Freshwater life

Martyn G Kelly, Trevor D Cris, Ben Lamb and Brian Whitton

Introduction

Without the River Tees there would be no Teesdale and so, whilst much of the attention in this book is focussed on the plant and animal life in the fields and fells, we should not ignore either the river or the numerous tributary streams that feed it. Cow Green Reservoir, too, plays an important part in the story of Upper Teesdale, not just because of the ways in which it has altered the landscape and habitats in the upper valley, but also because the decision to impound the river precipitated many significant ecological studies and, ironically, raised the profile of the Teesdale rarities beyond a small band of botanical cognoscenti.

The River Tees was the first British River to receive a detailed biological survey (by Butcher and colleagues in the mid-1930s). This was followed in the 1970s and 1980s by studies of the upper reaches of the main river and its tributaries by Durham University and the Freshwater Biological Association (later Institute of Freshwater Ecology and now Centre for Ecology and Hydrology). Since the previous edition of this book, further studies have investigated a wide range of factors including gravel, heavy metals, availability of salmonid spawning habitat and water colour.

The upper tributaries of the Tees range from torrential streams, fed at times of peak flow mainly by surface run-off, to calcareous streams with some or much of their water from limestone springs. Those with the most water from springs are the ones which vary least in flow and have the highest calcium concentrations. The drier the weather the higher the calcium concentration of water in the upper Tees, which can reach 30 mg/litre or more, and can be considered to be 'hard', whereas in wet weather the concentration may fall well below 10 mg/litre and thus considered 'soft' (see Table 1).

Substance	Inflow	Outflow
Calcium	3.50 - 37.2	6.40 - 8.90
Magnesium	0.39 - 1.75	0.60 - 0.90
Sodium	2.10 - 3.96	2.40 - 2.88
Potassium	0.24 - 1.47	0.30 - 0.44
Chloride	3.00 - 5.00	4.20 - 4.90
Sulphate	7.20 - 16.30	7.80 - 10.20
Nitrate-nitrogen	0.00 - 0.15	0.09 - 0.16

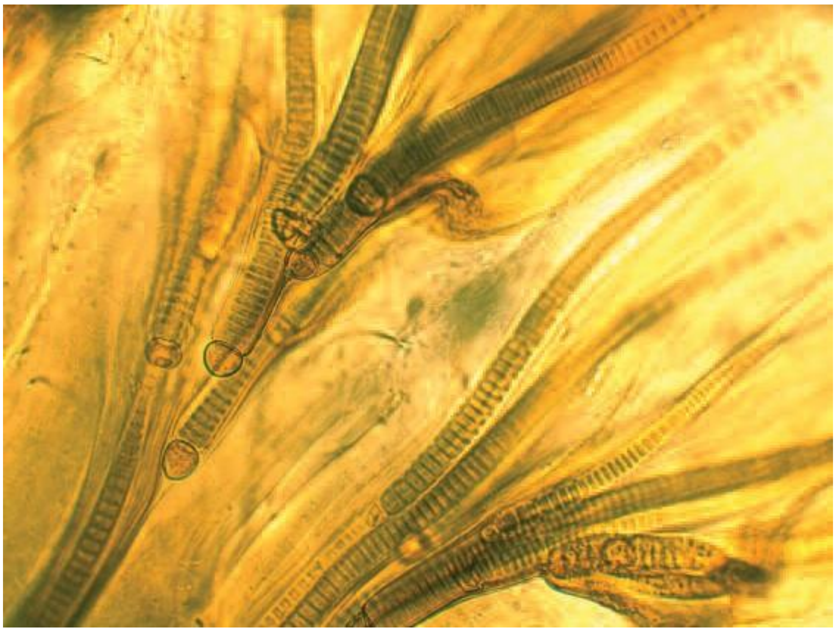
Table 1: Range of concentration (mg/litre) of selected chemical susbstances in the River Tees at the inflow and outflow of Cow Green reservoir. For each substance the range of values observed between April 1975 and March 1976 is shown. Note that the reservoir evens out the fluctuation (from Crisp, 1977).

The Tees is unusual amongst British rivers in being comparatively large at a relatively high altitude (550 m). It has a steep headwater slope and is extremely flashy. Butcher et al. (1937) noted that at times the rise in water level was so rapid that the flood resembled a tidal wave and the first waters of a spate are very turbid. This wave was known locally as 'the roll' and it was generated by rapid snow melt or severe downpours following longer periods of dry weather. The severity of the spates has been reduced somewhat by the reservoirs in Baldersdale and Lunedale, and since the construction of Cow Green reservoir the wave has not occurred. Nonetheless, the Tees in spate is still spectacular.

Algae

The algae form a large but often neglected part of the biodiversity of Britain and Ireland, accounting for about three quarters of all the photosynthetic species. The extent of the diversity of Upper Teesdale streams is illustrated by a survey of a single 10 m length of Harwood Beck in 1992 to 1993 (Kelly, 2006). Four visits to the site over the course of the year yielded between 16 and 45 species per visit, with a total of 70 species in an area of about 90 m² of the stream bed. Diatoms (Bacillariophyta) represented the greatest number of species, but green algae (Chlorophyta) and blue-green algae (Cyanobacteria) were also well represented. In addition there was one record of a freshwater red alga (Audouinella hermannii).

The blue-green algae of Upper Teesdale are of particular interest because of their prominence in the upper part of streams combining drainages from limestone and peat-rich soil. Slapestone and Red Sikes are the best places to see these algae. Unlike the nuisance species of lowland lakes and reservoirs, the Teesdale species dominate in water with very low nutrient concentrations for much of the year. Rivularia forms dark-green or brownish hemispherical colonies which range from 1 mm to about 2 cm on the upper surface of pebbles and small rocks.



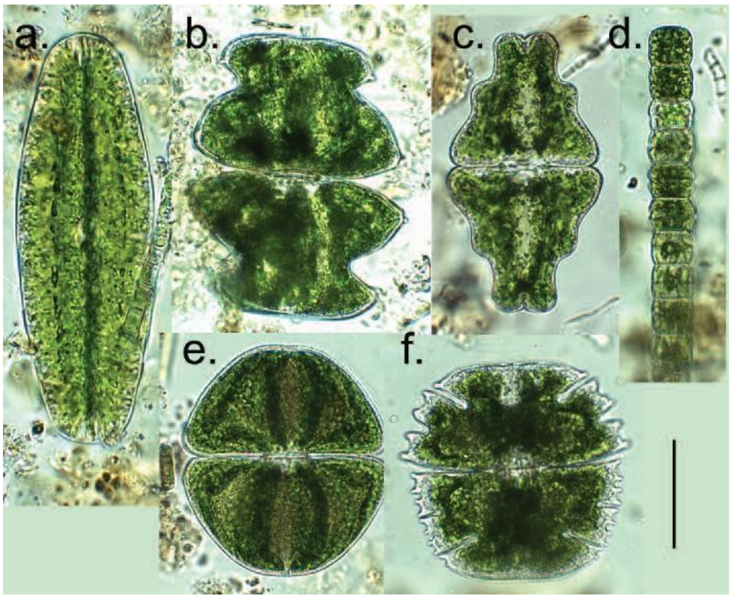
Microscopic view of filaments of the cyanobacterium *Rivularia* from Sand Sike, Upper Teesdale. The light-coloured cell at the base of each filament is a heterocyst, responsible for nitrogen fixation. The base of each filament is approximately 10 micrometres (= 1/100th of a millimetre) in diameter. © Martyn Kelly

Another species, Schizothrix lardacea, forms reddish mats on the stream bed and may partly explain how Red Sike got its name. Colonies of another blue-green alga, Nostoc commune, are often intermingled with mosses at the edge of the calcareous streams. Both Nostoc and Rivularia can fix atmospheric nitrogen and so are less dependent on dissolved nitrogen in the water.

The ecology of these organisms has been studied by Brian Whitton and co-workers from the University of Durham over a number of years. Rivularia and other blue-green algae in the region use the phosphorus in organic compounds formed by the breakdown of peat (Livingstone & Whitton, 1984). This may explain their abundance in the uppermost stretches of streams where there is a good supply of this from peat drainage. Whilst concentrations of dissolved phosphorus in the calcareous streams are normally very low (often less than 1 mg/litre), there are short periods, especially during early spring, when organic phosphorus is much higher, sometimes reaching concentrations over 1 mg/litre for short periods. When this happens, the Rivularia colonies release filaments which glide over the surface of the rock and then aggregate to form new colonies. These can often be seen in May as tiny, almost black, spots.

The Freshwater Biological Association collected samples of phytoplankton — the algae suspended in the water — after the dam closed in June 1970 (Atkinson, 1998). Since then the phytoplankton has been dominated by diatoms, which are characterised by beautifully sculpted cases of silica known as frustules. The first found to be common was Tabellaria flocculosa var. flocculosa, which is also common in the surrounding streams and pools. This and other early colonists were probably washed into the reservoir from the catchment, whereas later arrivals such as Aulacoseira italica were probably introduced in other ways such as on the feet of birds. Phytoplankton other than diatoms which have been recorded include the blue-green alga Oscillatoria (now recognised as Planktothrix), desmids and colonies of the green alga Sphaerocystis.

Desmids are not just found in the plankton of Cow Green reservoir. Boggy pools, such as those beside the Pennine Way between Widdy Bank Farm and the bottom of Cauldron Snout, are also rich habitats for this large group of algae which are most abundant in soft water and acidic habitats.



A selection of desmids from a boggy pool beside the Pennine Way in Upper Teesdale: a. *Netrium oblongum*; b. *Micrasterias oscitans (*var*. mucronata)*; c. *Eurastrum didelta*; d. *Desmidium* cf*. aptogonum*; e. *Cosmarium ralfsii*; f. *Micrasterias truncata*. © Martyn Kelly

Desmids are green algae, mostly unicellular (though a few form filaments) and with a central constriction dividing the cell into two ‘semi-cells’. They are best sampled by taking a handful of submerged Sphagnum cuspidatum from within a boggy pool and squeezing the brown humic water into a sample container. As they are relatively large, they can be easily seen and identified using low and medium- power objectives on a compound microscope.

Bryophytes and higher plants

The late Reverend H G Proctor provided one of the best records of the aquatic vegetation prior to flooding (Proctor, 1971). The hard Whin Sill rock at the top of Cauldron Snout formed a low natural dam creating a slow-flowing stretch of the Tees, known as the Weel, which resembled a long, narrow mountain lake, very different from most upland rivers.

This was reflected in the flora, which resembled that of a much lower stretch of river. Proctor’s list of plants includes species of Sparganium, Potomageton, Myriophyllum, Callitriche aquatilis and aquatic Ranunculus. He was the first to find the water sedge (Carex aquatilis) in the Tees catchment, which was also discovered below Middleton-in-Teesdale by Mrs T Dent. The Weel has unfortunately gone and macrophytes in the reservoir are sparse and almost entirely limited to a few fringing rushes and sedges.

Below Cauldron Snout, however, we find a flora much more typical of an upland river. Here the current is extremely fast, and few angiosperms can survive except in sheltered pools at the edge. Those that do occur are found on rocks and boulders and are dominated by aquatic mosses. One bryophyte worthy of particular mention is Schistidium (formerly Grimmia) agasizzii. Until Nigel Holmes found it in the Tees it was known only from Ben Lawers in Scotland. In the Tees it was found to be quite abundant upstream of Middleton, where it was frequently fully submerged in very fast currents (Holmes, 1976).

The effects of Cow Green reservoir can also be seen below the dam. Armitage (1977) noted an increased cover of bryophytes after the dam was closed and Holmes and Whitton (1981) suggested that this was due to a raising of the minimum flow rather than a decrease in the number of floods. Subsequently plant growths have increased still more in some middle stretches of the river.

Invertebrates

The invertebrate fauna of the Upper Tees is dominated by insects, particularly stoneflies (Plecoptera) and mayflies (Ephemoroptera). 25 of the 35 British stonefly species have been found in the Upper Tees system (Brown, Crag and Crisp, 1964). There have been numerous studies on various insect groups and also on the downstream drift of aquatic invertebrates. Some of the most intensive have been studies of the fauna of the Cow Green reservoir (Armitage, 1978).

An increasing number of trained volunteers is monitoring the health of invertebrate life in the Upper Tees as part of The Riverfly Partnership. This national scheme trains volunteers to gather, sort and record invertebrate samples using a standardised method and set of equipment. The Riverfly Partnership's interest focuses on three key groups of riverflies: the up-wing flies or mayflies (Ephemeroptera), caddisflies or sedges (Trichoptera) and stoneflies (Plecoptera). Volunteers collect, identify and count the nymphs and larvae of these groups and the data they collect are used to generate a simple index of the ecological quality of the site. If this index falls to a level that suggests that there may be a problem, the Environment Agency and the Tees Hub Co-Ordinator at the Tees Rivers Trust are both alerted. This results in an investigation which attempts to identify the reason for the alert.

The Tees Riverfly Partnership volunteers have experienced both the best and the worst. A highlight was the discovery of hundreds of casts from mass- hatchings of large Plecoptera in the Greta and watching bullheads ambush and devour unsuspecting olives in the sample tray. Collecting a sample from the Tees at Piercebridge and finding nothing where four weeks earlier there had been a wealth of life was, by contrast, a low point. Both illustrate the rewards and importance of citizen science in helping us to understand and monitor the health of the Tees.

Two of the most spectacular invertebrate species are the white-clawed crayfish (Austropotomobilis pallipes) and the large mayfly (Ephemera danika).

Left: native white-clawed crayfish (*Austropotomobilis pallipes*) from a survey in Upper Teesdale and, right, a specimen of the introduced signal crayfish (*Pacifastacus leniusculus*). © Ben Lamb

The white-clawed crayfish resembles a small lobster and is found in various parts of the Upper Tees and in some of its major tributaries. In recent years its survival in the Tees catchment has been threatened as a result of escapes of the invasive North American signal crayfish (Pacifastacus leniusculus). The signal crayfish is a large, polytrophic crustacean which has invaded waterways across much of Europe (Findlay et al., 2014). This animal is larger and more aggressive than its native cousin and outcompetes it for food and habitat. Additionally, and far more seriously, it carries the crayfish plague, Aphanomyces astaci. It is this invasive Oomocyte fungus that has impacted white-clawed crayfish throughout most of the Tees to such an extent that only a few isolated populations of the native species still remain in Upper Teesdale.

Adult mayfly (missing one tail) near Beckstones Wath bridge near Mickleton
© Sara Cox

The large mayfly is notable both for its large-size and for the synchronised emergence of the adults. In the 1930s Butcher and colleagues found it to be uncommon in the Tees and recorded it only at the lowland site, Eryholme. It now occurs in Cow Green and in the River Lune and in some years large swarms of adults have been seen near Cotherstone.

Fish

The upper Tees is a game fish, rather than a coarse fish, river. Before the days of industrial pollution and abstraction in its lower reaches, it was a major salmon and sea trout river. Between 1904 and 1912 the annual catch by commercial nets in the history was 7,239 salmon and 5,522 sea trout and rod anglers took about 500 salmon and 30 sea trout each year. However industrial developments from about 1920 onwards virtually destroyed the migratory salmonid fishery within a decade.

Following the collapse of the major Teesside industries in the late 1970s and 1980s, the pollution load was reduced, and the recovery of salmon and sea trout stocks began. Continued improvements to water quality, particularly in the estuary, brought about by strong regulation from the Environment Agency and its predecessor, the National Rivers Authority, has led to a gradual recovery of the salmon and sea trout stocks, to the extent that juvenile salmon are now abundant and widespread throughout most of the Tees catchment. Despite a relatively low level of angling activity, the annual declared rod catch for salmon has shown a steady rise over the past 20 years.

Some of the upper tributaries, including Egglestone Burn, Bowlees Beck and the rivers Lune and Balder have become established as very important spawning and nursery streams for both salmon and sea trout. However, High Force presents an insurmountable barrier for migratory fish.

European eel from Scur Beck near Lartington © Ben Lamb

Within the upper reaches of the river Tees eel is found as far upstream as High Force, minnow occurs upstream of Cauldron Snout, bullhead occurs well up into the headwaters and brown trout is found throughout almost the entire length of the river. Butcher et al. suggested that grayling was introduced to the Tees in about 1880 and in the 1930s its upstream limit was between Piercebridge and Rokeby. However it has increased its range and now occurs at least as far upstream as Middleton-in-Teesdale. Stone loach occurs in the main river at least as far upstream as Middleton, and is also found in the rivers Lune and Balder.

Perch has been introduced to Hury reservoir and the rainbow trout is an introduction in both Lunedale and Baldersdale reservoirs. Rainbow trout have escaped from the reservoirs and for a short period of time in the late 1990s managed to breed successfully in Carl Beck and some even reverted to the migratory Steelhead form. However, it appears that this population has now disappeared, as juvenile rainbow trout have not been observed for at least the past decade.

The wild brown trout in the upper Tees tend to be small, typically about 100 g each, though a few larger fish are caught each year. Since the construction of Cow Green reservoir, fish in the reservoir have grown rapidly and specimens of over 1.8 kg were taken in the early years after impoundment.

Invasive Non Native Species

Invasive Non-Native Species (INNS) pose an enormous threat to global biodiversity. Waterways are particularly susceptible to INNS. Aside from the signal crayfish (above) a number of highly invasive plant and animal species are already present in the upper Tees, both in the water itself as well as on the riverbanks. Himalayan balsam (Impatiens glandulifera), Japanese knotweed (Falopia japonica) and giant hogweed (Heracleum mantegazzianum) are present and the Tees Rivers Trust is co-ordinating efforts to control them. However, there are other species that pose a great threat to the ecology of the river. Of particular note are salmon fluke (Gyrodactylus salaris) and killer shrimp (Dikerogammarus haemobaphes). The Tees biosecurity plan (2014) sets out measures to avoid their introduction as well as actions to contain them and ensure their swift eradication.

Visitors to Upper Teesdale should be aware of the risk of both importing and exporting invasive species. It is important that clothing and equipment, in particular walking shoes, canoes and angling gear, is checked for any foreign matter, cleaned and dried.

How have the reservoirs influenced aquatic life in Upper Teesdale?

In addition to altering the flow regime (see above), Cow Green and the other reservoirs of Upper Teesdale have had a number of other effects on the biology of the Tees and her tributaries. Impounding a huge quantity of water in one of the coolest parts of the country also affects the temperature of the river, due to water's high specific heat capacity. This means that there is not just a narrower range of flows, but also a narrower range of temperature recorded.

The difference between coolest and warmest temperatures in the Tees below Cow Green dropped by 1 – 2 °C, which may not seem a lot, but one consequence is to delay the warming of the river water in Spring by about a month which, in turn, delays the development of young trout. However, Crisp et al. (1983) went on to show that any reduction in growth rate due to lower temperatures was actually offset by other side-effects of the dam (such as a less harsh flow regime) to result in an increase in the total density of fish downstream.

Patrick Armitage (2006) has shown significant shifts in the types of invertebrate found in the Tees below Cow Green, with a decrease in taxa that are adapted to a harsh hydrological regime, as might be expected. Maize Beck, a tributary which joins just below Cauldron Snout, and which has a natural flow regime, shows many fewer changes over the same time period.

The reservoirs also have major effects on the movement of gravel by the river. Gravels provide habitat for phytobenthos and invertebrates, a growing medium for macrophytes and spawning medium and juvenile habitat for fish and fry. They also have a great influence on the geomorphology of the river, forming pools, riffles, banksides and bars.

Brook lamprey, a species found in local becks such as Wilden Beck near Cotherstone.
© E J Langton-Airey

The presence of several reservoirs in Upper Teesdale has had a significant impact both on the mobility of gravels through the system as well as on the flow that provides the energy to move, form, deposit and erode gravel from flood plains and banksides. Rayner and Girvan (2010) estimate that the impoundments on the Balder and Lune systems have collectively reduced salmonid spawning habitat potential by 900,000 eggs. They also note the loss of spawning downstream due to lack of replenishment. Work to augment gravel in the Balder was carried out below Hury Reservoir in 2007 by the Environment Agency and again in 2012 by the Tees Rivers Trust.

References

- Armitage, P D (1977), Invertebrate drift in the regulated River Tees and an unregulated tributary, Maize Beck, below Cow Green dam. Freshwater Biology **7:** 167-183.
- Armitage, P D (2006), Long-term faunal changes in a regulated and an unregulated stream – Cow Green thirty years on, River Research and Applications **22:** 957-966.
- Atkinson, K (1998), 'The initial development of net phytoplankton in Cow Green reservoir (Upper Teesdale): a new impoundment in Northern England', pp 30-43, in Round F E (ed.), Algae and the Aquatic Environment, Biopress, Bristol.
- Brown, V M, Cragg, J B & Crisp, D T (1964), The Plecoptera of the Moor House National Nature Reserve, Westmorland. Transactions of the Society for British Entomology **16:** 123-134.
- Butcher, R W, Longwell, J & Pentelow, F T K (1937), Survey of the River Tees, Pt III, Water Pollution Research Technical Paper № 6, HMSO.
- Crisp, D T (1977), Some physical and chemical effects of the Cow Green (Upper Teesdale) impoundment. Freshwater Biology **7:** 109-120.
- Crisp, D T, Mann, R H K & Cubby, P R (1983), Effects of regulation on the River Tees upon fish populations below Cow Green Reservoir, Journal of Applied Ecology **20:** 371-386.
- Findlay, J D S, Riley, W D & Lucas, M C (2014), 'Signal crayfish (Pacifastacus leniusculus) predation upon Atlantic salmon (Salmo salar) eggs.', Aquatic conservation: marine and freshwater ecosystems, **25:** 250-258.
- Rayner, S and Girvan, J (2010), Tees Reservoir Flows and Gravel Project, Pre-Feasibility Report, Report to the Environment Agency, Royal Haskoning, Newcastle.

- Holmes, N T H (1976), The distribution and ecology of Grimmia agassizii (Sull. & Lesq.) in Teesdale. Journal of Bryology **9:** 275-278.
- Holmes, N T H & Whitton, B A (1981), Phytobenthos of the River Tees and its tributaries, Freshwater Biology **11:** 139-168.
- Kelly, M G (2006), 'A comparison of diatoms with other phytobenthos as indicators of ecological status in streams in northern England, 139-151', Proceedings of the 18th International Diatom Symposium (edited by A Witkowski), Biopress, Bristol.
- Livingstone, D & Whitton, B A (1984), Water chemistry and phosphatase activity of the blue-green alga Rivularia in Upper Teesdale streams, Journal of Ecology **72:** 405-421.
- Proctor, H G (1971), Aquatic macrophytes of the Weel of the Tees, The Vasculum **56:** 59-66.