IMPROVING WATER QUALITY ON THE RIVER WHARFE FROM OUGHTERSHAW TO THE OUSE:

A CITIZEN SCIENCE PROJECT

iWharfe 2020: chemical and biological (diatom) evidence for nutrient pollution in the River Wharfe

Yorkshire Dales Rivers Trust

Addingham Civic Society Environment Group

Ilkley Clean River Group

iWharfe2020: chemical and biological (diatom) evidence for nutrient pollution in the River Wharfe based on data from samples collected in 2020

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Executive Summary

- iWharfe2020 is a citizen science project. On the 24th August 2020 two sets of water samples were collected from 50 sites along the full length of the River Wharfe and from 10 selected tributary sites.
- Following a significant rain event on the day before sampling, riverflow was high. However, river levels remained the same at all sites during the time period samples were being taken.
- One set of samples was sent to ALS Ltd for faecal bacteria analysis. The results of these analyses were reported previously (Battarbee et al. 2021). The second set of samples was used for water chemistry. It included samples analysed in the field for pH and dissolved oxygen and samples delivered to CEH Lancaster for nutrient and alkalinity analysis.
- In the weeks following the 24thAugust diatom samples were collected from 46 sites of the 50 main river sites and riverfly samples were taken from 18 sites along the river.
- Here we report on the results of the chemical and biological analyses, focussing especially on the nutrient and diatom data. Our objectives were to use these data to assess the ecological condition of the river and identify sources of nutrient pollution.
- **Although the data only provide a snapshot in time they clearly show that phosphate-P discharges from the Ilkley STW, probably in combination with similar discharges from the Ben Rhydding and Burley/Menston STWs a short distance downstream, are the single most serious sources of nutrient pollution on the river.**
- The diatom data also indicated nutrient pollution of the river from sources in or close to Grassington. The Grassington STW final effluent outfall is likely to be a significant source of P but the evidence suggests there are additional sources of nutrient pollution upstream of the STW outfall.
- Only a small number of tributaries were included in the iWharfe survey but the results indicate that in many cases they are significantly more polluted than the main river by both phosphate and, in some cases, nitrate. Diffuse nitrate pollution is especially apparent in becks, such as Collingham Beck, with catchments characterised by arable land-use.
- Using the Water Framework Directive classes for ecological status, the diatom data indicate that the Wharfe main river has a “high” status from its headwater to Ilkley and a “good” or “moderate” status from Ilkley to Tadcaster. No ecological assessment from Tadcaster to Cawood was possible owing to the lack of appropriate substrates for diatom sampling in this, the lowest reach, of the river.
- Introducing phosphorus removal treatment at Otley, Thorp Arch and Wetherby in recent years has proved effective and we recommend the installation of similar P-removal units at Ilkley, Ben Rhydding and Burley/Menston STWs.
- Since our survey in August 2020 the Environment Agency has conducted a new survey of the Wharfe and put together a “Weight of Evidence” assessment, proposing that a part of the river should be designated as a “Sensitive Area” under the Urban Wastewater Treatment Directive. Should the proposal be successful plans to remove nutrients from the Ilkley STW discharge will be required and implemented by 2030.

- Although nutrient pollution of the main river is dominated by point source discharges from STWs, nutrient pollution of tributary becks is caused more by diffuse pollution from agriculture, septic tanks and surface runoff. Enforcement of rules designed to protect watercourses from farming and septic tank discharges is needed.
- Whilst the results presented here highlight the importance of controlling P discharges from the Ilkley STW final effluent outfall, further work is required to establish whether the frequent but intermittent discharges from the storm overflows also contribute to the problem of nutrient pollution at this point in the river.
- A grant from Ilkley Town Council to fund a project designed to address this question has recently been received. A report is planned by December 31st this year.

Introduction

The iWharfe project is a citizen science project concerned with water quality in the River Wharfe. It was designed by the Ilkley Clean River Group, Yorkshire Dales Rivers Trust, Addingham Environment Group, Dales to Vale River Network and the Environment Agency and involves charities and other community groups from along Wharfedale working together (see Acknowledgements for a full list). Funding was provided by local councils, charities and private donations (see Acknowledgements for a full list).

The principal aim of iWharfe2020 was to raise awareness about river water quality by showing how concentrations of faecal bacteria (of concern for human health) and nutrients (of concern for ecosystem health) varied along the river on a single day. We reported the results for faecal bacteria in 2021 (Battarbee et al. 2021). Here we focus on nutrient pollution.

Nutrient pollution, especially phosphorus (P), is mainly caused by the discharge of sewage effluents and runoff from agricultural land. It is a problem for the River Wharfe and for almost all rivers in the UK.

Nitrogen and phosphorus are essential plant nutrients found in very low concentrations in natural waters, sufficiently low to limit the growth of algae in water. Phosphorus is more often limiting than nitrogen, especially in upland waters. Increases in concentration as a result of human activity can lead to excessive growths of algae in waterbodies as well as cause major changes in aquatic plant and animal communities in rivers and lakes. This process is called eutrophication.

Eutrophication is a major global problem. It came to prominence in the 1960s when many lakes around the world turned green from excessive algal growth as discharges of nutrient-rich sewage effluent, enriched by P contained in newly formulated washing powders, rapidly increased after the Second World War.

It is now mandatory under the EU Wastewater Treatment Directive for all sewage works serving populations of more than 10,000 upstream of standing waters to strip P from the treated effluent. This is often referred to as ”tertiary treatment”. A classic example is the Windermere Tower Woods treatment works that installed P-removal processes in 1992.

Tertiary treatment it is not mandatory in running waters. The legislation was mainly directed at standing waters where eutrophication is a more serious problem. In lakes, oxygen consumed by decomposition processes in deep water cannot be replenished during the summer period when the water column is thermally stratified. In extreme cases deep water can become anoxic causing fish kill.

In running waters serious anoxia is rare but because of the loss of P from agricultural soils and the lack of statutory controls on P discharge from waste-water treatment plants, P concentrations in rivers can also be high creating problems of eutrophication downstream.

High P concentration with its associated biological consequences is now one of the main reasons why so many watercourses in the UK fail to be classed as “high” or “good” status under the EU Water Framework

Directive (WFD) and why the EA are requiring water companies including YW to invest in P-removal technologies in many of its waste-water treatment plants.

On the River Wharfe, three STWs have now had tertiary treatment for P removal installed. They are capable of reducing the concentration of orthophosphate by approximately 95%. These are Otley (2019), Thorp Arch (2020) and Wetherby (2019) (Graham Weston, personal communication). A further P removal plant is due to be installed at the small STW serving Draughton and requirements for P removal at Ilkley are being considered under Urban Waste Water Treatment Regulations.

An assessment of the eutrophication status of the various waterbodies in the Wharfe catchment has recently been completed by the Environment Agency (Dacombe & Wait, 2022).

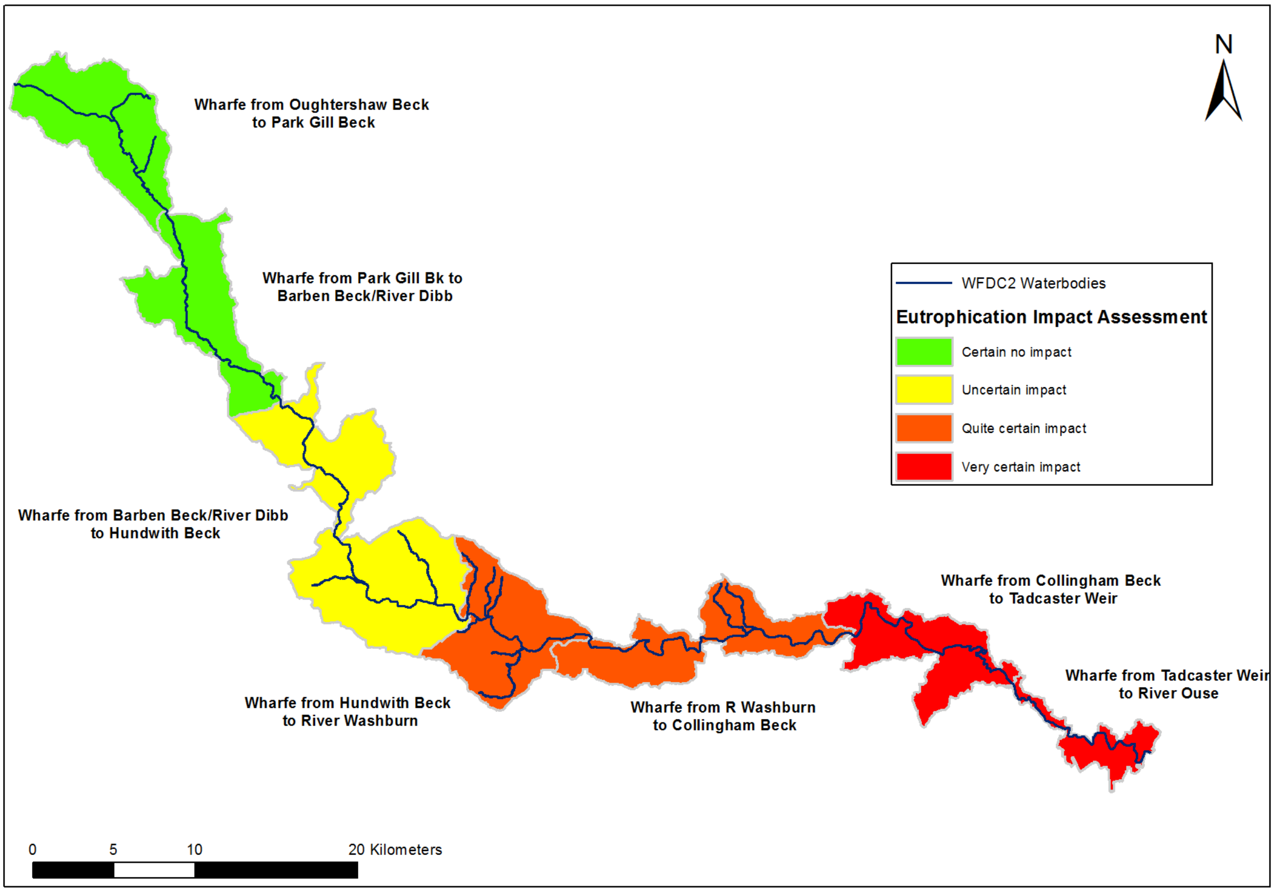

Figure 1. Wharfe catchment showing the eutrophication status of individual water bodies in 2021 (from Dacombe & Wait 2022)

In the iWharfe project we used two complementary approaches to assess the impact of nutrient pollution on the ecology of the river and identify pollution sources. The first was to determine how nutrient chemistry changed along the entire length of the river. This required the use of volunteers to collect samples on the same day over the course of a few hours during a period when riverflow conditions could be assumed to be very similar at all sites.

The second approach involved the collection and analysis of diatoms growing on stones in the river-bed as biological indicators of nutrient pollution. Diatom populations are much less affected by short term variations in river-flow so sampling need not be carried out at all sites simultaneously.

We additionally used the "Riverfly" methodology to survey macroinvertebrate populations at some sites. For logistic reasons we were not able to collect samples from all sites along the river in a consistent way. The data

(Appendix H) nevertheless provide valuable supporting information especially for the upper reaches of the river where chemical, diatom and macroinvertebrate data are all available and in accordance.

Sites

Potential sites for sampling were identified from the headwaters of the Wharfe above Oughtershaw to the confluence of the river with the Ouse at Cawood, a distance of approximately 125 km. Sites selected included crossing points, such as road bridges, footbridges and stepping stones, and bankside recreational areas (sites known to be used for swimming and paddling). Of the total number of sites identified, 50 were located along the main river. These are listed in Appendix A. In addition sites on 10 tributaries were also included (Appendix B) and sampled at points close to their confluence with the main river. In some cases, e.g. the River Skirfare and the River Washburn, tributaries were selected because of their size. Others, e.g. Hambleton Beck and Collingham Beck, were selected because of their special interest as inflows likely to contain high nutrient loads. Where possible sites were selected to coincide with sites used by the EA for monitoring enabling comparisons to be made between EA and iWharfe data. However, such comparisons have not yet been made.

To enable samples to be collected at approximately the same time on the same day the river was divided into five zones (Figure 2) each with its own sampling team. Although the river was running quite high on the day of sampling (24th August 2020) (Appendix C) there had been little rain for the preceding 24 hours and flow conditions were similar along the length of the river (Appendix D).

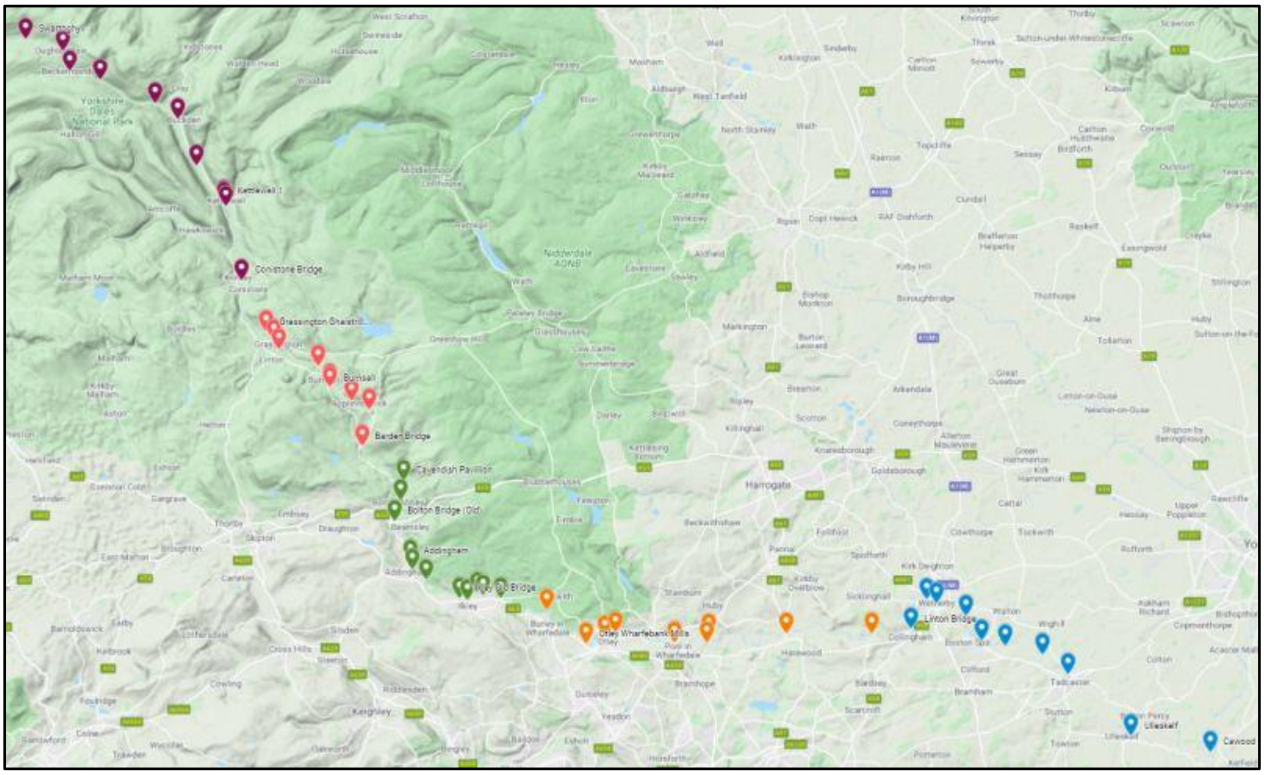

Figure 2. iWharfe sample sites showing five zones from the headwaters in Langstrothsdale in the northwest to the confluence with the River Ouse at Cawood in the southeast. The five zones are shown by different coloured markers.

Methods

Water chemistry

The five field teams were drawn from members of the Yorkshire Dales Rivers Trust and Environment Agency staff using stainless steel buckets to take water samples. One litre sample bottles were used to take samples for chemical analysis. Determinands included orthophosphate, total phosphorus (TP), nitrate, total nitrate (TN) and suspended solids (SS) (see Appendix E for analytical details). Samples were analysed by CEH Lancaster. Field measurements of samples for pH and dissolved oxygen (DO) were also made using a YSI ProDSS meters, courtesy of the EA.

Diatom analysis

Samples for diatom analysis were taken close to the sites used for water sampling on a number of days between the 18th September and 19th October 2020 working downstream from Swarthghyll to Newton Kyme Viaduct. Two additional sites were included, at Yockenthwaite and Ilkley Golf Course respectively (Appendix A). Water chemistry data for these sites are therefore missing. However, to enable the diatom data from these two sites to be included in the statistical analysis of the combined diatom-chemistry data-set they were allocated the chemistry of the sites immediately upstream (Appendix A).

Fig. 3. Diatom sampling

The samples were collected from river-bed cobbles using standard methods for epilithon (Battarbee et al. 2001). Sampling took place on low-flow days to enable easy hand searching. At each site epilithic material was brushed off three carefully selected cobbles and amalgamated in the field into a single sample (Fig. 3).

The character of the river channel changes markedly between Newton Kyme and Tadcaster. The water becomes deeper and the substrate muddy. Cobbles suitable for diatom sampling are not present. Consequently we have no diatom data to match the chemistry of the water samples taken at Newton Kyme Village, Tadcaster Weir, Ulleskelf and Cawood sites.

Samples were prepared for microscopy and analysed by Henderson Ecology. A minimum of 300 valves were counted for each sample and Trophic Diatom Index (TDI) scores were calculated (Kelly et al. 2008). Summary data are shown in Appendix F. A full data-set can be found on the YDRT website: https://www.ydrt.org.uk/what-we-do/projects/current-projects/iwharfe/

Invertebrate sampling and analysis

Macroinvertebrates were collected using three-minute kick sampling and taxa were identified in the field using standard Riverfly Partnership protocols (https://www.riverflies.org/). Eighteen samples were taken from Beckermonds in Langstrothsdale to Linton Weir. Most samples were taken from sites close to water chemistry and diatom sample sites. However, as pointed out above, there are several gaps in the sampling sequence due to difficulty in sampling in high flow conditions, the unavailability of volunteers along some sections of the river and the unsuitability of the kick sampling method for the deep water stretch of the river from Newton Kyme to Cawood. The results are shown in Appendix H.

Results

Water chemistry: Main River

Figure 4 shows the results of the water chemistry from the 50 sites along the main river. By sampling on the same day at approximately the same time of day the data are comparable between sites as they can be assumed to be relatively unaffected by differences in rates of effluent discharge from STWs and CSOs and differences in riverflow between sites. On the 24^{th} August riverflow was quite high (Appendix C). In these conditions we expect the input of nutrients from agricultural sources to be relatively high due to increased runoff from the land via tributary streams, whereas the contribution of nutrient inputs from sewage effluents directly discharged into the river is likely to be masked due to dilution by the high flows. Repeated surveys under different flow regimes and at different times of year are needed to capture the full range of variability.

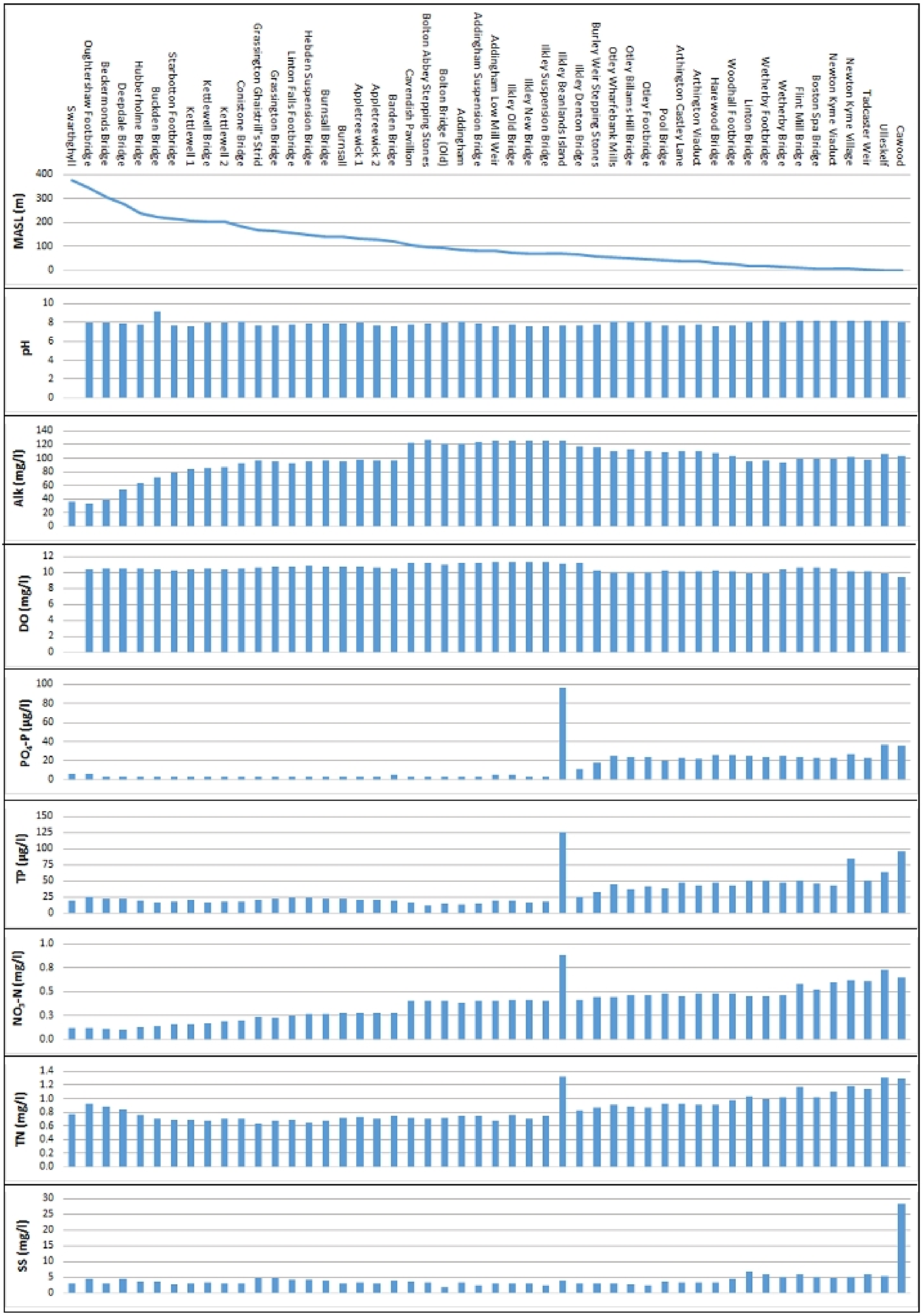

Figure 4. Physico-chemical data for 50 sites from the River Wharfe ordered from the headwaters downstream to the confluence with the River Ouse at Cawood.

There are clear downstream patterns in the data that indicate changes in water quality related to catchment geology, soils and land-use as well as nutrient pollution.

pH and alkalinity

pH and alkalinity are very closely related variables. However, whereas pH is relatively constant at values between ca. 7.5 and 8 along the river, alkalinity is low in the headwaters and increases gradually downstream from ca. 35 mg/l to ca. 80 mg/l at Starbotton. The increase in alkalinity downstream is probably due to the progressive change in the mixture of low alkalinity surface water running off through acidic upland soils and more alkaline groundwater in the river from the underlying limestone bedrock. The pH is high throughout this section of the river.

Further downstream between Barden Bridge and the Cavendish Pavilion site at Bolton Abbey there is a step change in alkalinity from ca. 100 mg/l to 120 mg/l. It is matched by a step change in nitrate concentration and a small elevation in dissolved oxygen levels (Fig. 4). These higher values of alkalinity and dissolved oxygen are sustained downstream for some distance before dropping back but nitrate levels continue to remain high. Whereas the higher alkalinity levels could be related to the input of more alkaline groundwater possibly associated with geological fault structures known to occur in this vicinity (Scruton & Powell 2006), the nitrate values suggest a nutrient input associated with human activity. The Bolton Abbey fish farm lies between the two sampling points and may be the cause of the water quality change but further investigation is needed to assess this possibility.

Dissolved oxygen

Whereas oxygen in the atmosphere is abundant, oxygen dissolved in water is scarce, varying daily and seasonally according to water temperature and photosynthetic activity. Cold water holds more oxygen then warm water. Photosynthetic activity creates oxygen whereas respiration consumes oxygen. In unpolluted running waters oxygen concentrations are at or about saturation levels during the day and night. For example the 100% saturation level for oxygen in water of 20^o C is 8.84 mg/l.

In organically polluted waters, however, the process of organic matter breakdown by bacteria consumes oxygen causing saturation levels to decrease. Typically such a reduction in dissolved oxygen levels can occur downstream of sewage works or CSOs, with values recovering as the organic matter is decomposed and oxygen levels are replenished by turbulent mixing with the atmosphere.

Values in the Wharfe on the 24th August (Fig. 4) vary in the main between 10 and 11 mg/l. These are somewhat higher than the expected level for water at 20^o C indicating slight super-saturation from photosynthetic activity and no evidence of oxygen depletion at any site. Slight differences between sites may be related to differences in the time of day the samples were taken as photosynthetic activity follows a diurnal cycle.

Changes in dissolved oxygen following diurnal variations in light and temperature and other determinands are continuously monitored at the Cromwheel corner in Ilkley by the Environment Agency (https://telemetry-data.com/open;jsessionid=WGJ9P6zm5yYZEoX3XekEZqGwRroxqI85AByY3ga6.mac@noded2).

Phosphorus (orthophosphate and TP)

Orthophosphate and Total Phosphorus (TP) values in the data-set (Fig. 4) are very closely related. The orthophosphate is the fraction of inorganic phosphorus dissolved in the water column whereas TP includes phosphorus (P) bound in particulate matter. In running waters phosphorus is usually the key micro-nutrient controlling algal growth and thereby the substance most likely to cause eutrophication when introduced into a waterbody by human activity whether from sewage treatment works, runoff from urban surfaces or agriculture.

Phosphate is present in very low concentrations in most natural waters. It is measured in µg/l (parts per billion) and P values are used to classify water quality with respect to nutrient pollution. However, as the concentration of P in running waters varies considerably with water flow many measurements across different flow conditions are needed to establish the nutrient pollution status of any single waterbody with confidence. As waterflow was high on the 24th August the P concentrations recorded (Fig. 4) are likely to be lower than average as the P from STW effluents is diluted by the river. On the other hand, as all samples were taken under similar flow characteristics along the river as a result of the synoptic sampling approach adopted, the data from site to site are very consistent and it is possible to identify significant downstream changes and potential pollution sources with a degree of confidence. However, it is probable that not all pollution sources have been revealed. Repeat surveys under low flow conditions and in different seasons are needed to identify the full range of point sources likely to be contributing to the nutrient load.

Values of orthophosphate in the upper reaches of the Wharfe on the 24th were often below the limit of detection. On this day all sites upstream of Ilkley had values less than 10 µg/l potentially indicating high quality water with respect to nutrient pollution. However, very low values for phosphate may not necessarily be an indication of low pollution. Where phosphorus is a limiting nutrient for growth it can be taken up immediately by benthic algae leaving concentrations of phosphate-P in the water column below the limit of detection. This is likely to be the case in the upper reaches of the Wharfe as there are rich benthic algal biofilms on the river-bed cobbles along this stretch of the river and as the river receives nutrient-rich effluent from the succession of village STWs between Buckden and Beamsley. A re-survey in winter when algal growth is at a minimum may enable this distinction to be recognised more clearly, although a complicating factor will be a reduction in nutrient loading from STWs during winter when tourist numbers are at a minimum.

Fig. 5. R. Wharfe, Ilkley STW final effluent outfall looking downstream towards Beanlands Island.

Further downstream the large spike in P concentration at Beanlands Island close to the Ilkley STW is clear to see as is the transition from very low concentrations to higher values between Ilkley and Otley (Fig. 4). The size of the spike may be an artefact reflecting the location of this sample site in the downstream plume of wastewater being discharged from the Ilkley STW (Fig. 5). The value at the Denton Bridge site, sufficiently downstream from the STW for the wastewater to be fully mixed and diluted, may better represent the nutrient impact of the STW on the river. The increase in concentration values from Ilkley to Otley is especially notable indicating the pollution impact not only of the Ilkley STW but also of additional inputs from Ben Rhydding and Burley/Menston STWs.

Below Otley concentrations remain at a relatively constant level until close to the confluence with the Ouse. The last two sites sampled at Ulleskelf and Cawood respectively have values of almost 40 µg/l, almost double those upstream.

The lack of a significant increase downstream from Otley may be due to the installation of P stripping units at the Otley and Wetherby STWs in 2019 and Thorp Arch STW in 2020. The effectiveness of the process can be seen from the Thorp Arch data (Appendix G, Graham Weston, person. comm.). It shows concentrations in the final effluent of ca. 3 mg/l before P removal to less than 0.5 mg/l after. However, repeat sampling along this stretch of the river under different flow conditions and at different times of year coupled with an examination of pre-intervention nutrient data is needed to examine fully the impact of these P-removal schemes.

Total Phosphorus is a measure of the dissolved phosphorus and particulate phosphorus combined. It is a variable of more importance in lakes than rivers as much of the biologically active phosphorus in lakes can be held in the phytoplankton. Upland rivers such as the Wharfe lack phytoplankton. The algal biomass is held largely in the benthos. In the Wharfe data TP values (Figure 4) are approximately double those of orthophosphate and follow the orthophosphate values very closely indicating STWs as the dominant source.

Nitrate nitrogen

Nitrogen along with phosphorus is a key nutrient in freshwater ecosystems. In pristine systems nitrogen concentrations, usually as nitrate, are below detection limit or are very low as nitrogen is almost completely taken up by the growth of terrestrial plants and algae in river and lake catchments. Consequently almost all the nitrate in river systems is derived from human activity of some kind.

In the Wharfe values increase almost monotonically from the headwaters to the confluence with the Ouse. A small component of the concentration along the length of the river but of relatively greater importance in the headwaters is nitrogen derived from atmospheric pollution. The South Pennine region has received high amounts of nitrogen deposition over the last 150 years from the combustion of fossil fuels, principally coal, to the extent that nitrate concentrations in moorland streams exceeded 50 µeq/l in the 1970s and 1980s before controls on coal and oil combustion in UK power stations were introduced. Although emisssions of nitrogen gases has decreased strongly over the last 30 years significant amounts of nitrate remain in moorland soils and streams in the Pennines (Battarbee et al. 2014).

More importantly in the Wharfe are nitrates derived from agricultural sources and human wastewater. The steady increase in values from the headwaters downstream probably reflects contributions from both these sources. The spike in concentrations at Beanlands Island is clearly caused by the inflow of treated effluent from the Ilkley STW and the continued increase in values downstream probably reflects the increase in relative importance of arable land in the catchment in the lowland reaches of the river. Nitrate losses from arable land tend to be proportionally higher than phosphate as nitrate is more easily leached. Evidence for this can be seen from the data from Wetherby downstream where the ratio of nitrate to phosphate increases. This is especially apparent from the Collingham beck data (see below).

An anomaly in the nitrate data is the step increase in values between the Barden Bridge and Cavendish Pavilion sites coinciding with the step increase in alkalinity (see above). We have no explanation for this. Although the outflow from the Bolton Abbey fish farm lies between the two sampling points it seems unlikely that this is the cause of the change especially as there is no obvious matching increase in the concentration of P. As noted above further work is needed to explain these data.

Total nitrogen

Total nitrogen (TN) is a measure of both dissolved and particulate forms of nitrogen. TN values are relatively high along the full length of the river. The spike at Beanlands Island shows that sewage effluent makes a major contribution to the TN values, as for TP, and the increase in concentration downstream probably reflects the progressive increase in the importance of inputs from arable agriculture (as noted above for nitrate-N). The reason for the high concentrations in the headwaters of the Wharfe is not known.

Suspended solids

Suspended solids (SS) is a measure of the particulate concentration in the water column. In rivers this is normally caused by the inwash of bankside soil and the resuspension of riverbed sediments during high flow conditions. It causes turbidity and inhibits light penetration and is detrimental to most freshwater life. Of concern in particular for a river such as the Wharfe is the extent to which fine sediment settles out in lower flow conditions behind impoundments and seals river-bed gravels, degrading conditions for benthic fauna and fish-egg survival.

Values of SS are likely to vary considerably with weather conditions and the passage of high flow events. On the iWharfe sampling day flows were high along the full length of the river (Appendix C). Suspended solid measures are relatively uniform (Fig. 4). The only outlier was at Cawood where SS values were more than five times higher than sites upstream. This is probably due to the influence of the River Ouse, just a short distance downstream.

Water chemistry: tributary becks and rivers

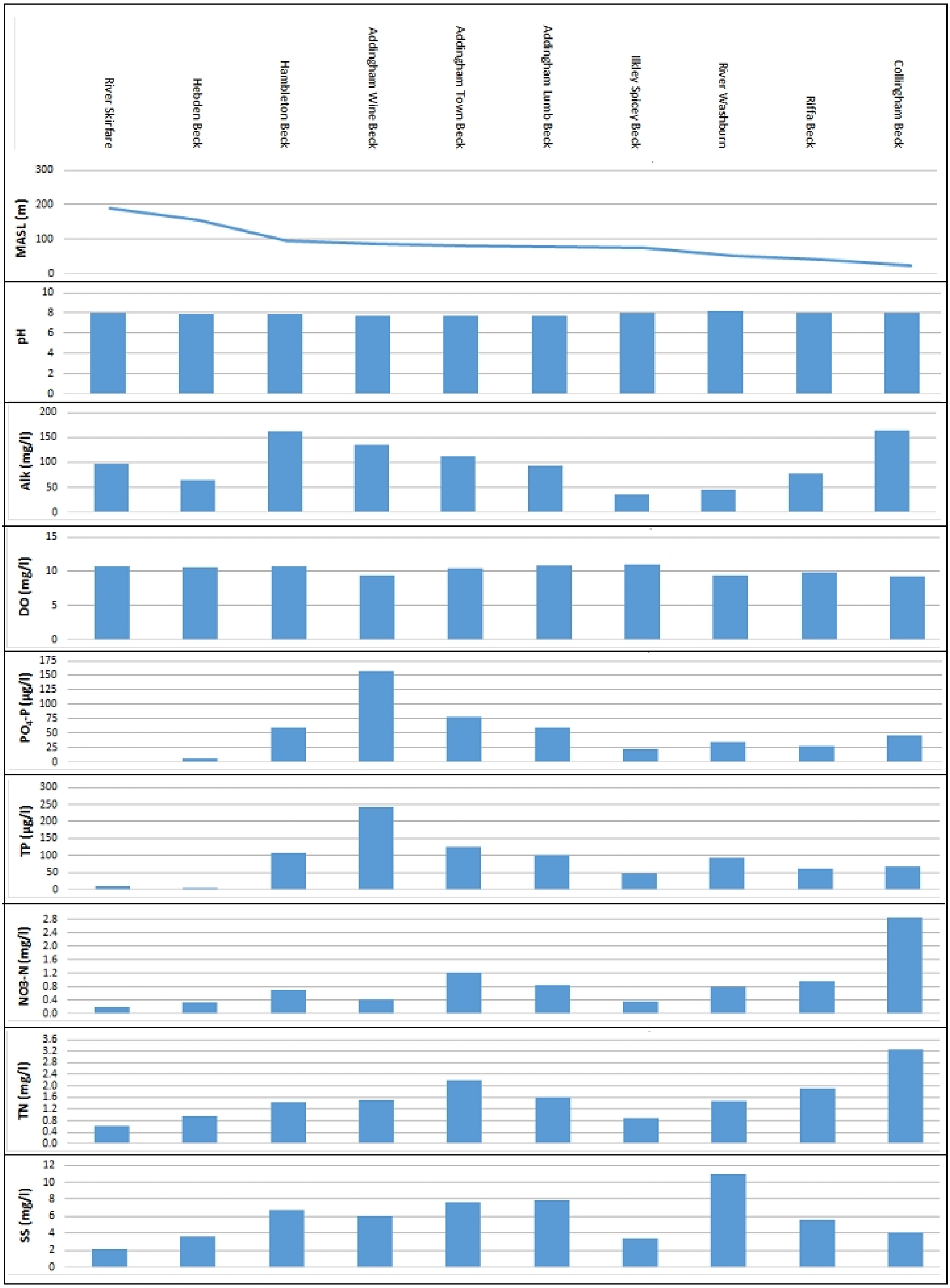

Figure 6: Physico-chemical data for selected tributaries of the River Wharfe ordered from upstream to downstream.

Only a small number of tributaries were sampled as outlined above (Appendix B). The data are shown in Fig. 6.

River Skirfare

The river Skirfare in Littondale is a major tributary of the Wharfe. It has very similar water quality to the Wharfe and similar catchment characteristics with respect to geology, land use and settlement pattern. Values for most determinands at the sampling point at the main road bridge (Fig. 6) are almost identical to those at Kettlewell just a few km upstream on the Wharfe (Fig. 4). Judging from a single sample the Skirfare does not appear to be different from the Upper Wharfe and therefore acts, despite its size, neither to dilute nor increase nutrient concentrations in the main river. Examination of EA data for comparable sites on the Skirfare and the Wharfe collected over many years could be conducted to assess this observation.

Hebden Beck

Hebden Beck joins the Wharfe just downstream of the Hebden Suspension Bridge. Concentrations of nitrate and phosphate are quite low, only slightly above the values for the main river, and thereby have little or no impact on the nutrient concentrations in the main river. However, Hebden Beck has a different pollution problem. The water and stream-bed sediments are strongly contaminated by heavy metals, especially lead (Pb) and Zinc (Zn) as a result of a long history of lead mining in the catchment. Heavy metal concentrations were not measured in the iWharfe project, but they are routinely measured by the EA and the legacy of mining in the catchment has been studied previously in some detail (Jones et al. 2013, Valencia-Avallan 2017). Consequently it is classified by the EA as a failing waterbody under the Water Framework Directive https://environment.data.gov.uk/catchment-planning/WaterBody/GB104027064190. Metal concentrations are especially high in high flow conditions as groudwater levels rise and flush out contaminants from old mine workings (Jones et al. 2013).

Hambleton Beck

Hambleton Beck was sampled at Bolton Bridge. Its principal headwaters drain the valley running from Chelker Reservoir and the small village of Draughton. It receives wastewater from the Draughton STW. It has relatively high nitrate and phosphate concentration probably mostly derived from the STW. The high phosphate concentration in the Beck has been identified by the EA as the reason for the Beck not achieving "good" status under the WFD (cf. Fig. 1). YW has consequently been required to fit a P-removal stage into the treatment process at the site during the current funding cycle (AMP-7). Despite the high concentration of both phosphate and nitrate it is clear from a comparison of data from upstream and downstream of its confluence with the Wharfe that the stream has little effect on water quality in the main river due to its small size relative to the main river.

Addingham Becks: Wine Beck, Town Beck and Lumb Beck

The principal becks flowing through the parish of Addingham were sampled as part of the iWharfe project. These becks were of special interest as they had been the focus of the Addingham 4Becks project, an earlier project concerned with flooding and water quality in the village funded and co-ordinated by the Yorkshire Dales Rivers Trust (Taylor et al. 2019). All three becks show significantly higher concentrations of nutrients compared with values for the main river (Fig. 7), although as for Hambleton Beck, they have little or no impact on water quality in the main river as concentrations of N and P downstream of the respective confluences are no higher than upstream values.

In the case of Wine Beck the high concentration of P in particular is thought to be caused by discharges from a poorly maintained septic tank serving a local fixed caravan site, a pollution source that was also thought to be the cause of high faecal bacteria concentrations in the beck (Battarbee et al. 2021). The use of the septic tank has subsequently been discontinued with sewage from the site now (from 2021) being pumped into the main sewer on Bolton Road.

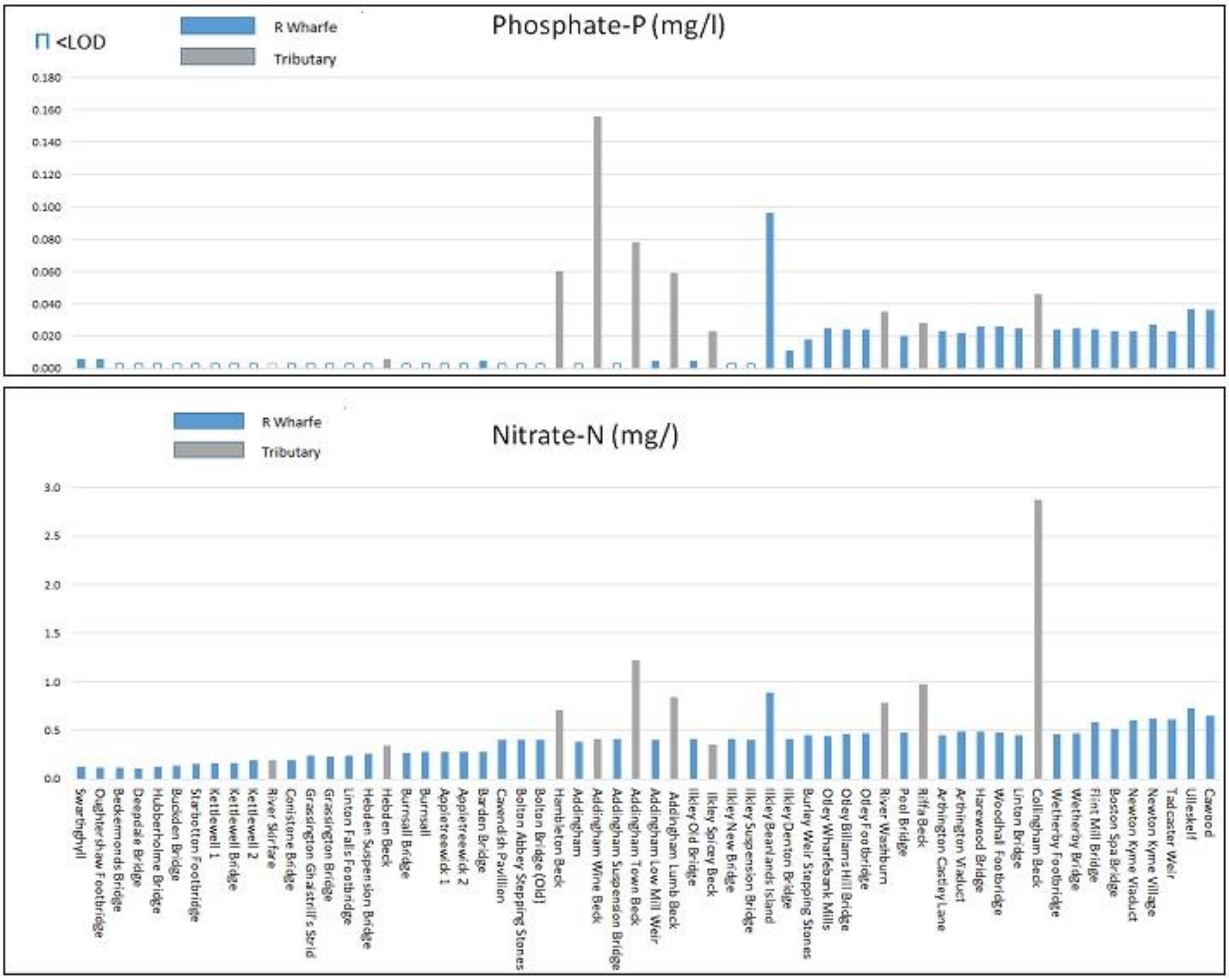

Figure 5: Phosphate-P and nitrate-N data for all sites. Main river sites in blue, tributaries in grey.

Town Beck and its major tributary Back Beck in Addingham rises in the hills above the village, it flows through agricultural land and then through the village before reaching the Wharfe at Low Mill. The concentration of phosphate-P on the day of sampling was almost 80 µg/l. This is a high value similar to ones previously measured during the 2018 4Becks project (Taylor et al. 2019). Unlike Hambleton Beck there are no sewage effluent inflows into the beck but we know from the 4Becks project that phosphate-P concentrations increase from the headwaters downstream as a result of both diffuse and point-source pollution. Diffuse sources include inwash of fertilisers and manure from agricultural fields and erosion of soils from exposed stream banks. Point sources include discharges from poorly maintained septic tanks and surface water runoff from highways and housing estates, especially Big Meadow Drive estate.

Nutrient concentrations in Lumb Beck (Fig 8) are also high. Lumb Beck predominantly has an agricultural catchment although there are scattered farmhouses with septic tanks and a large fixed-caravan site in the catchment. Further work is needed to assess the relative contributions of these different sources to water quality in the beck.

Fig. 8. Lumb Beck

Data from the three Addingham becks taken together illustrate that nutrient pollution in tributary becks can be high. Nutrients are derived from multiple sources. However, their impact on the main river is open to question as in no case is the nutrient concentration of the main river increased downstream of the tributary inflows. On the other hand, if, as pointed out above, P is a limiting nutrient for benthic algal growth in the main river, a downstream increase in P concentration might not be expected.

Spicey Beck

Spicey Beck in Ilkley was included in the iWharfe sampling programme as a beck that had attracted interest in an earlier project on faecal bacteria contamination (Battarbee et al. 2021). It is also an unusual beck in that its upper reaches flow through moorland and its lower reaches are urbanised. At no point in its catchment does it flow through agricultural land. The only nutrient sources in the moorland are from the atmosphere, phosphorus from dust and nitrogen from acid deposition. In the lower reaches nutrients will be derived from surface water runoff as the beck passes through back gardens and receives runoff from highway drainage. The lower beck also has a high faecal bacteria counts from time to time (Battarbee et al. 2021) and thought to be the result of misconnected wastewater pipes from private residents in its catchment. Water with high faecal bacteria concentrations will also have high nutrient concentrations.

Nutrient concentrations for Spicey Beck are higher than those in the main river but not as high as those in the Addingham becks upstream, possibly due to the lack of agricultural land in its catchment. A feature of the Spicey Beck chemistry is its relatively low alkalinity of ca 40 mg/l in comparison with other tributaries and with the main river where values for this part of the Wharfe are over 100 mg/l. This value reflects the origin of the water on Ilkley Moor where waters are naturally acidic and in all probability further acidified by almost two centuries of acid rain. Such acidified waters in the Pennines and elsewhere in the UK are slowly recovering from the impacts of acid deposition (Battarbee et al. 2014). In other tributary catchments with moorland headwaters the acidity would be fully neutralised by the passage of the water through agricultural land, but in the case of Spicey Beck the proximity of the moorland to the edge of the town probably prevents this process fully taking place.

River Washburn

The River Washburn is a major tributary of the Wharfe. It is unusual as it contains four large drinking water reservoirs in its catchment. A significant fraction of water in the river is consequently piped away and the discharge to the Wharfe is consequently both reduced in amount and subject to variability based on operational requirements by YW rather than by rainfall patterns.

On the day of sampling for iWharfe nitrate and phosphate values were higher than for the main river (Fig. 7). We have no data for the inflows and outflows of the reservoirs but as standing waters generally act as nutrient traps the relatively high nutrient concentration in the river as it enters the Wharfe is probably due to diffuse inputs from agricultural land downstream of Lindley Wood Reservoir and possibly from the fish farm at Farnley.

Riffa Beck

Riffa Beck was included in iWharfe as a typical beck in Mid-Wharfedale draining a predominantly agricultural catchment, similar to the lower reaches of the River Washburn comprising both grassland and arable fields. The somewhat higher values of nitrate compared to phosphate (Fig. 5) may indicate the relatively higher proportion of arable cultivation in the catchment.

Collingham Beck

Collingham Beck is situated in Lower Wharfedale. It drains a low-lying largely agricultural land with extensive tracts of arable cultivation. Most arable crops require the application of fertilisers that unless carefully managed can be lost to watercourses. Normally nitrate is more easily leached from arable fields than phosphate. The very high concentration of nitrate shown in Fig. 7 not matched by an equally standout value for phosphate is probably indicative of fertiliser loss from arable crops in the catchment.

Diatoms

Diatom samples were collected from the same sites as samples for water chemistry from Swarthghyll in the headwaters of the Wharfe as far downstream as Newton Kyme Viaduct. As pointed out above diatom samples were not taken from the lowest four sites in the river, between Newton Kyme village and Cawood, as suitable substrates for diatom sampling were not present at those sites. In this lowland stretch of the river water depth is greater than upstream and the channel bed is muddy rather than stony. At all other sites upstream river-bed cobbles were present offering ideal substrates for epilithic diatom growth and allowing comparison between epilithic diatom assemblages unbiased by substrate type.

Whereas samples for water chemistry were sampled on a single day to minimise variability due to changes in weather conditions and waterflow, diatom samples were taken on a number of different days afterwards working down the river from Swarthghyll to Newton Kyme Viaduct (Appendix F). The first date of sampling was 18th September 2020 and the last 19th October 2020. Collection therefore took place over a period seven weeks after water sampling. However, it is apparent from the nature of the data (Fig. 8) that little or no turnover in the composition of the diatom assemblage occurred despite considerable variation in weather and riverflow conditions during the sampling period.

Altogether 46 samples were analysed and 129 taxa identified to species level. Valve counts per sample varied between 304 and 1355. The percentage composition of each species was calculated and percentage data for the most common taxa are shown in Fig. 8. Date for selected taxa can be seen in Appendix F and all data are available from the YDRT iWharfe web page (https://www.ydrt.org.uk/what-we-do/projects/current-projects/iwharfe/).

Visual inspection of the data, confirmed by statistical analysis using the CONISS program (John Birks and Kuber Bhatta, pers comm), shows that the data can be divided into three zones, from Swarthghyll to Linton Falls, from Linton Falls to Ilkley Beanlands Island and from Beanlands Island to Newton Kyme Viaduct.

Zone 1: Swarthghyll to Grassington

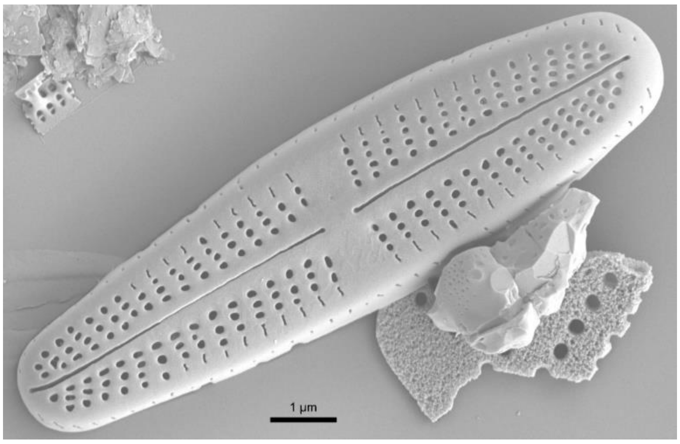

Fig. 9 Achnanthidium minutissimum (with permission of Ingrid Juettner)

The epilithic diatom assemblage in Upper Wharfedale is dominated by *Achnanthes* species, *Achnanthidium minutissimum* (Fig. 9) and *Cocconeis* species. These are taxa that are firmly attached to substrates either by a short apical mucilage stalk in the case of *A. minutissimum* or in an adnate position in the case of *Cocconeis* where mucilage excretion through the raphe slit forms the attachment. Such traits are associated with fast flowing water enabling diatoms to remain attached to mobile channel bed substrates during high flow events.

Nutrient concentrations in Upper Wharfedale are extremely low. Phosphate-P levels are often below the limit of detection (<5 µg/l). Although diffuse pollution from agricultural land undoubtedly occurs and there are numerous point sources of nitrate and phosphate from STWs serving the villages of Oughtershaw, Buckden, Starbotton, Kettlewell and Conistone, there is no clear evidence of eutrophication along this section of the main river. Nutrient concentrations are very low probably due to the diluting effect of the relatively high volumes of clean water in the main river and to uptake by benthic algae.

Zone 2: Grassington to Ilkley

Although nitrate and phosphate concentrations show no significant increase in the river below Grassington, possibly because of high flows and nutrient uptake by algae, evidence of nutrient pollution is indicated by the diatom data. *Achnanthidium minutissimum* remains dominant but *Nitzschia palea* and *Melosira varians* appear and become constant components of the flora downstream to the Ouse (Fig. 10).

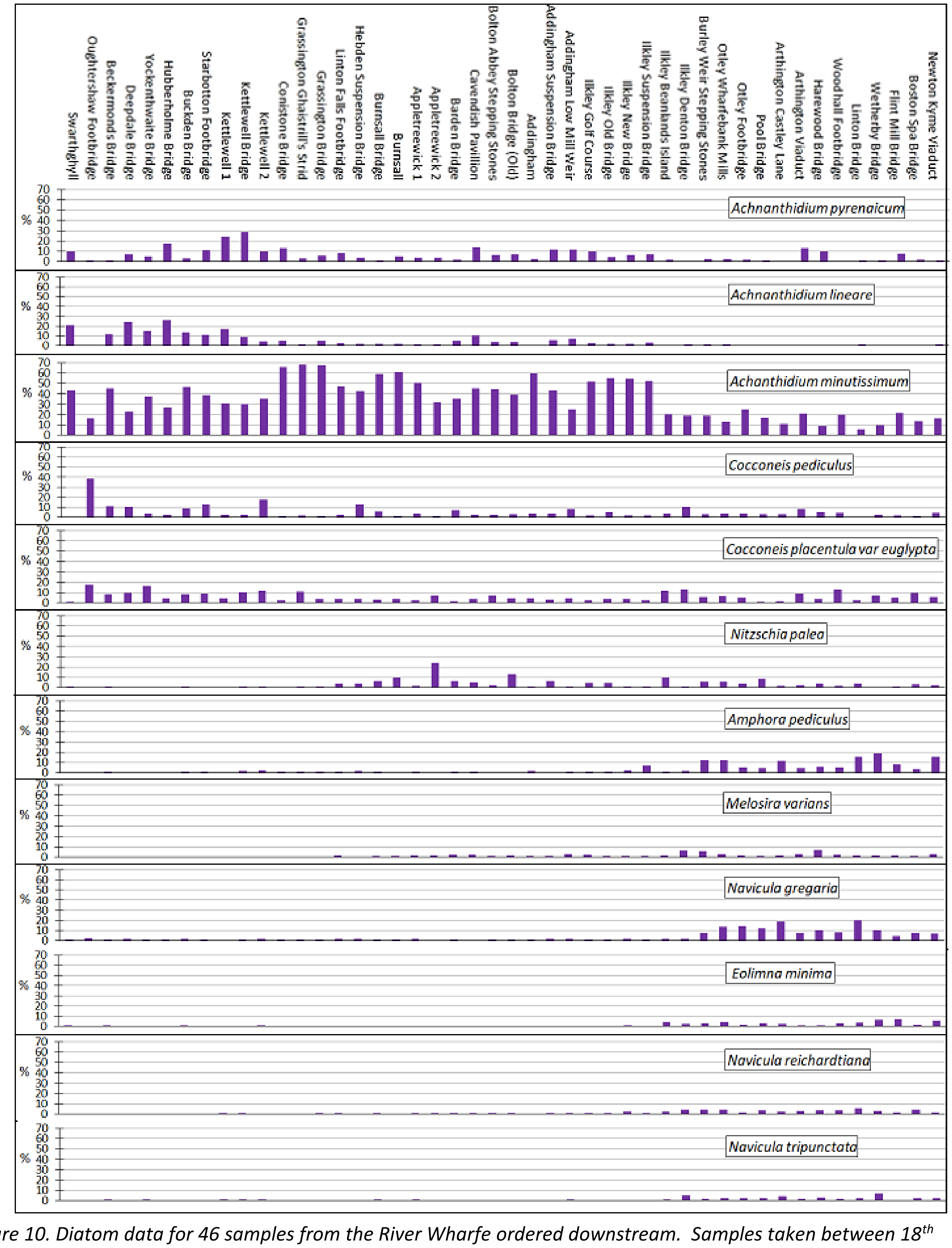

Figure 10. Diatom data for 46 samples from the River Wharfe ordered downstream. Samples taken between 18th September and 19th October 2020. Analysis: Gina Henderson.

The appearance of these two species indicate pollution occurring from organic matter as well as nutrients. *Nitzschia palea* (Fig. 11) is known to be tolerant of organic matter pollution (Palmer 1969) and there is some evidence that its competitive advantage in organically polluted water is its capacity for heterotrophic nutrition. *Melosira varians* on the other hand is often found in running water associated with rich biofilms that can coat substrate surfaces in such waters. As a filamentous species with limited ability to attach itself directly to a substrate it benefits from the protection provided by the biofilm reducing the risk of filaments being swept downstream (cf Kelly 2018).

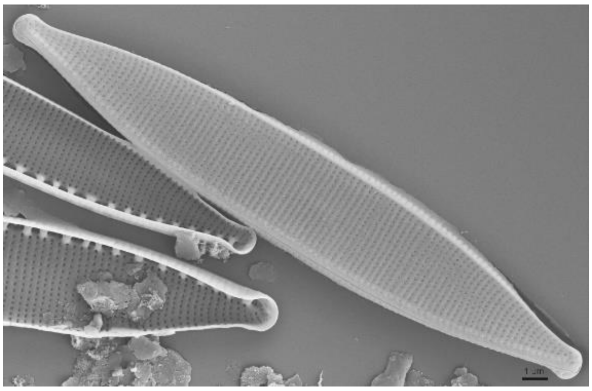

Fig. 11 Nitzschia palea (with permission of Ingrid Juettner)

The change in diatom flora occurs close to the Grassington STW, a treatment plant that serves the population of Grassington, Threshfield and Linton. The continuous discharge of nutrient-rich final effluent and the intermittent discharge of nutrient and organic rich untreated effluent from storm overflows probably accounts for the biological change. However, samples upstream of the STW also contain small amounts of *N. palea* suggesting that there are also significant pollution inputs in the river section between Ghaistrill's Strid and Linton Falls. This is unsurprising as our survey of faecal bacteria concentrations conducted at the same time (Battarbee et al. 2021) showed high concentrations of *E. coli* at these sites. Sources of nutrient pollution in the Grassington area upstream of the Grassington STW potentially include both livestock from farms and effluent from STWs and septic tanks.

The diatom assemblages between Grassington and Ilkley remain remarkably constant indicating that although there are also further inputs of nutrients from agricultural land and from small STWs, such as Burnsall, Appletreewick and Beamsley STWs, none is sufficiently high to cause any significant deterioration in water quality. As phosphate-P is continually being added to the river from STW discharges as well as from agriculture, the exceptional low values of phosphate-P indicate, as pointed out above, that P is being taken up quickly by benthic algae leaving the concentration of P in the water column below the limit of detection.

Zone 3: Ilkley to Tadcaster

Fig. 12. Eolimna minima (from Wetzel et al. 2015)

It is very clear that the most marked change in the composition of the diatom flora along the river occurs between the Cromwheel corner and Beanlands Island in Ilkley. At this point in the river there is a strong decline in the relative abundance of *Achnanthidium minutissimum*, the dominant diatom in the assemblage upstream, and the increase of several taxa indicative of nutrient rich waters including *Eolimna minima* (Fig. 12) and several *Navicula* species. *Navicula gregaria* especially increases further downstream and becomes the dominant species in the assemblage. This species and most other taxa that increase at this point are motile species. Unlike *A. minutissimum* which attaches to the stony substrate via a short mucilage stalk, these motile species move freely in the organic biofilm that coats the cobbles. The biofilm itself becomes dominated along this stretch of the river by filamentous green algae, mainly *Cladophora* (Fig. 13), that trap organic matter and also provide a substrate for the growth of epiphytic diatoms. The increase in *Cocconeis* taxa in particular at this point (Fig. 10) may be due to this change in microhabitat.

Fig. 13. River-bed cobble with filamentous green algae

There can be little doubt that the changes in diatom taxa between the Cromwheel and Beanlands are due to the impact of effluent discharge from the Ilkley STW. The change in the composition of the diatom assemblage coincides exactly with the increase in nutrient concentration. The spike in concentration at Beanlands Island is especially noticeable. The size of the spike, however, is somewhat anomalous, probably because the water sample was taken only a short distance downstream from the final effluent outfall and within the plume of the discharge. However, samples from Denton Bridge, and Burley Weir further downstream where the water column is likely to be fully mixed show how background phosphate concentrations in the river continue to rise. This may be due to additional phosphorus inflows from the Ben Rhydding and Burley/Menston STWs as neither of these STWs have P-removal processes installed.

Although there is some variability the overall diatom assemblage composition from Ilkley downstream to Tadcaster is remarkable uniform and this matches the nutrient chemistry data (Fig. 4) along this section of the river. The lack of any increase in phosphate concentration and thus of any species turnover in the diatom data is probably due to the introduction by YW of P-removal at Otley, Wetherby and Thorp Arch STWs as described above.

Discussion

Strengths and limitations of the data

The concentration of nutrients in rivers in time and space is inherently variable depending principally on variations in the strength of contributions from different pollution sources, and variations in river-flow. Of these, river-flow variability caused by changes in antecedent rainfall in the catchment, is the most important. In the iWharfe project the strategy of sampling all along the river at approximately the same time during a period when flow conditions were similar if not identical was designed to control this variable and thereby enable the relative importance of different pollution sources to be identified more clearly.

On the day in question flow conditions were similar at all sites. River levels were relatively high with the river fully occupying its channel but not over-topping its banks. In these conditions it is likely that diffuse pollution from agricultural land and from urban surfaces becomes relatively more important through inwash, and that direct discharges from point sources, especially STWs, become less important due to dilution effects.

These conditions can be characterized as being intermediate between low flows, when treated effluents from STWs discharges are relatively undiluted, and high flow conditions after heavy rainfall when spills of untreated effluents can occur.

The chemical data (Fig. 4) clearly indicate the power of the synoptic approach as the variability of concentrations between adjacent sites downstream is very low.

Although the approach adopted allows comparability between sites, the chemical data only provide a snapshot of water quality conditions. Chemistry varies with flow and can change significantly within hours as rainfall events can alter river flows quickly and cause rapid changes to concentrations, both enhancing and diluting them as events move downstream. Repeated synoptic surveys in different seasons and under different flow regimes are needed to capture the full range of conditions.

Diatom assemblages on the other hand are far less influenced by individual events and can remain stable for months or even years changing more gradually through time in response to longer term changes in water quality. Consequently, whereas water chemistry sampling along a river needs to be carried out swiftly during constant flow conditions, diatom sampling can be conducted more slowly over a period of week or months in some cases. In the iWharfe project the diatom samples were collected over seven weeks, sampling carefully at periods of low flow. Inspection of the data (Fig. 10) shows that there are no obvious discontinuities in assemblage composition that can be ascribed to time of sampling.

Nutrient pollution: main river

Nitrate and phosphate data from samples collected on the 24th of August 2020 show concentrations increasing along the river from its headwaters to its confluence with the Ouse at Cawood. Excluding the spike in values at Beanlands Island which, as noted above, we believe is caused by close proximity of the sampling site to the Ilkley STW sewage outfall plume, there is a marked step-up in phosphate concentration between the Ilkley Cromwheel and Otley Wharfedale Mills. This coincides exactly with a marked diatom assemblage change towards species indicative of nutrient enrichment (Fig. 14). It is the most significant ecological change along the whole river and is undoubtedly related to effluent discharge from Ilkley STW and probably to the additional nutrient rich discharges from Ben Rhydding and Burley STWs further downstream.

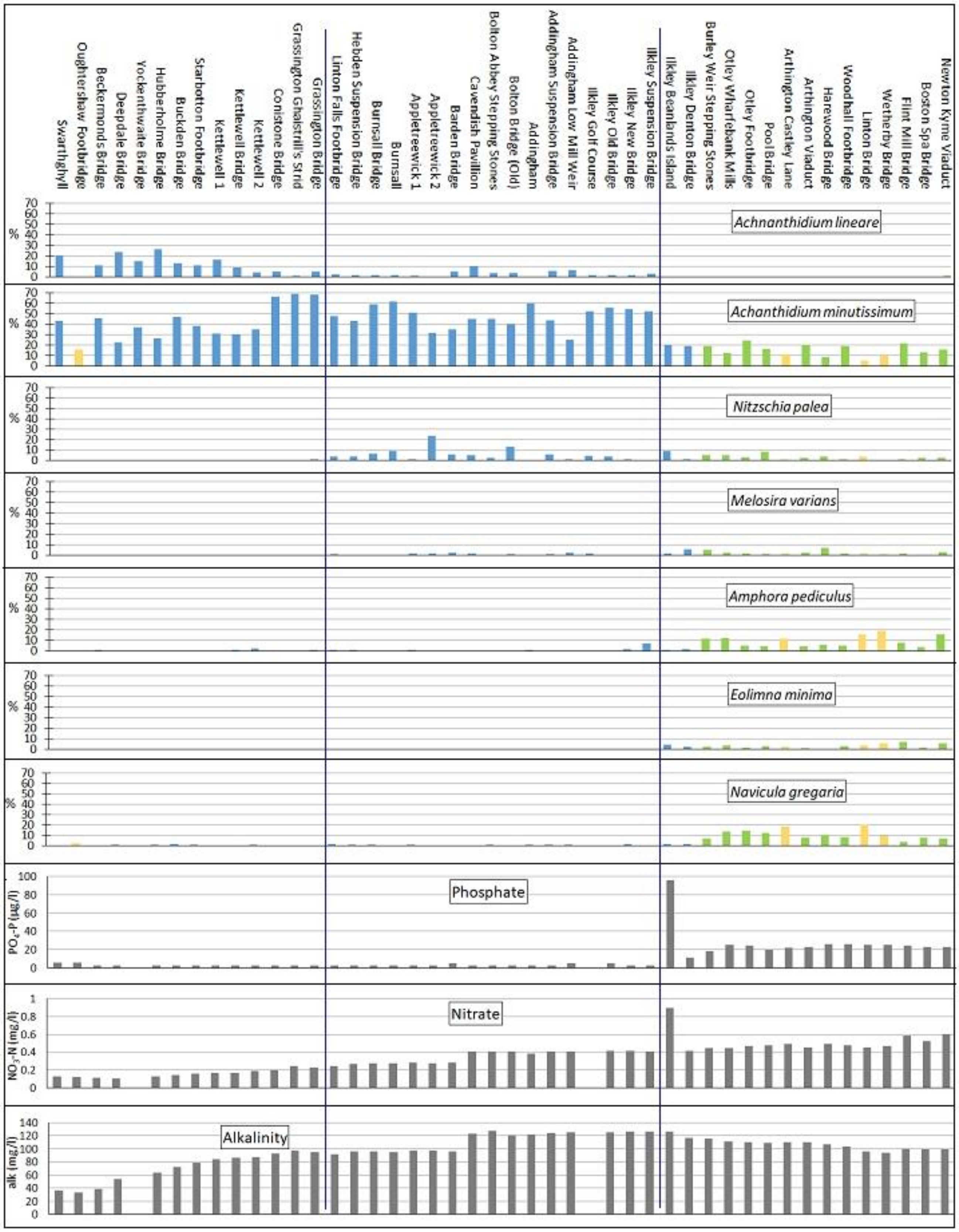

Fig. 14. Summary diatom and chemistry data for the River Wharfe for sites from the headwaters to Newton Kyme Viaduct showing ecological status, high (blue), good (green), moderate (yellow) based on Trophic Diatom Index (TDI) scores (Kelly et al. 2001, 2008)

Further upstream there is also evidence of nutrient pollution at Grassington. This is not indicated by the nutrient chemistry data as phosphate-P is below or close to the limit of detection in that stretch of river probably due to uptake by benthic algae (see above) and dilution of point source discharges by high river flows. Further samples for nutrient chemistry need to be taken above and below the STW at Grassington at a time of low flow and during the winter period, a time of low algal growth to assess these alternatives. The change in the diatom assemblage, however, although not as marked as the change in Ilkley, clearly indicates nutrient pollution in the Grassington area. The first point of change occurs upstream of the Grassington STW at Linton Falls (Fig. 14) suggesting there are sources of nutrient pollution in addition to discharges from the STW.

There is also evidence of additional nutrient pollution in the lowest reaches of the Wharfe between Tadcaster and Cawood. Nitrate levels in particular are higher probably as a result of nitrate leaching from arable fields in this the most agriculturally rich part of the catchment. Although both nitrate and phosphate are lost from agricultural land nitrate loss is proportionally higher than from sewage effluent. As noted above we have no diatom data for this stretch of the river owing to the lack of stones in the river-bed from which epilithic populations could be sampled. Consequently it is difficult to assess whether these high nitrate concentrations have an ecological impact.

Nutrient pollution: tributaries

In this study samples were taken from only a small number of tributaries. Nevertheless, the results provide a number of insights into water quality both in comparison with each other and in comparison with the main river. The concentration of phosphate varies greatly from very low values, below the limit of detection in Upper Wharfedale, to quite high values in the mid-Wharfedale becks in the Addingham reach. In each case, however, or at least on the specific day the samples were taken, there is no evidence that the nutrient loading from the tributary becks is responsible for any downstream increase in main river concentrations owing to the dilution offered by the relatively high flows in the main river. The fact that the diatom assemblages do not appear to differ upstream and downstream of the respective tributary inflows further shows that nutrient pollution from agricultural land, at least upstream of Newton Kyme (Fig. 14), is of lesser importance than direct nutrient rich sewage effluent discharges.

The observation that the concentration of pollutants in many of the becks is higher than in the main river focuses concern on to the becks themselves. Although several large tributaries are designated as individual waterbodies under the Water Framework Directive most of the smaller ones are not and are not therefore monitored as such by the EA under WFD. In many cases whereas the larger water bodies they form a part of are classified as being of “good” or even “high” status, reflecting the condition of the main river, many of the small becks are in poorer condition. A clear example is Town Beck in Addingham which is polluted by nutrients from farms, septic tanks and surface water runoff, yet the overall waterbody it forms a part of has a “good” status for nutrients.

It is important in future to identify smaller watercourses that are in poor condition that, because of their size, are not being detected by current monitoring protocols. Such watercourses are integral parts of river catchments, they are centres of biodiversity supporting richer assemblages of invertebrate fauna than the main river and act as spawning and nursery streams for fish, especially native brown trout.

Controls

Fig. 15 Phosphorus removal unit at Otley STW (Photo, Yorkshire Water)

Although there is clear evidence of nutrient pollution from agriculture along the Wharfe, especially in the lower reaches of the river where crop cultivation is the dominant land-use, the principal sources of phosphate pollution are the discharges from STWs in the stretch of river between Ilkley and Otley. As yet there are no controls on phosphorus discharge from the Ilkley, Ben Rhydding or Burley/Menston STWs. This is the section of river where the most significant ecological change takes place and where the trophic diatom index (TDI) shows a drop in water quality from "high" above the Ilkley STW to "good" below it (Fig. 14). The introduction of P stripping at the Otley STW in 2019 (Fig. 15), at Wetherby in 2020 and Thorp Arch in 2019 is probably the reason P concentrations and diatom assemblages do not change significantly downstream. There is every reason to believe that the installation of tertiary treatment to remove P from the Ilkley and neighbouring STWs would be beneficial and lift the ecological status of the river from "good" to "high".

The diatom data also indicate that P removal units at Grassington would also be beneficial. However, the Grassington STW may not be the only important source of P in this stretch of the river as the first point of change in the diatom assemblage occurs upstream. As noted above further work is needed to identify such sources in the Grassington area. Potential additional sources include discharges from private STWs, such as Long Ashes, septic tanks and surface water runoff from urban surfaces and agriculture.

Some of these diffuse forms of nutrient pollution are difficult to control although appropriate legislation is in place. There is a requirement for septic tanks to discharge to soakaways (https://www.gov.uk/permits-you-need-for-septic-tanks) and not to watercourses but this requirement is widely ignored. Moreover, the creation of riparian buffer zones can reduce nutrient loss from fields and stream banks both by controlling soil erosion and restricting livestock access to becks, but implementation of the "Farming rules for Water" (https://www.gov.uk/government/publications/applying-the-farming-rules-for-water/applying-the-farming-rules-for-water) introduced by Defra in 2018 to reduce diffuse pollution from agricultural lands is poorly enforced.

Nutrient loading from untreated and treated sewage

Our data show that the most significant impact of nutrient pollution on the river occurs between the Cromwheel corner site and the Beanlands Island site (Fig. 4), sites situated immediately upstream and downstream of the Ilkley STW. However, in this study we did not take samples for either nutrient chemistry or diatom analysis between the storm overflow discharge point and the final effluent discharge point. From our results it is therefore impossible to differentiate the importance of these two sources of nutrient pollution on the ecology of the river. Data are lacking for both the concentration of P (and its variability) in the storm overflow effluent and also for the volume of effluent discharge for each event. It is probable, however, that the treated effluent (Fig. 16) has a greater impact owing to its continuous flow. Recent work conducted in the summer of 2022 supports this view. By sampling between the two discharge points we were able to show that both the increase in phosphate-P concentration and the major change in diatom assemblage composition occurred downstream of more final effluent outflow and not downstream of the storm overflow (data yet to be reported). Repeat surveys are needed in different seasons to assess whether this pattern is consistent throughout the year.

Fig. 16. Final effluent outfall, Ilkley STW

Conclusions

Because water chemistry in a river varies strongly with changes in flow conditions we used citizen science volunteers to take samples for water chemistry along the full length of the river on the same day. There had been rain previously and the river was running high but there was no rain on the day of sampling and flow conditions remained constant. Consequently there was little site to site variability in the chemical data enabling overall downstream trends and points of change to be clearly seen. The data showed:

- Very low overall values of P concentration, especially phosphate-P, in the upper reaches of the river, partly related to relatively low inputs but also probably related to depletion of reactive phosphorus in the water column by algal uptake in the benthos;
- A marked step increase in phosphate-P concentration downstream of Ilkley caused by effluent discharge from the Ilkley STW probably added to by the Ben Rhydding and Burley/Menston STWs;
- Constant concentrations from Otley to Tadcaster probably reflecting the effectiveness of tertiary P stripping units installed at Otley, Wetherby and Thorp Arch STWs in recent years;
- A gradual increase in nitrate-N downstream related to a combination of discharges from STWs and nitrate pollution from fertiliser application to arable land, especially in the Lower Wharfe; and
- Higher nutrient concentrations in several tributary becks, including Town Beck and Lumb Beck in the Addingham parish, than in the main river, probably indicating nutrient pollution from several catchment sources including livestock agriculture, septic tanks, private STWs and surface water runoff.

Samples for diatom analysis were taken at the same sites as the samples for nutrient chemistry. Diatoms growing on stone surfaces on the river-bed are not affected by short-term variations in river flow but vary more in response to sustained changes in water quality over longer periods. In rivers with low overall concentrations of nutrients, such as the Wharfe, diatoms are thereby more reliable indicators of nutrient pollution than direct measurements of nutrient chemistry. The diatom data showed:

- A small but significant change in species composition in the main river in Grassington. The first point of change occurs at the Linton Falls sampling site, upstream of the Grassington STW outfall, indicating that the change is in part due to sources of nutrients other than the STW;
- A major change in diatom composition in Ilkley immediately downstream of the Ilkley STW. The diatom assemblage downstream is characterised by a decline in the abundance of attached species and an increase in the number of motile species. These changes are consistent with the impact of nutrient enrichment unequivocally caused, in this case, by pollution from the STW upstream as indicated by the coincidental increase in phosphate-P concentration at this site in the river;
- Little overall change in the diatom flora from Ilkley to Newton Kyme the lowest site downstream suitable for epilithic diatom sampling. This stability is matched by the phosphate-P data;
- Although nitrate-N concentrations increase downstream in the lower reaches of the river there are no corresponding changes in the diatom flora indicating that phosphate-P is more important in driving ecological change than nitrate-N.

In summary, although these data are limited in time and to some extent in space, they clearly indicate that discharges from the Ilkley STW, probably in combination with the Ben Rhydding and Burley/Menston STWs, are the single most serious sources of nutrient pollution on the river. Using the Water Framework Directive classes for ecological status on the basis of this single sample the diatom data indicate that the Wharfe main river has a "high" status from its headwater to Ilkley and mainly a "good" status from Ilkley to approximately Tadcaster. A small number of samples fall slightly below the "good/moderate" boundary.

Prospects for controlling nutrient pollution

Despite this decline in ecological status in Ilkley restoration to a "high" status appears unlikely in the near future given the EA's national objective of prioritising waterbodies that are as yet at less than "good" status. However, there is a possibility that the Wharfe between Collingham Beck and Tadcaster Weir could be designated as a "Sensitive Area" for eutrophication and thereby enable the EA to require nutrient reductions to be made under Urban Wastewater Treatment Regulations (UWWTR) at large sewage treatment works upstream (David Barber, pers. comm.).

Every four years the EA works with Defra to review such designations. They require evidence of certainty of eutrophication in water bodies, gathered through a 'Weight of Evidence' (WoE) approach and are designated when there is high certainty of a eutrophication problem in a water body receiving 'qualifying discharges' (QDs) with a population equivalent (PE) ≥ 10,000, criteria that would include the Ilkley STW.

The latest proposals for Sensitive Area designation are currently being reviewed by Defra. This is anticipated to be no later than May 2023. Once designations have been made, the nutrient reduction requirements will need to be met within 7 years of the effective date of the next Urban Wastewater Treatment Identification of Sensitive Areas Notice, so by 2030. The qualifying discharges which have been identified are being included in water company Business Plans under the Periodic Review 24 (PR24) process. Should the designation be confirmed by Defra and Business Plans agreed by Ofwat, then the nutrient removal will be required to be implemented at the Ilkley STW by 2030.

Further work

The approach adopted in iWharfe, using synoptic surveys to collect samples for nutrient chemistry and diatom analysis, has proven to be effective. Further work using this approach is needed to:

- Assess the extent to which these data are representative of conditions in different seasons. Repeating the survey in winter when algal growth and nutrient demand is lowest is a priority;

- Identify sources of nutrient pollution in the Grassington area by sampling more intensively along the river from Conistone to Burnsall;
- Differentiate the relative importance of the storm overflows and the final effluent discharges on river ecology at the Ilkley STW by more intensive sampling along the river from Addingham to Otley; and
- Assess the extent of nutrient pollution in tributary becks by intensive field-scale sampling of representative becks from their headwaters to their junction with the main river.

The ultimate question concerns the impact of nutrient pollution on the wider ecology of the river. From the data we have so far the priority is to understand the impact of the untreated and treated effluent discharges both separately and in combination from the Ilkley and neighbouring STWs on the river. This requires not only diatom data but also acquisition of data on other algae, especially filamentous algae, and on invertebrate communities.

A grant to fund some of the priorities for further work identified here has already been awarded to the Ilkley Clean River Group by Ilkley Town Council and Wharfedale Naturalists Society. Samples for nutrient chemistry, diatoms, filamentous algae and macroinvertebrates have already been collected and analysed. A report on the results is expected by the end of December 2022.

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Yorkshire Dales National Park Authority
Ilkley Clean River Group
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Upper Wharfedale Field Society
Friends of the Dales
Burley-in-Wharfedale Walkers are Welcome
Otley 2030
Wildlife Friendly Otley
Boston Spa, Wetherby & Villages Community Green Group
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The Rivers Trust

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Ilkley Town Council
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Wharfedale Naturalists Society
Salmon & Trout Conservation UK
Patagonia
EU WaterCog
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97 people who donated through Crowdfunding

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Appendix A. Main river sites

iWharfe sites sampled by citizen science teams for water chemistry on the 24th August 2020 except for *Yockenthwaite and *Ilkley Golf Course. These two sites were sampled for diatoms only (Appendix F). Water chemistry data shown here for these sites are copied from the sites immediately upstream. Colours shows sites allocated to different zones for sampling by different citizen science teams.

Code	Sample Site	MASL (m)	pH	Alk (mg/l)	DO (mg/l)	PO_4-P (µg/l)	TP (µg/l)	NO_3-N (mg/l)	TN (mg/l)	SS (mg/l)	Lat	Long
Z1-0	Swarthghyll	377		36.2		6	19	0.125	0.77	2.9	54.23546	-2.23566
Z1-1	Oughtershaw Footbridge	343	7.97	33.4	10.4	6	25	0.119	0.93	4.4	54.22867	-2.20046
Z1-2	Beckermonds Bridge	306	7.94	38.7	10.6	3	22	0.114	0.88	3	54.21806	-2.19429
Z1-3	Deepdale Bridge	277	7.88	53.5	10.5	3	22	0.104	0.84	4.4	54.21303	-2.16645
Z1-3	** Yockenthwaite*	*265*	*7.88*	*53.5*	*10.5*	*3*	*22*	*0.104*	*0.84*	*4.4*	*54.20894*	*-2.15260*
Z1-4	Hubberholme Bridge	237	7.80	63.1	10.5	3	20	0.129	0.76	3.6	54.19966	-2.11469
Z1-5	Buckden Bridge	223	9.13	71.8	10.4	3	17	0.140	0.7	3.7	54.19143	-2.09360
Z1-6	Starbotton Footbridge	214	7.67	78.1	10.3	3	18	0.156	0.69	2.7	54.16625	-2.07619
Z1-7	Kettlewell 1	206	7.57	83.6	10.4	3	21	0.163	0.69	3	54.14668	-2.05023
Z1-8	Kettlewell Bridge	205	8.00	86.1	10.5	3	17	0.166	0.68	3.3	54.14581	-2.05098
Z1-9	Kettlewell 2	204	8.00	87.0	10.4	3	18	0.190	0.71	2.9	54.14369	-2.04904
Z1-11	Conistone Bridge	182	8.10	92.7	10.6	3	18	0.198	0.71	3	54.10340	-2.03367
Z2-1	Grassington Ghaistrill's Strid	167	7.65	96.6	10.7	3	21	0.240	0.64	4.9	54.07548	-2.01129
Z2-2	Grassington Bridge	165	7.71	94.6	10.7	3	23	0.230	0.68	4.7	54.07065	-2.00447
Z2-3	Linton Falls Footbridge	158	7.77	92.1	10.8	3	24	0.245	0.69	4.1	54.06591	-1.99985
Z2-4	Hebden Suspension Bridge	149	7.84	95.5	10.9	3	24	0.265	0.65	4.1	54.05714	-1.96260
Z2-6	Burnsall Bridge	141	7.88	96.1	10.7	3	22	0.272	0.68	3.9	54.04641	-1.95163
Z2-7	Burnsall	140	7.89	95.1	10.7	3	22	0.276	0.72	3	54.04476	-1.95161
Z2-8	Appletreewick 1	133	7.93	97.3	10.7	3	21	0.282	0.73	3.3	54.03724	-1.93126
Z2-9	Appletreewick 2	130	7.70	96.7	10.6	3	21	0.276	0.7	2.9	54.03218	-1.91488
Z2-10	Barden Bridge	120	7.63	96.1	10.5	5	20	0.280	0.75	3.9	54.01260	-1.92186
Z3-1	Cavendish Pavillion	104	7.83	123.0	11.3	3	16	0.407	0.72	3.6	53.99366	-1.88319
Z3-2	Bolton Abbey Stepping Stones	97	7.89	127.0	11.3	3	13	0.408	0.71	3.3	53.98327	-1.88626
Z3-3	Bolton Bridge (Old)	94	7.96	121.0	11.0	3	15	0.406	0.72	2	53.97195	-1.89161
Z3-5	Addingham	84	8.03	122.0	11.2	3	14	0.387	0.74	3.4	53.94983	-1.87673
Z3-7	Addingham Suspension Bridge	83	7.87	124.0	11.3	3	15	0.409	0.74	2.4	53.94532	-1.87451
Z3-9	Addingham Low Mill Weir	80	7.57	125.0	11.3	5	19	0.408	0.68	3.1	53.93964	-1.86203
Z3-9	**Ilkley Golf Course*	*76*	*7.57*	*125.0*	*11.3*	*5*	*19*	*0.408*	*0.68*	*3.1*	*53.93201*	*-1.85557*
Z3-11	Ilkley Old Bridge	72	7.78	125.0	11.3	5	20	0.414	0.76	2.9	53.92906	-1.83043
Z3-13	Ilkley New Bridge	71	7.59	126.0	11.3	3	16	0.412	0.71	3	53.92806	-1.82349
Z3-14	Ilkley Suspension Bridge	70	7.57	126.0	11.3	3	18	0.405	0.74	2.4	53.93234	-1.81494
Z3-15	Ilkley Beanlands Island	69	7.68	126.0	11.1	96	126	0.891	1.32	3.9	53.93106	-1.80850
Z3-16	Ilkley Denton Bridge	68	7.72	117.0	11.2	11	26	0.411	0.83	3	53.92929	-1.79260
Z4-1	Burley Weir Stepping Stones	59	7.75	116.0	10.2	18	33	0.449	0.87	3	53.92267	-1.74934
Z4-2	Otley Wharfebank Mills	55	8.03	111.0	10.1	25	44	0.442	0.91	3	53.90423	-1.71318
Z4-3	Otley Billams Hill Bridge	51	8.05	113.0	10.1	24	37	0.464	0.88	2.7	53.90854	-1.69514
Z4-4	Otley Footbridge	48	8.06	110.0	10.1	24	42	0.468	0.87	2.4	53.91059	-1.68469
Z4-6	Pool Bridge	42	7.73	109.0	10.2	20	39	0.480	0.92	3.6	53.90514	-1.63063
Z4-9	Arthington Castley Lane	40	7.69	110.0	10.1	23	47	0.451	0.93	3.3	53.90925	-1.59859
Z4-8	Arthington Viaduct	39	7.77	110.0	10.2	22	43	0.488	0.91	3.4	53.90470	-1.60076
Z4-10	Harewood Bridge	30	7.60	107.0	10.3	26	47	0.488	0.91	3.4	53.90980	-1.52626
Z4-11	Woodhall Footbridge	25	7.73	103.0	10.2	26	43	0.480	0.98	4.4	53.90946	-1.44608
Z5-1	Linton Bridge	20	8.03	95.5	9.9	25	51	0.452	1.03	6.9	53.91252	-1.40986
Z5-3	Wetherby Footbridge	18	8.14	96.4	9.9	24	50	0.458	0.99	6.1	53.92860	-1.39503
Z5-4	Wetherby Bridge	15	8.11	93.8	10.4	25	47	0.467	1.02	5.1	53.92654	-1.38607
Z5-5	Flint Mill Bridge	13	8.16	99.9	10.6	24	50	0.581	1.17	5.9	53.91964	-1.35839
Z5-6	Boston Spa Bridge	9	8.18	99.1	10.6	23	46	0.520	1.02	5.1	53.90615	-1.34400
Z5-7	Newton Kyme Viaduct	9	8.17	99.2	10.5	23	43	0.602	1.11	4.9	53.90312	-1.32178
Z5-8	Newton Kyme Village	8	8.15	102.0	10.2	27	85	0.619	1.19	5	53.89865	-1.28756
Z5-9	Tadcaster Weir	5	8.17	98.4	10.2	23	51	0.615	1.14	5.9	53.88758	-1.26371
Z5-10	Ulleskelf	0	8.17	106.0	9.9	37	64	0.727	1.31	5.4	53.85414	-1.20442
Z5-11	Cawood	0	8.11	104.0	9.5	36	96	0.650	1.30	28.4	53.84516	-1.13091

Appendix B. Tributaries

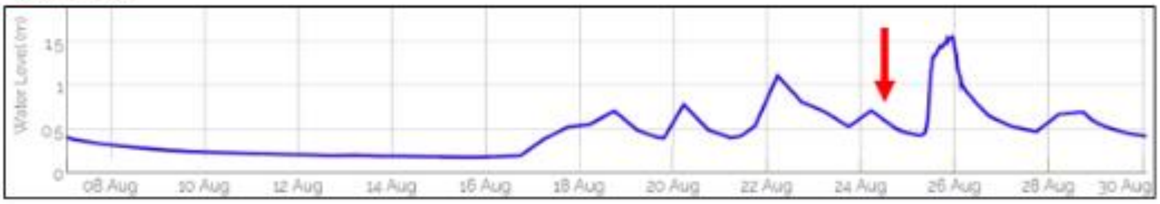
iWharfe sites sampled by citizen science teams for water chemistry on the 24th August 2020.

Code	Sample Site	MASL (m)	pH	Alk (mg/l)	DO (mg/l)	PO_4-P (µg/l)	TP (µg/l)	NO_3-N (mg/l)	TN (mg/l)	SS (mg/l)	Lat	Long
Z1-10	River Skirfare	191	7.97	96.1	10.7		12	0.196	0.6	2.1	54.11837	-2.04493
Z2-5	Hebden Beck	155	7.93	63.7	10.5	6	5	0.345	0.96	3.6	54.05752	-1.96035
Z3-4	Hambleton Beck	95	7.89	161.0	10.7	60	109	0.705	1.44	6.7	53.97252	-1.89401
Z3-6	Addingham Wine Beck	86	7.72	135.0	9.5	156	242	0.415	1.5	6	53.94876	-1.87669
Z3-8	Addingham Town Beck	82	7.74	112.0	10.5	78	126	1.220	2.2	7.6	53.94257	-1.87169
Z3-10	Addingham Lumb Beck	79	7.70	92.9	10.8	59	102	0.841	1.62	7.9	53.93352	-1.86245
Z3-12	Ilkley Spicey Beck	74	8.03	34.9	11.0	23	47	0.354	0.9	3.4	53.92815	-1.82867
Z4-5	River Washburn	51	8.21	45.9	9.5	35	93	0.786	1.47	11	53.91342	-1.64945
Z4-7	Riffa Beck	41	7.97	78.0	9.9	28	62	0.980	1.92	5.6	53.90835	-1.60951
Z5-2	Collingham Beck	23	8.04	163.0	9.3	46	68	2.870	3.25	4.1	53.91009	-1.41192

Appendix C: River levels at five EA hydrometric monitoring stations on the River Wharfe

The sites represent the five iWharfe zones and show river levels from August 8th to 30th. The morning of the day of sampling on 24th August 2020 is indicated by the arrow.

Kettlewell



Netherside Hall

Addingham

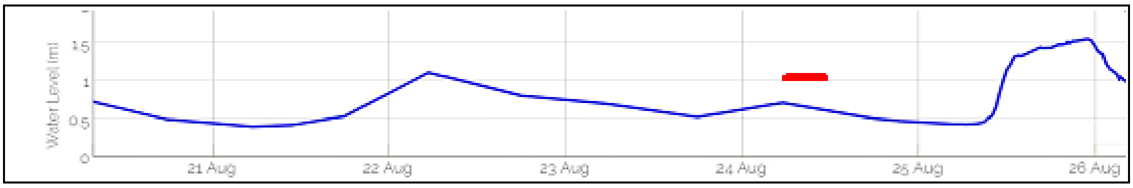
Otley

Collingham

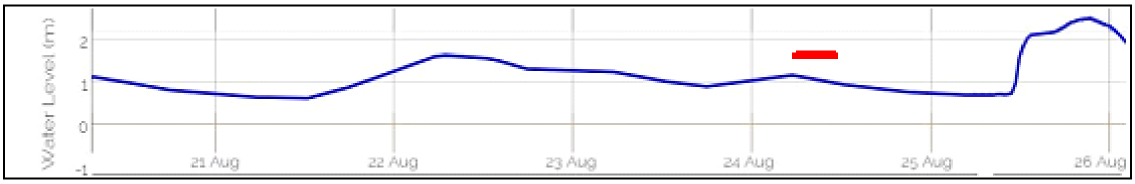
Appendix D: River levels at five EA hydrometric monitoring sites on the River Wharfe

The data show river levels at the monitoring sites between August 20th and 26th and the time of sampling for the five iWharfe zones between approximately 7.30 am and 12.30 pm on the 24th August 2020 (red bar).

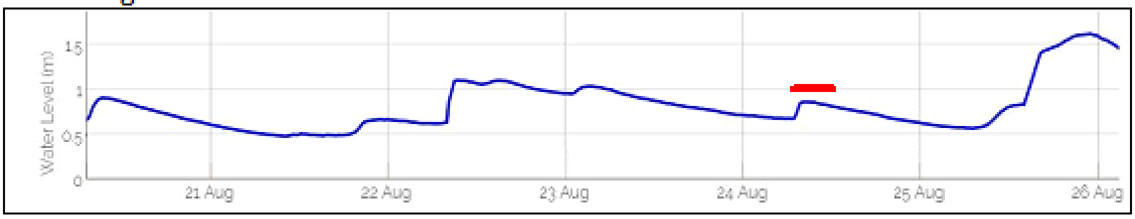
Kettlewell



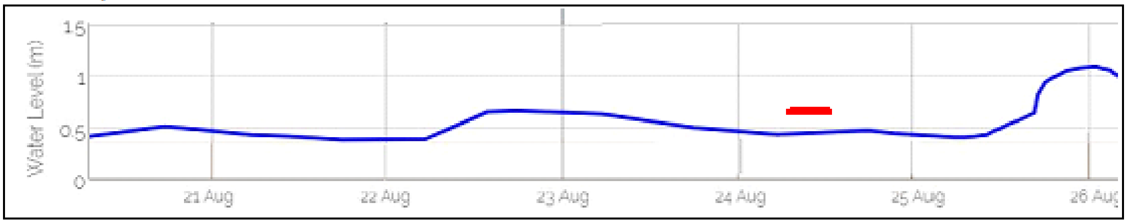
Netherside Hall



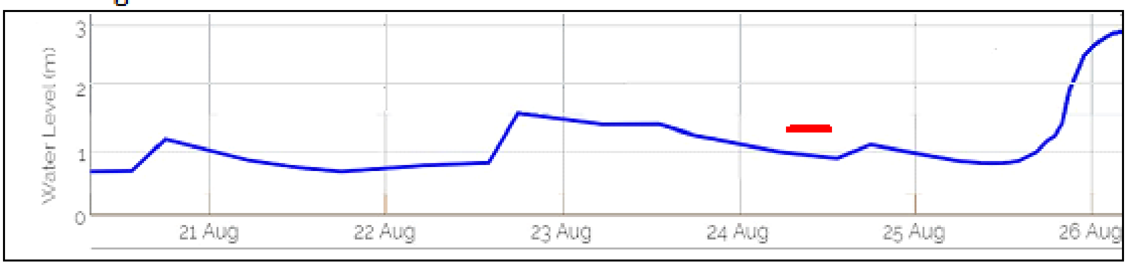
Addingham



Otley



Collingham



Appendix E. CEH Lancaster Analytical Methods

Alkalinity

Alkalinity was determined using the Metrohm 814 sample processor and Metrohm 888 Titrando diluter which performs analyses automatically using predefined methods. A complete titration method comprises sample dilution, dispensing of acid, stirring and waiting times, the actual titration and the calculation of results.

Using a measuring cylinder, 50ml of water sample is measured into cups then the pH is altered using 0.01M H_2SO_4 to reach an end point of pH 4.1.

The pH electrode is calibrated before use using pH 4 and pH 7 buffer solutions. A 20mg/l $CaCO_3$ solution is used as an AQC sample to test accuracy, this is run every 20 samples.

Total phosphorus

The analysis of Total Phosphorus (TP) using a $K_2S_2O_8$ digestion and subsequent molybdenum blue colorimetric analysis was carried out on a Seal discrete analyser.

Unfiltered (TP) samples were digested in a matrix of $K_2S_2O_8$ and 1N sulphuric acid. These were then placed in an autoclave under heat and pressure to complete the digestion procedure. Once digested the samples were allowed to cool and then measured colorimetrically using a SEAL AQ2 discrete analyser. Phosphorus was determined using ammonium molybdenum blue chemistry with the addition of ascorbic acid to control the colour production.

Calibrations were run using standards prepared and digested in the same manner as the samples using a top standard of 0.2mg/l, with control standards analysed every ten samples to check precision and reproducibility throughout the run. Blanks were run every 20 samples with AQC samples to check for accuracy. The data are corrected by the mean of the blanks previous to them to correct for any matrix effects.

Nitrate-N

The analysis of nitrate was carried out using an Ion Chromatography system. Unacidified samples were filtered through Whatman Cellulose Acetate filters with a nominal pore size of 0.45µm.

Samples were then run through a Dionex ICS2100 Reagent Free Ion Chromatograph (RFIC) with an ASAP autosampler, Carbonate Removal Device (CRD), AS18 2mmx250mm column, AG18 2mmx50mm Guard Column, KOH Eluent and using Chromeleon software.

An Isocratic programme was used. The cell and column temperatures are set to 35°C, Eluent concentration is set to 33mM, suppressor current is 21mA, flow of 0.25ml/min and an acquisition length of 12 minutes. The calibration range for nitrate is 0-6mg N/l

Precision and reproducibility is checked using QC samples at ten sample intervals and accuracy checked using a different QC sample every 20 samples.

Phosphate-P

PO_4-P concentrations were measured colorimetrically using a Seal Analytical AQ2 discrete analyser. [PO_4-P] is determined by reaction with acidic molybdate in the presence of antimony to form an antimony-phospho-molybdate complex. Ascorbic acid reduces this to the intensely blue phosphomolybdenum complex, measured spectrophotometrically at 880nm.

Calibration is produced by automatic dilution of a single stock solution of 0.2 mg/l PO_4-P; concentrations are obtained using a calibration curve within the range 0 – 0.2 mg/l PO_4-P. Control standards of 0.1 mg/l PO_4-P are analysed every 10 samples.

Total dissolved nitrogen

A Shimadzu TOC-L analyser, equipped with a TNM-L module, was used to measure Total Dissolved Nitrogen (TDN) in filtered water samples.

TDN was measured by combustion at 720°C, with a catalyst, which converts all nitrogen to nitric oxide. The nitric oxide is measured by a chemiluminescent reaction with ozone.

There are two calibration ranges for the instrument which combined cover a range of 0-10 mg/l for nitrogen. Any samples with values greater than the highest calibrant were diluted within range using 18.2 MΩ deionised water. Reference samples at 3 relevant concentrations across this range were used to check the calibration.

Suspended solids

Particulate matter from water was extracted under vacuum onto a pre-weighed glass fibre filter (Whatman GF/C) which had been ashed for at least 1 hour at 550°C. For Total Suspended Solids (TSS) the filter containing the particulates was dried at 105±5°C and then weighed to give the weight of particles >1.2µm.

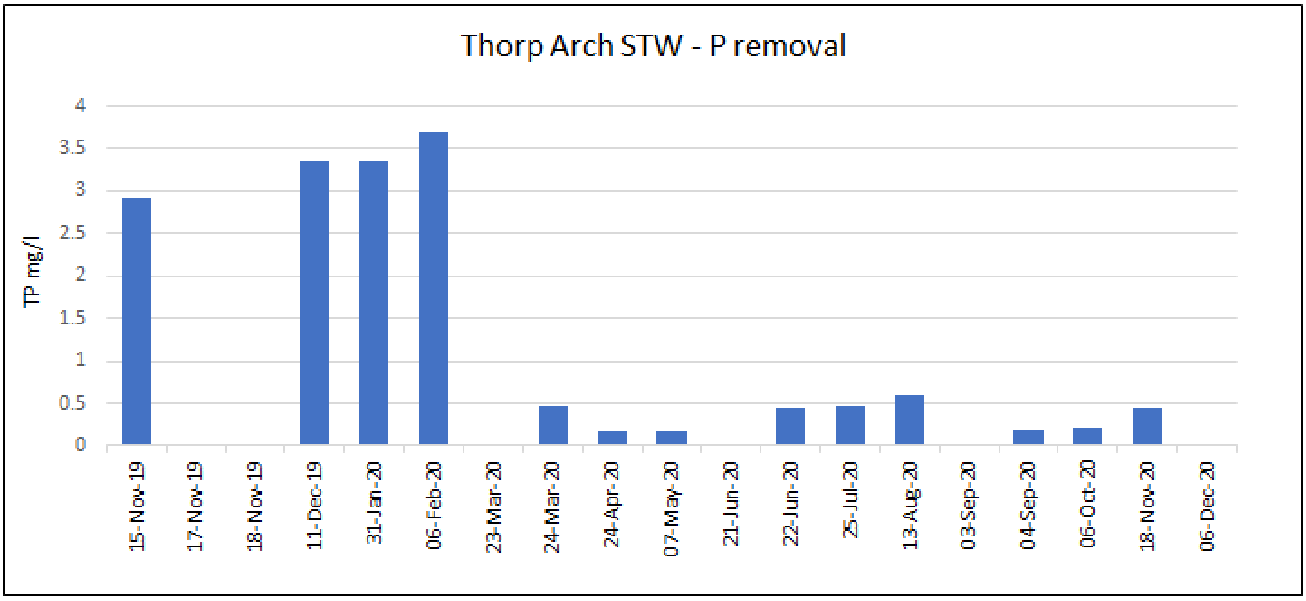
Appendix F: Diatom data

Diatom data for selected taxa shown in Fig. 10 from iWharfe sites from Swarthghyll to Newton Kyme Viaduct.

Code	River Location	Date	Achnanthidium pyrenaicum	Achnanthidium lineare	Achanthidium minutissimum	Cocconeis pediculus	Cocconeis placentula var euglypta	Nitzschia palea	Amphora pediculus	Melosira varians	Navicula gregaria	Eolimna minima	Navicula reichardtiana	Navicula tripunctata
Z1-0	Swarthghyll	18.09.20	9.6	20.5	43.0	0.0	0.6	0.4	0.0	0.0	0.6	0.6	0.0	0.0
Z1-1	Oughtershaw Footbridge	18.09.20	0.6	0.0	16.0	39.0	17.1	0.0	0.0	0.0	2.2	0.0	0.0	0.0
Z1-2	Beckermonds Bridge	18.09.20	0.4	11.4	45.3	10.8	8.2	0.4	1.1	0.0	0.7	0.2	0.0	0.2
Z1-3	Deepdale Bridge	18.09.20	6.7	24.0	22.4	10.2	9.3	0.0	0.0	0.0	1.3	0.0	0.0	0.0
N/A	Yockenthwaite Bridge	18.09.20	4.8	14.9	37.2	3.6	15.9	0.0	0.0	0.0	0.2	0.0	0.0	0.6
Z1-4	Hubberholme Bridge	18.09.20	17.6	26.0	26.4	2.3	4.3	0.0	0.0	0.0	1.2	0.0	0.0	0.0
Z1-5	Buckden Bridge	18.09.20	3.0	13.2	46.9	9.0	7.9	0.2	0.6	0.0	1.7	0.2	0.0	0.0
Z1-6	Starbotton Footbridge	18.09.20	11.0	10.8	38.5	12.6	8.9	0.0	0.3	0.0	1.0	0.0	0.0	0.0
Z1-7	Kettlewell 1	18.09.20	24.1	16.5	30.8	2.5	4.2	0.0	0.0	0.0	0.0	0.0	0.5	0.3
Z1-8	Kettlewell Bridge	18.09.20	28.7	8.9	30.2	2.2	10.3	0.5	1.3	0.0	0.3	0.0	0.3	0.3
Z1-9	Kettlewell 2	18.09.20	9.8	4.4	35.3	17.3	11.5	0.2	2.2	0.0	1.3	0.4	0.0	0.4
Z1-11	Conistone Bridge	18.09.20	13.0	5.2	65.9	0.3	2.1	0.0	0.1	0.0	0.3	0.0	0.0	0.0
Z2-1	Grassington Ghaistrill's Strid	21.09.20	3.1	0.9	68.7	1.9	10.6	0.6	0.5	0.0	0.8	0.0	0.0	0.0
Z2-2	Grassington Bridge	21.09.20	5.6	5.2	68.1	0.3	3.6	0.9	0.9	0.0	0.2	0.0	0.3	0.0
Z2-3	Linton Falls Footbridge	21.09.20	8.4	2.4	47.3	2.4	3.7	3.5	0.9	1.3	1.9	0.0	0.6	0.0
Z2-4	Hebden Suspension Bridge	22.09.20	3.5	1.9	42.9	12.5	3.5	3.8	1.4	0.0	1.4	0.0	0.0	0.0
Z2-6	Burnsall Bridge	22.09.20	1.0	1.6	58.9	5.3	3.1	6.5	0.6	0.6	1.2	0.0	0.4	0.3
Z2-7	Burnsall	22.09.20	4.8	1.7	61.3	0.3	3.8	9.4	0.0	0.1	0.3	0.0	0.0	0.0
Z2-8	Appletreewick 1	22.09.20	3.5	1.3	50.8	3.6	2.2	1.5	1.1	1.6	1.3	0.0	0.7	0.4
Z2-9	Appletreewick 2	22.09.20	3.5	0.5	31.9	0.8	6.7	23.9	0.0	1.6	0.0	0.0	1.1	0.0
Z2-10	Barden Bridge	22.09.20	1.7	5.1	35.2	6.8	1.7	5.9	0.3	2.5	0.3	0.0	0.6	0.0
Z3-1	Cavendish Pavillion	22.09.20	13.8	10.1	45.0	2.1	3.7	4.8	0.3	1.9	0.0	0.0	0.3	0.0
Z3-2	Bolton Abbey Stepping Stones	22.09.20	6.4	3.8	**44.8**	1.9	6.6	2.3	0.0	0.4	1.1	0.0	0.6	0.0
Z3-3	Bolton Bridge (Old)	22.09.20	6.9	3.5	39.3	3.0	4.3	13.0	0.0	1.3	0.6	0.0	0.6	0.0
Z3-5	Addingham	22.09.20	2.6	0.0	60.0	3.2	4.5	0.8	1.3	0.5	1.0	0.0	0.0	0.0
Z3-7	Addingham Suspension Bridge	22.09.20	11.2	5.9	43.2	3.4	2.8	6.0	0.0	0.9	1.2	0.0	1.1	0.0
Z3-9	Addingham Low Mill Weir	22.09.20	11.8	6.7	24.9	8.2	4.3	0.9	0.4	2.6	1.3	0.0	0.6	0.4
N/A	Ilkley Golf Course	29.09.20	9.8	2.0	51.8	1.4	2.4	4.4	0.6	2.1	0.3	0.0	0.8	0.0
Z3-11	Ilkley Old Bridge	22.09.20	4.5	1.8	55.3	4.8	3.8	3.9	0.7	0.4	0.4	0.0	0.4	0.0
Z3-13	Ilkley New Bridge	22.09.20	6.5	1.7	54.2	1.4	3.8	1.2	2.1	0.3	1.7	0.2	2.4	0.0
Z3-14	Ilkley Suspension Bridge	22.09.20	7.0	3.2	52.3	1.8	2.5	0.5	7.2	0.2	0.7	0.0	0.8	0.0
Z3-15	Ilkley Beanlands Island	22.09.20	1.9	0.0	20.1	3.5	11.2	9.4	1.2	1.6	1.9	4.2	2.1	0.5
Z3-16	Ilkley Denton Bridge	22.09.20	0.0	0.3	18.7	10.1	13.0	1.2	1.7	6.1	1.7	2.3	4.0	4.6
Z4-1	Burley Weir Stepping Stones	22.09.20	2.4	0.6	19.0	3.0	5.6	5.3	11.9	5.3	7.4	2.7	4.2	1.8
Z4-2	Otley Wharfebank Mills	23.09.20	2.3	0.6	12.6	3.5	6.1	5.3	12.3	2.6	13.7	4.1	4.4	2.3
Z4-4	Otley Footbridge	23.09.20	1.4	0.0	24.6	3.5	5.0	3.4	5.0	1.6	14.2	1.6	1.8	2.3
Z4-6	Pool Bridge	23.09.20	0.3	0.0	16.7	2.8	0.8	8.5	4.2	1.1	12.1	3.1	3.7	2.3
Z4-8	Arthington Castley Lane	27.09.20	0.0	0.0	10.8	3.2	1.2	1.5	11.5	1.7	18.6	2.4	2.0	4.4
Z4-9	Arthington Viaduct	27.09.20	13.1	0.0	20.6	7.9	8.6	2.5	4.5	2.7	7.5	0.9	2.7	1.8
Z4-10	Harewood Bridge	27.09.20	9.7	0.0	8.7	4.8	3.6	3.8	5.6	6.9	10.5	0.8	3.8	2.8
Z4-11	Woodhall Footbridge	27.09.20	0.0	0.0	19.2	4.0	13.0	1.3	5.0	1.9	8.4	2.9	3.3	1.7
Z5-1	Linton Bridge	27.09.20	1.2	0.6	5.2	0.0	2.3	3.5	15.7	1.7	20.3	3.8	5.5	2.3
Z5-4	Wetherby Bridge	27.09.20	0.5	0.0	9.7	1.9	6.6	0.0	18.9	1.5	10.0	6.1	2.9	6.8
Z5-5	Flint Mill Bridge	19.10.20	7.9	0.0	21.4	1.3	4.9	1.0	7.9	1.6	3.9	6.9	1.3	0.0
Z5-6	Boston Spa Bridge	27.09.20	1.6	0.0	13.2	0.5	9.2	2.6	3.7	0.5	7.7	1.6	4.5	2.4
Z5-7	Newton Kyme Viaduct	19.10.20	1.1	1.1	16.0	4.1	5.8	2.5	15.4	3.0	7.2	5.8	1.7	2.2

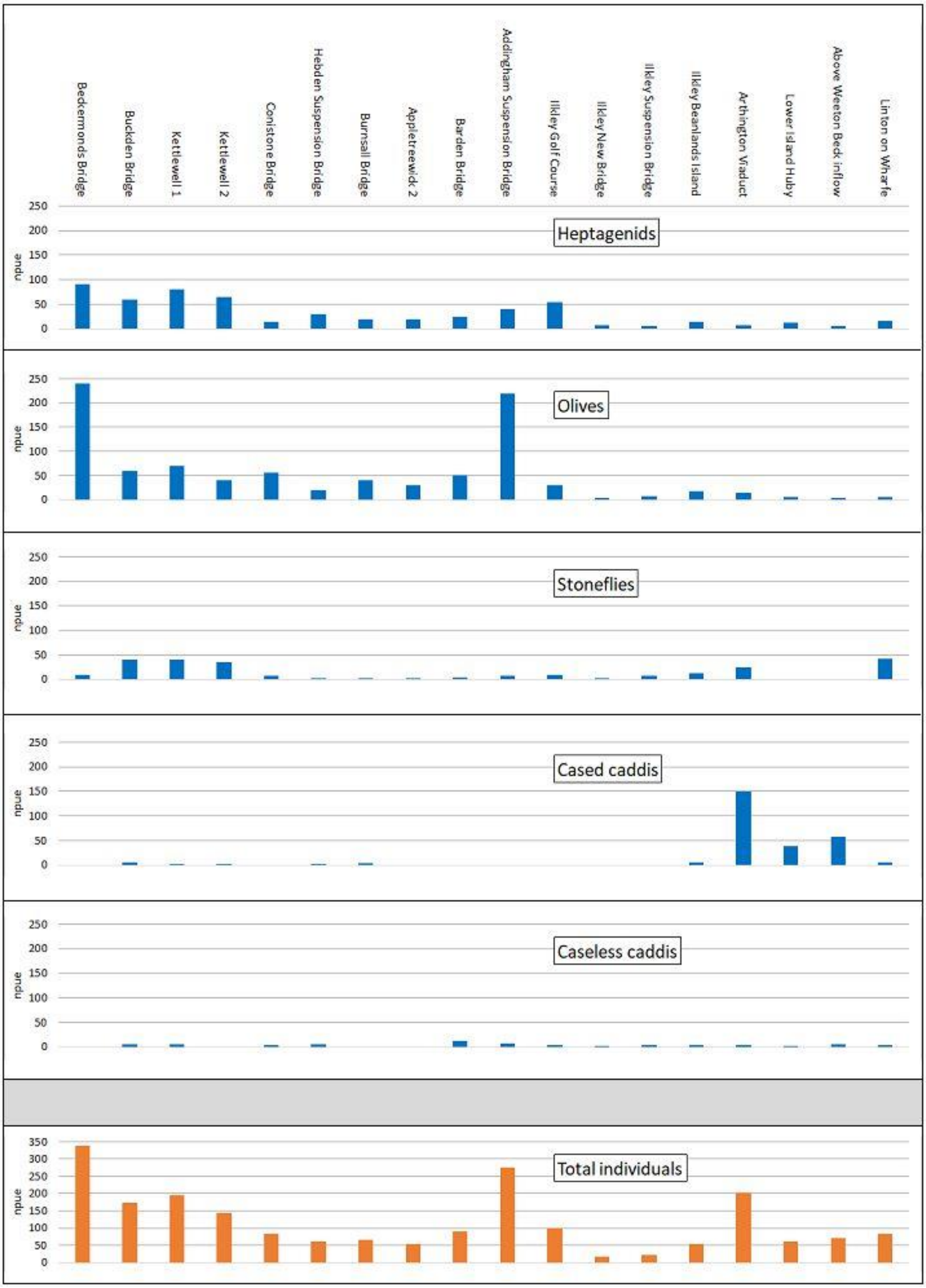
Appendix G: P removal data for Thorp Arch STW

Data provided by Graham Weston of Yorkshire Water



Appendix H: Aquatic macroinvertebrates

Aquatic macroinvertebrate data are based on three-minute kick samples and field analysis following the Riverfly Partnership protocol.



Our intention in the project was for all the sites sampled for water chemistry and diatoms to be sampled for macroinvertebrates as well as diatoms. However, it was only possible to sample 18 sites, predominantly those in the river upstream of Ilkley. Only four sites were sampled downstream of Ilkley.

Despite their patchiness, the data show several interesting features. Samples from Upper Wharfedale show high numbers of mayflies and stoneflies indicative of clean, cool, well oxygenated water. These data accord closely with the water chemistry and diatom data for this section of the Wharfe.

Heptagenid and baetid (olives) mayflies dominate downstream as far as Ilkley. However, they decline, not in the section downstream of the Ilkley STW but between the Ilkley Golf Course and Ilkley New Bridge sites. There is no significant change in water quality at this point and therefore no obvious explanation. New samples are needed from these sites to confirm this observation. Invert numbers remain low downstream as far as Beanlands Island.

No samples were taken between Beanlands Island and Arthington. At Arthington and at two sites downstream the kick samples contained high numbers of cased caddis larvae.

End