advocated by the West Wales River Pollution Sub-Committee in 1935 and this received substantial local press coverage. It was stated that abundant fish food existed and that pollution was so slight and intermittent as to be harmless. Restocking was again advocated in 1945 when the Rheidol Protection Society combined with the Aberystwyth Angling Association. Subsequently the river was restocked with 2,000 brown trout in the spring of each of the years 1947, 1948 and 1949. Moreover, in 1950 about 50,000 fresh-water snails and 50,000 fresh-water shrimps were placed in the river. There does not appear to be any record of the success or failure of these projects.

Salmon restocking was advocated by Mr Cecil Hutchings in 1952 and a five-year-plan was adopted by the Angling Association. A total of 165,000 salmon ova was planted in the river between 1953 and 1956. Following the establishment of their salmon hatchery at Dolbantau on a tributary of the River Teify, the South West Wales River Board started a second salmon restocking project. Over one million salmon ova and unfed fry have been planted to date as shown in Table 4.

**Table 4.** Salmon statistics for the River Rheidol.

| | Restocking with ova and fry | Rod catch from statutory returns |
|---|---|---|
| 1952 | — | 0 |
| 1953 | 25,000 | 0 |
| 1954 | 40,000 | 0 |
| 1955 | 50,000 | 1 |
| 1956 | 50,000 | 1 |
| 1957 | — | 0 |
| 1958 | — | 2 |
| 1959 | — | 1 |
| 1960 | 107,000 | 4 |
| 1961 | 83,500 | 2 |
| 1962 | 74,000 | 16 |
| 1963 | 201,000 | 12 |
| 1964 | 252,000 | 12 |
| 1965 | 153,000 | 94 |
| 1966 | — | 134 |
| 1967 | 70,400 | 110 |
| 1968 | 63,000 | 34 |
| 1969 | 10,200 | 42 |
| 1970 | — | 81 |
| 1971 | — | 120 |
| 1972 | — | 123 |

The water bailiff's redd counts are not regarded as particularly accurate but the increase in redd counts from 5 in 1953 to over 300 in 1966 by the same experienced bailiff, reflects the increasing salmon population of the river. Similarly the increasing rod catch shown in Table 4 reflects an increase in salmon population. To what extent this increase is natural recolonization and to what extent it is enhanced by restocking is difficult to ascertain. There is some circumstantial evidence that the restocking had a substantial effect. The first restocking by the River Board took place in the 1960–1 winter when 107,000 salmon ova and fry were planted out followed by 83,500 in the winter of 1961–2. In 1965, which is four years after the first restocking

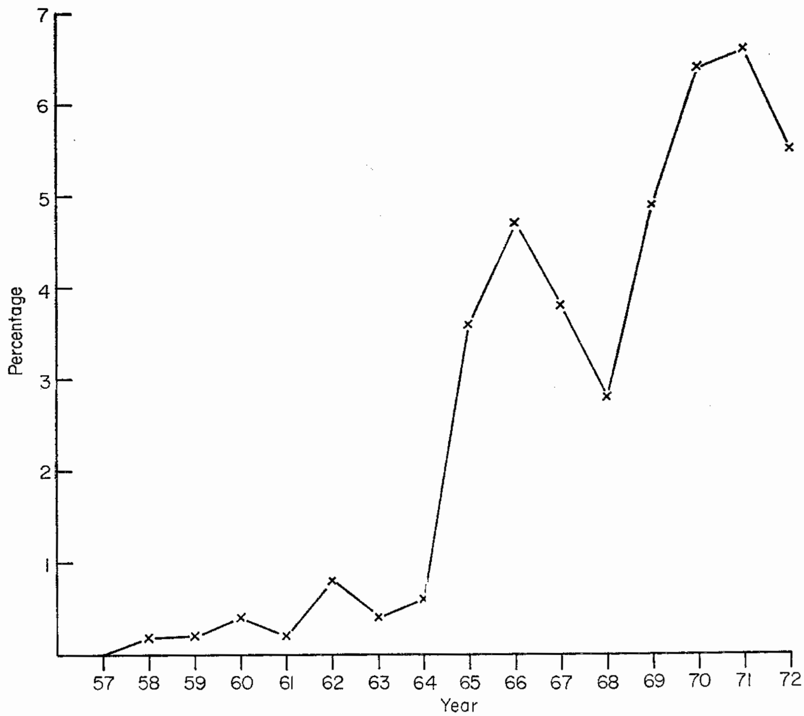


**Figure 2.** Rheidol salmon catch as a percentage of the total salmon rod catch for south west Wales.

and three years after the second restocking, the anglers' rod returns indicated a catch of 94 salmon consisting of small salmon (4-year-old) and grilse (3-year-old). This was a considerable increase over the 12 salmon reported for 1964. Salmon populations fluctuate considerably from year to year, and to allow for this the Rheidol salmon catch is expressed as a percentage of the total rod catch for all the rivers of south-west Wales in Fig. 2. This confirms the improving nature of the salmon populations, especially the 1965 increase. It does not seem likely that such a remarkable and sudden increase could have occurred without the boost given by the restocking project.

The statutory rod returns underestimate the rod catch because not all anglers make returns. Bailiffs' records indicate that 84 salmon were caught in 1969 and 208 in 1970 compared with 42 and 81 respectively listed on statutory returns. Thus the rod catch data in Table 4 is probably less than half of the true catch. Almost all the salmon are caught in the 12 miles of river below Cwm Rheidol reservoir and the yield of salmon is of the order of 20 per mile per annum which compares favourably with the best salmon rivers in south-west Wales. The poor salmon catch in 1968 is probably a reflection of the outbreak of Ulcerative Dermal Necrosis. The river has since recovered from this setback.

## The hydroelectric scheme

### BRIEF DESCRIPTION

The scheme was instituted by the Central Electricity Generating Board in 1958 and the works commissioned in 1961 and 1962. There are three stages and three reservoirs in this scheme which is outlined in Fig. 3. The upper

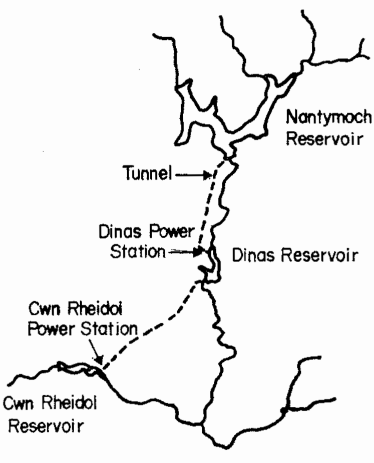


**Figure 3.** Plan of hydroelectric scheme

stage consists of Nantymoch reservoir and Dinas Power Station to which it is linked by the 4 km pressure tunnel. Nantymoch reservoir has an area of 275 hectares and enables the seasonal variation of rainfall to be regulated. Some streams outside the catchment are brought in by means of underground aqueducts. The total plant capacity of the upper stage is 13,000 kW.

The middle stage consists of the smaller Dinas reservoir which is linked to the main power station at Cwm Rheidol by a 4·4 km pressure tunnel. The total plant capacity of this stage is 42,000 kW.

The lower stage consists of Cwm Rheidol reservoir which was constructed to regulate the flow to the main river from the irregular generating periods. This stage has a plant capacity of 1 megawatt.

## PROMOTION OF THE SCHEME

There was considerable apprehension about the effect on pollution and fisheries when the details of the hydroelectric scheme were announced in the early 1950's. The South West Wales River Board sought protection which was subsequently embodied in the North Wales Hydroelectric Act of 1955, and in a supplementary parliamentary undertaking. The implications of these protective clauses and undertakings were as outlined below.

1. The Generating Board appointed pollution consultants including Emeritus Professor Lily Newton who has maintained a close and active interest in the River Rheidol for over 40 years. The Board undertook treatment measures where necessary during construction of the scheme and where it was anticipated that zinc and lead bearing strata and spoil would be exposed and disturbed. This normally took the form of dressing with limestone.

2. The river flow between Dinas reservoir and Cwm Rheidol reservoir was reduced as a result of the scheme so that there was less dilution for the polluted mine water emanating from Cwm Rheidol Mine. In order to compensate for this a treatment plant was constructed in the form of a limestone filter which is described by Treharne (1962). In addition the flow of water through the mine workings was reduced by works which prevented surface water entering a mine shaft on the plateau above the mine. This latter work was carried out in co-operation with Cardiganshire County Council.

3. The Cwm Rheidol reservoir inundated a considerable amount of spawning gravel for salmon and sea trout. In order to compensate for this loss, the Generating Board incorporated a Borland Fish lock to allow migratory fish to pass the Cwm Rheidol dam. They also built a fish ladder at the opposite end of the reservoir to enable fish to pass Rheidol Falls and thereby utilize a stretch of river up to Gyfarllwyd Falls which had previously been inaccessible. These developments indicate foresight at a time when the migratory fish population was negligible.

4. A restocking fund was agreed for Nantymoch reservoir and Dinas reservoir and stocking with 15,000 brown trout took place in 1963 and 1964. The fishing was reasonably good initially but then deteriorated over a period of years. Two research studentships were awarded at University College of Wales, Aberystwyth, for the study of the ecology of Nantymoch (Billington

1972). Very few brown trout survive in the reservoir for more than four years and the possibility of fish being affected by metal pollution caused by run-off from mine spoil is being considered (E. Howells *pers. comm.*). The restocking fund was also used to build three trout rearing tanks at Cwm Rheidol Power Station. Each tank has a capacity of 1,000 yearlings and rainbow trout *Salmo gairdneri* Richardson and brown trout are transferred to Dinas reservoir on a monthly basis. This put and take fishery has proved to be very successful. The rearing tanks were affected, however, by intermittent metal pollution during high rainfall periods following dry weather when a proportion of the fish would die. Recirculation of water is now carried out during such periods in order to avoid using polluted stream water.

## REGULATION OF FLOWS

The regulation of river flow below Cwm Rheidol Reservoir since 1962 has probably played an important part in improving water quality. The large oscillations in water quality at times of heavy rainfall following dry spells have been dampened sufficiently by the regulation to reduce the levels of toxic metals.

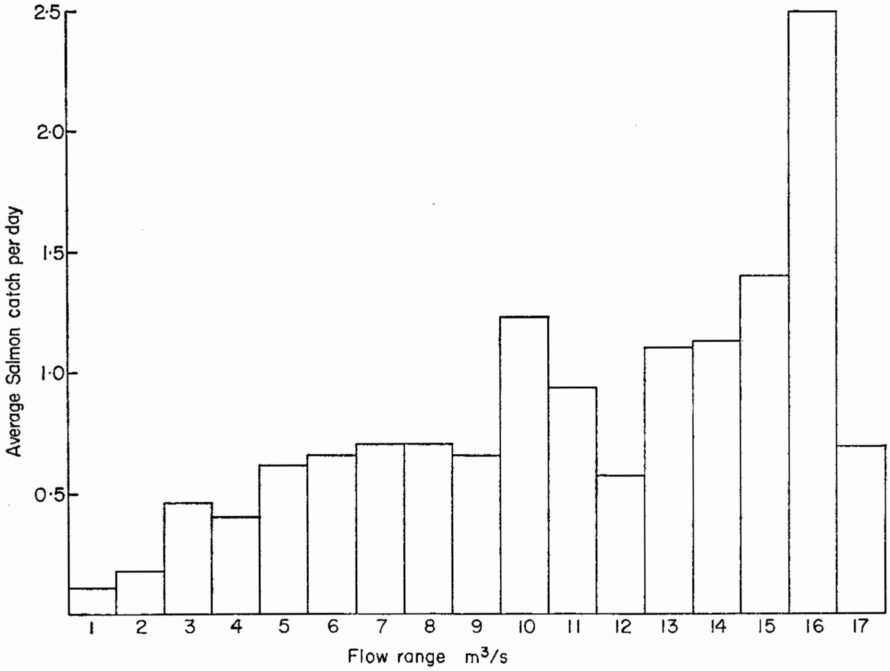


**Figure 4.** Relationship of salmon catch and flow for the River Rheidol 1966–1971.

Prior to regulation the river bed was unstable and supported hardly any rooted vegetation. The vegetation consisted of only small patches of algae and bryophytes on the more stable stones. After regulation the river bed became stabilized and vegetation such as water crowfoot *Ranunculus* sp. and water starwort *Callitriche* sp. became established. The regulated flows probably benefited the whole food chain in the river and may have resulted in an improved production of salmon parr. Indeed this may well have contributed substantially to the apparent success of the River Authority restocking project.

The compensation flow of 1·87 $m^3/s$ is frequently augmented in the summer months by generating water. This often results in good angling conditions during dry weather when neighbouring rivers are experiencing very poor angling conditions. Conversely, but less frequently, a spate provides good angling conditions for neighbouring rivers which may not be experienced by the River Rheidol due to impoundment. A study of the relationship between river flow and angling success (River Authority Annual Report 1972–3) confirms that angling success for salmon increases with increased flow, as shown in Fig. 4. The average salmon catch is particularly poor at flows of less than 3 $m^3/s$ which includes the flow range most frequently occurring.

## Future exploitation of natural resources

### MINERALS

In 1968 a number of companies started to show interest in prospecting for minerals in the Rheidol and neighbouring catchments. This development was viewed with alarm by the River Authority and the Generating Board. Any disturbance of ores or spoil or release of mine water could increase pollution. A close watch was therefore kept on these activities. An example of the dangers to the river of even preliminary prospecting occurred in October 1969 when a bulldozer levelling a site for a drilling rig caused the collapse of the front of a sealed off adit at Cwm Rheidol Mine. The 'blow out' of underground water contained 3,106 mg/l suspended solids, 1,500 mg/l iron, 230 mg/l soluble zinc and 148 mg/l soluble lead. Fish in the river were killed, and the river bed down to Cwm Rheidol reservoir was covered with yellow ochre. The company involved was convicted for the pollution but the consequences remain today. The Generating Board's limestone filter became blocked with ochre and was rendered ineffective. Renewal of the filter media allowed only of temporary relief and the filter became gradually silted up again. Typical analytical results for mine water entering and leaving the filter for before the 'blow out' and after are given in Table 5. The opening of the sealed adit has apparently increased the flow of water to the filter, and in allowing access of air, may have accelerated oxidation resulting in a higher concentration of metals in solution.

**Table 5.** Analysis of mine water entering and leaving the C.E.G.B. filter at Cwm Rheidol Mine.

| | pH | Zn | Pb |
|---|---|---|---|
| 23 May 1969 | | | |
| entering | 3·5 | 22·5 | 0·06 |
| leaving | 6·0 | 2·6 | nil |
| 5 June 1973 | | | |
| entering | 3·2 | 50·0 | 0·07 |
| leaving | 3·6 | 45·0 | 0·03 |

(results in mg/l except pH)

Mine water is exempt from the statutes (Rivers (Prevention of Pollution) Acts 1951–1961) if discharged in the same quality as when raised from underground. The River Authority applied to the Secretary of State for Wales for Orders revoking this exemption. A Public Enquiry was held in 1970 and subsequently the Secretary of State approved the application and made the appropriate Orders. This strengthens the River Authorities' powers to control pollution in the catchment. It was stated at a Public Enquiry that it was not the intention of the River Authority to stop mining in the area but only to ensure that discharges comply with reasonable standards so that the receiving waters are not polluted.

## WATER SUPPLY

Routine water samples are taken by the River Authority at Nantymoch reservoir and its principal feeder streams. Typical results for reservoir water near the dam for the period May to November 1972 are given in Table 6. There appears to be no significant difference in metal content at different depths but zinc concentrations are higher near the submerged Bryn-ar-arf mine. The results in Table 6 indicate that the metals are usually within the World Health Organization International Drinking Water Standards of 1·0 mg/l for copper, 0·1 mg/l for lead and 5·0 mg/l for zinc. It is sensible, however, to utilize water which is less polluted than Nantymoch if available. Thus although Cardiganshire Water Board have an allocation of water in

Nantymoch reservoir, they prefer to abstract water from two unpolluted tributaries of the reservoir.

**Table 6.** Analysis of Nantymoch water based on six samples from May to November 1972.

| | Mean | Range |
|---|---|---|
| pH | 5·2 | 5·1–5·3 |
| Cu | — | nil–0·04 |
| Fe | 0·37 | 0·28–0·54 |
| Pb | — | nil–0·01 |
| Zn | 0·066 | 0·03–0·10 |
| Cd | nil | nil |

(results in mg/l except pH)

The Water Board is interested in the water quality of the lower reaches of the River Rheidol and has instigated a sampling programme in collaboration with the River Authority in order to assess its suitability for water supply. Interest has also been shown in abstracting water from the river gravels of the lower reaches but because of possible metal pollution (particularly the levels of lead), the matter is still under consideration.

A recent report by the Water Resources Board, the Wales and Midland Study (1971), proposes a considerable enlargement of Nantymoch reservoir and its joint operation for transferring water to regulate the River Severn and for the generation of electricity as at present. This proposal is currently the subject of careful consideration and investigation. Some of the aspects being studied are (a) the effect of reduced flows on the dilution available for mine effluents (b) the effect of reduced flows on salmon angling success and fish migration and (c) the possibility of a deterioration in the quality of water at Nantymoch due to an enlarged reservoir flooding more mines and spoil tips.

## FISHERIES

Future development is possible along the following lines.

1. Dinas Reservoir has been developed as a successful 'put and take' fishery by the C.E.G.B. When the demand for more fishing is sufficient the next stage would be to similarly develop Nantymoch Reservoir. This would be a difficult prospect, however, because of the large size of the reservoir, its unfavourable water quality, and the very large fluctuations in water level.
2. The reservoir at Cwym Rheidol contains immature, and at times, mature migratory fish and not a great deal of angling is carried out there. There is

currently a proposal to develop the lake as a brown trout fishery through restocking. This will require careful consideration because of the possibility of high predation by the brown trout on the juvenile migratory fish resident in the reservoir and which pass through the reservoir.

3. The main river between Rheidol Falls fish ladder and Gyfarllwyd Falls is not yet fully utilized by migratory fish. There is a tendency for migratory fish to 'home' to the part of the river in which they originated and the colonization of this section of the river can be expected to continue gradually.

4. Gyfarllwyd Falls on the main river and Mynach Falls on the Afon Mynach both form obstructions to migratory fish. The provision of fish ladders is not practicable at the present time and in any case no work should be done which would detract from their aesthetic qualities. It would however, be possible to develop the water upstream by stocking with unfed fry. It would first be necessary to find out if smolts could survive the migration down the falls. If not then smolt traps could be installed upstream and the smolts transported manually in oxygenated tanks to sites downstream. A similar trapping and trucking scheme is operated in the upper reaches of the River Towy (Howells & Jones 1972).

The recreational use of the River Rheidol and its reservoirs is currently almost exclusively angling. There is an increasing interest in other water-based sports and if the population continues to increase one can foresee demands requiring the integration of these sports in the Rheidol catchment.

## Concluding remarks

The main recovery of water quality after the cessation of mining activities was a natural process. Man's active role has been largely to control new activities in order to prevent any further degradation of the environment. The three major potential threats to the river have been the hydroelectric development, the recent mineral prospecting and the proposals for water supply. So far as the hydroelectric scheme is concerned the C.E.G.B. has shown a highly responsible attitude and have minimized the effect of their activities on the environment. Moreover, the controlled flows have probably benefited the river ecology whereas the creation of three reservoirs has provided a new amenity.

The abstraction of water or the transfer of water to other river systems from the upper reaches of a river is potentially harmful. In the case of the River Rheidol the loss of water might mean (a) less volume for diluting the more serious mine effluents such as at Cwm Rheidol Mine; (b) the reduced flow might adversely affect angling success as indicated by Fig. 4; (c) the reduced flow might cause a reduction of wetted area and result in a reduced biological production which could affect the juvenile migratory fish. From an ecological point of view it would be preferable to regulate flows and abstract water from above the tide (Iremonger 1970; Howells & Jones 1972).

At the time of writing there are no major exploratory works for metals being undertaken in the Rheidol catchment. The possibility remains however, that further interest will be shown should the world price of some of these metals continue to rise. So long as the human population increases and governments are committed to a growing economy then the demand for minerals will increase until the resource is exhausted. It is normally technically feasible to treat polluted mine water to a standard which will reasonably safeguard river systems and this should be one of the conditions imposed on those seeking to exploit the mineral resources of this country. The cost should be borne by the company concerned and the capital and running costs should be taken into account in assessing whether the operation is an economically sound enterprise. It would be undesirable to allow the activities of one section of the community to take place at the expense of another and every effort should be made to prevent the River Rheidol from degenerating to the sterile conditions of the nineteenth century.

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