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

A CITIZEN SCIENCE PROJECT

Faecal bacteria data from samples collected on the 24th August 2020

iWHARFE

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iWharfe is a citizen science project. It involves members of communities along the Wharfe valley, working together with the Environment Agency, Yorkshire Water and other agencies. It is funded by local donations and grants. The project was designed to provide a snapshot of water quality conditions along the entire length of the river on a single day and to raise awareness about water quality issues both for people and wildlife. Water samples were collected on the 24th August 2020. Here we report on results from samples analysed for faecal bacteria, the organisms in wastewater that cause gastro-intestinal illness.

Executive Summary

1. The R. Wharfe "Big Health Check" on the 24th August 2020 involved five teams of citizen scientists taking water samples from 60 sites along the R. Wharfe at approximately the same time on the same day.
2. Although riverflow was relatively high, conditions were similar along the full length of the river.
3. Samples for faecal bacteria analysis were stored in cool boxes and hand-delivered to a collection point in Wakefield. They were analysed for *E. coli* and Intestinal Enterococci (IE) at ALS Ltd Coventry, an accredited microbiology laboratory, within 24 hours of sampling.
4. The results showed high concentrations of both *E. coli* and IE at sites between Buckden and Barden Bridge in Upper Wharfedale and at Beanlands Island in Ilkley, relatively low concentrations in Langstrothdale and in the stretch from Bolton Abbey to Ilkley Suspension Bridge, and variable concentrations downstream from Burley to the Ouse confluence at Cawood.
5. As no spills of untreated effluent were occurring on the day of sampling it is very probable that high concentrations of faecal bacteria in the main river were caused by proximity to the outflow of treated effluent from Sewage Treatment Works (STWs) rather than to the outfall from Combined Sewer Overflows (CSOs).
6. Some downstream increases in faecal bacteria concentration have not yet been explained. Point sources not connected to the public sewer remain to be identified.
7. There is evidence that faecal bacteria in the river are also derived from diffuse agricultural sources. However, these are thought to be of lesser importance on the day of sampling as faecal bacteria concentrations in tributaries draining agricultural catchments did not cause an elevation of concentrations in the main river.
8. Downstream decreases in concentration occur between some sample points indicating bacterial die-off occurring in the water column. This applies especially to *E. coli*. Die-off is likely to be a significant process in explaining both absolute concentrations and the relative abundance of *E. coli* and IE at a number of sites along the river.
9. Concentration data from Burley downstream to Cawood are not easy to interpret. Variations from site to site in this part of the river probably relate to a combination of factors including point source inputs from STWs, diffuse inputs from agricultural land and urban surfaces, dilution by the river, dilution by cleaner tributaries and downstream die-off.
10. The data show that on the day of sampling many of the popular sites used for recreation were contaminated by high concentrations of faecal bacteria. Only three sites, Deepdale, Addingham

Suspension Bridge and Ilkley Suspension Bridge, had concentrations of *E. coli* and IE less than the EU Bathing Waters Directive's 95 percentile criteria for good quality. However, given the expected variability in faecal bacterial concentrations with riverflow, even these three sites would fail to meet the minimum standards for bathing if they were monitored as required by the Bathing Waters Directive.

11. Further work needed includes: (i) a repeat survey of the same sites under different flow, especially low-flow, conditions; (ii) an investigation to identify unknown point source inflows of faecal bacteria; and (iii) a more detailed assessment of the relative importance of individual STWs and tributary inflows along the river to the faecal bacteria load.

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 iWharfe 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.

A report on nutrient pollution is forthcoming. Here we report on results of the faecal bacteria counts. Our objectives were to identify potential sources of faecal bacteria pollution, apportion where possible the relative contributions of human and agricultural pollution sources along the river, and assess the potential exposure of members of the public using the river for recreation to faecal bacteria.

Counts were made of both *E.coli* and Intestinal Enterococci (IE), the two bacteria groups used in defining the quality of bathing water under the EU Bathing Waters Directive.

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 and sampled at points close to their confluence with the main river. In some cases, e.g. the Skirfare and the Washburn, these were selected because of their size. Others, e.g. Wine Beck and Spicey Beck, were selected because of their special interest as inflows likely to contain high concentrations of faecal bacteria.

To enable samples to be collected at approximately the same time on the same day the river was divided into five zones (Figure 1) each with its own sampling team. Although the river was running quite high on the day of sampling (24th August 2020) (Appendix B) there had been little rain for the preceding 24 hours and flow conditions were similar along the length of the river (Appendix C).

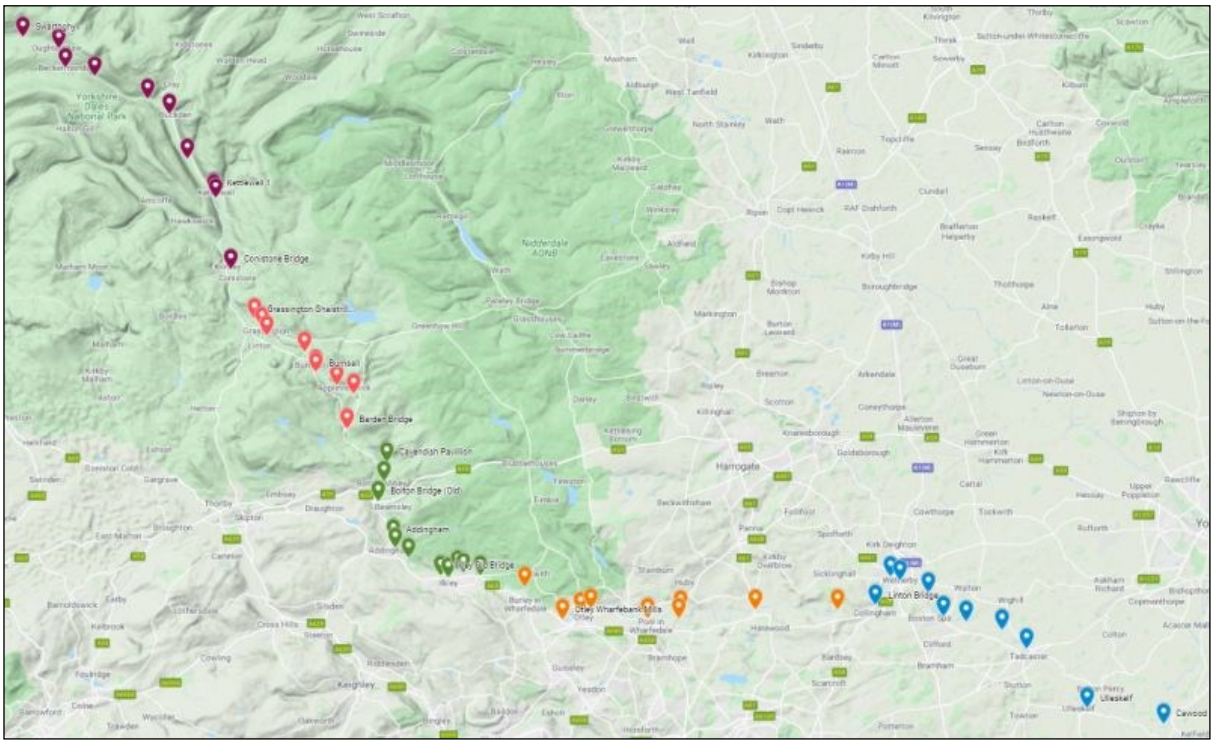

Figure 1. iWharfe sample sites showing five zones from the headwaters in Langstrothsdale in the northwest to the confluence with the River Ouse at Cawood in the southeast. The five zones are shown by different coloured markers.

Methods

The five field teams were provided with identical equipment including sterile sample bottles and cool bags to keep the samples between 2 and 8^{o}C. Samples were collected from the downstream side of bridges using a sample bottle on a lead-weighted rope or directly by wading into the river. In some cases samples were collected from the river bank using a throw bottle. Sampling began in the early morning and was completed in each zone by early afternoon.

The samples were collected and taken to ALS Ltd in Wakefield on the afternoon of the 24th August and then delivered to ALS Coventry for microbiological analysis within 24 hours of collection.

Sampling for faecal bacteria using sterilised containers

Results

Faecal bacteria patterns and potential pollution sources

Figure 2 shows the results of the faecal bacteria analyses for the 50 samples taken from 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 and differences in riverflow between sites. On the 24th August riverflow was quite high, but as far as we know, no spills of untreated effluent were occurring from any of the STWs on the river. In these conditions we expect the input of faecal bacteria from agricultural land to be relatively high following inwash from the catchment but inputs of treated effluents from STWs to be relatively low, diluted by high flows in the river.

There are clear downstream patterns in the data. For convenience these are described zone by zone.

Zone 1: Swarthghyll to Conistone Bridge

The Zone 1 samples are from the headwaters of the Wharfe in Langstrothsdale downstream to Conistone in Upper Wharfedale.

- The Swarthghyll sample was taken only a few km from the head of the valley. With the exception of one remote farm (Cam Houses) the site is situated upstream of all other human habitation in Wharfedale. At this point the river is only 2 m wide. The water is almost sterile with very low concentrations of both *E. coli* and IE typical of water draining from moorland.
- The Oughtershaw sample was taken slightly downstream of the village sewage treatment plant, a plant designed to serve a population of 17. The increase in concentrations at this point is probably due to the influence of treated effluent from this small STW.
- Values remain relatively low and constant along Langstrothdale, but then increase at Buckden

Zone 1: Upper Wharfedale, looking towards Starbottom and Buckden (photo: Sara Spillett)

Bridge upstream of Buckden village itself. Potential sources include inputs from septic tanks and from livestock from Hubberholme and Cray upstream.

- Values increase slightly from Buckden to the Kettlewell Recreational 1 site. This site is located upstream of the confluence with Kettlewell Beck. The lower concentrations at Kettlewell Bridge slightly downstream may reflect dilution by cleaner water from the tributary Beck. However, as the concentration of faecal bacteria in the Beck was not measured on this occasion this remains uncertain.

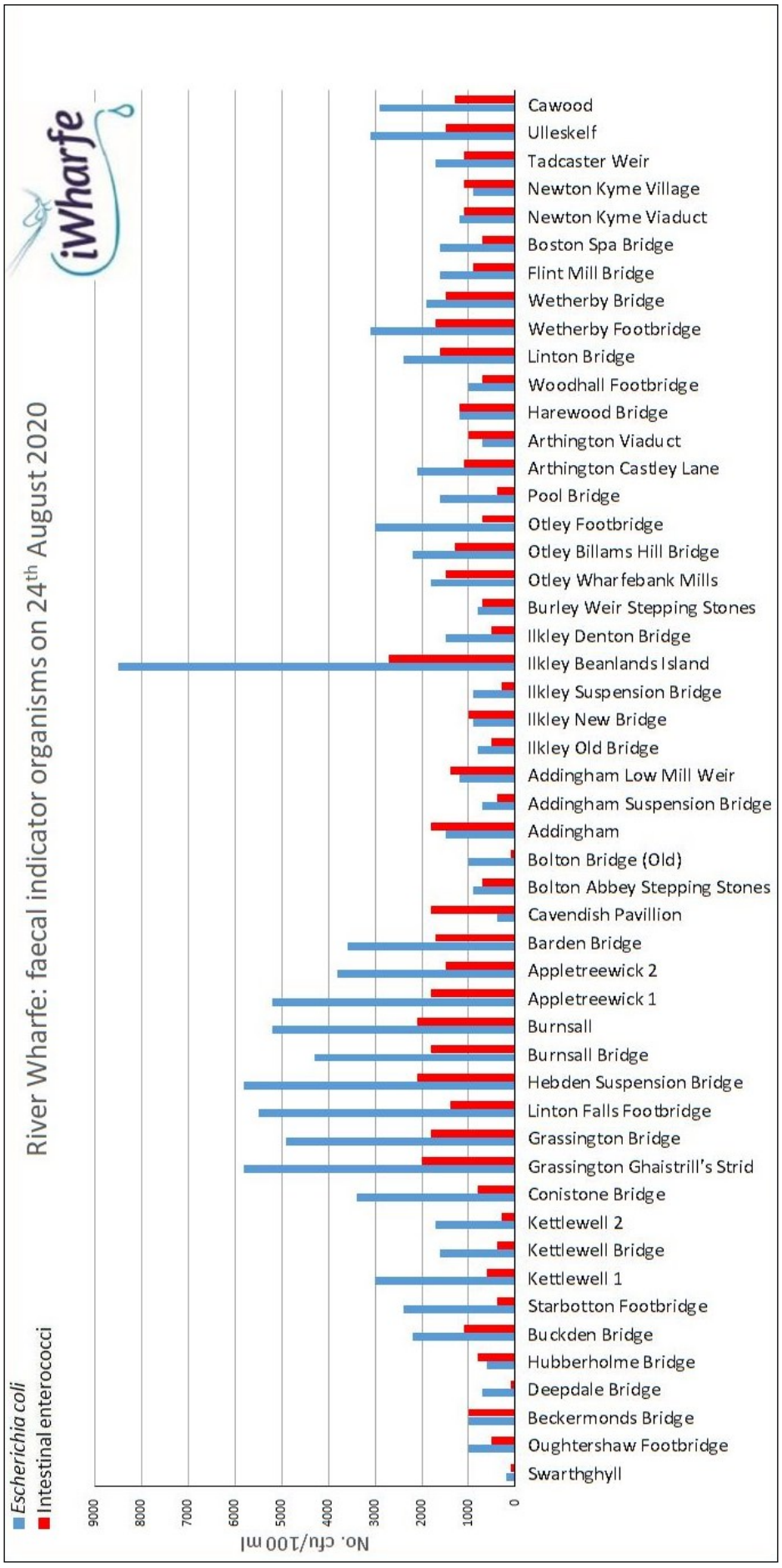

Figure 2. E. coli and IE data for 50 sampling sites on the R. Wharfe

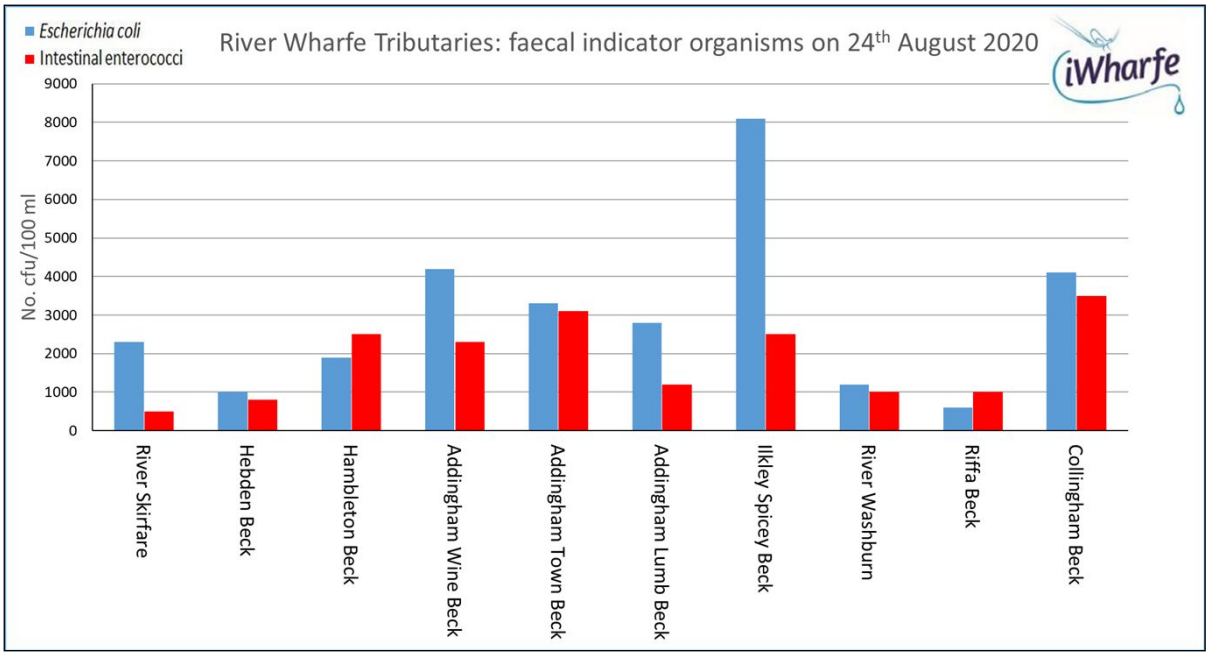

Figure 3. Faecal indicator organism data for selected tributaries of the R. Wharfe

- The data for Kettlewell Recreational 2 site are very similar to those for the Kettlewell Bridge site upstream. This is an unexpected result as the intended sampling point was positioned downstream of the Kettlewell SWT final effluent outlet. However as the exact position of the outlet could not be identified it is possible that the sample was unintentionally taken upstream of the outlet. This is an issue that needs to be resolved by further work.
- The final sampling point in Zone 1 at Conistone Bridge shows a further increase in concentration. The Bridge is upstream of Conistone village itself but downstream of Kettlewell STW and the inflow of the River Skirfare. The small village of Kilnsey, which includes Kilnsey Park Trout Farm is served by the Conistone STW, effluent from which is discharged into the Wharfe via the Davy Keld downstream from the bridge. As concentrations in the Skirfare (Figure 3) are lower than the main river, the Skirfare cannot account for the higher values observed at Conistone Bridge. These values could be explained, however, if indeed the Kettlewell 2 site sample failed to capture the impact of the Kettlewell STW as mentioned above.

Zone 2: Grassington Ghaistrill's Strid to Barden Bridge

- Values in Zone 2 are consistently high. The most remarkable feature is the significant increase in concentrations between Conistone Bridge and Ghaistrill's Strid above Grassington. This could be due to the effluent from Conistone STW but the possibility that private sewage treatment facilities, for example at Long Ashes Park, are additional important sources needs further investigation.
- The high values throughout the zone most probably reflects the input of treated effluent from a succession of STWs serving Grassington, Threshfield, Linton, Burnsall and Appletreewick. It is likely that contamination from agricultural livestock and from private septic tanks make contributions to these values in this popular tourist region, but judging from the data from Hebden Beck (Figure 3) their contribution is likely to be low.

Zone 2: Burnsall Bridge

Zone 3: Bolton Abbey to Ilkley

Zone 3: Cavendish Pavilion at Bolton Abbey

- The sample from the Cavendish Pavilion Bridge at Bolton Abbey is unusual as it has a very low concentration of *E.coli* but a relatively high abundance of intestinal enterococci. In most samples *E. coli* concentrations are two to three times higher than IE (Figure 2) reflecting the relative abundance of the two types of bacteria in human waste. The low concentration in *E. coli* is probably explained by die-off downstream from Barden Bridge as the river along this stretch is bounded by woodland. The high concentration of IE is less easy to explain. Although it dies more slowly than *E. coli* the IE value at the Cavendish Pavilion is higher than at Barden Bridge. There is a possibility that the Bolton Abbey Fish Hatchery upstream, whilst not being a source of *E. coli,* could be a source of IE. The role of fish farms in contributing to faecal bacteria concentrations needs further investigation.
- *E. coli* concentrations in samples from Bolton Abbey downstream to the Suspension Bridge in Ilkley, although variable, remain quite low, mostly less than 1000 cfu/100 ml.
- A number of tributaries were sampled along this length of the river (Figure 3). In each case values from the main river are less than those from the inflowing tributaries indicating that faecal

bacteria contamination from these agricultural catchments containing farmhouse septic tanks and, in some cases, small SWTs (e.g. at Draughton, Beamsley and Nessfield) has little or no impact on the *E. coli* levels in the main river. The higher concentrations in water entering the river from the tributaries are considerably diluted by the much larger volume of water in the main channel. All previous studies of *E. coli* along this stretch of the river support this interpretation.

Zone 3: Spicey Beck, Ilkley

- Of note are the high concentrations of *E. coli* from the Addingham Wine Beck and Ilkley Spicey Beck samples (Figure 3). Both these becks have been sampled previously. The Wine Beck values are thought to be caused by a poorly maintained septic tank serving a local caravan park, and the very high Spicey Beck values are thought to relate to a faulty sewer. Both observations deserve further investigation.

- The Beanland Island sample has the highest values of both *E. coli* and IE in the data-set. The site is situated downstream of the Ilkley Ashlands STW. Very high values in the region of 35,000 cfu/100 ml have been obtained from this site on a number of times previously in periods of low river flow. The value of ca. 8,000 cfu/100 ml on this occasion is relatively low probably illustrating the dilution effect of the river on the 24th August rather than any reduction in the concentration of *E. coli* and IE in the final effluent from the STW.

- The final site in Zone 3 at Denton Bridge shows much lower values than Beanlands Island upstream. This contrast in values between these two sites has been observed on many previous occasions. It probably reflects a combination of rapid die-off downstream from Ashlands STW but also may be related to incomplete mixing of the effluent with the main river at the Beanlands Island sampling site. Further more detailed local studies are needed to resolve this question.

Zone 4: Burley to Harewood

- The first site in Zone 4 at the Burley weir Stepping Stones shows relatively low numbers of *E. coli* and IE. This contrasts with the results from a previous sample from this site that showed higher numbers related to inputs from Ashlands STW and Ben Rhydding STW upstream.

Zone 4: Arthington Viaduct

- Downstream from Burley concentrations of both *E coli* and IE increase. The increase at the Otley Wharfebank Mills site could be due to the effluent input from the Menston/Burley STW upstream.

- Values remain relatively high through Otley, but there is a decrease between Otley Foot-

bridge and Pool Bridge despite the river receiving effluent from the Otley STW. This decrease might be because the River Washburn, that enters the Wharfe between the Otley STW and Pool Bridge brings in a substantial flow of relatively clean water (Figure 3).

- The data from Arthington are not easy to interpret. The Castley Lane site has relatively high concentrations but the Arthington Viaduct site, the point at which the final effluent outlet from the Arthingrton STW occurs has lower values. This could be because streaming of the effluent in the water column caused the collected sample to miss the flux from the STW, as may have been the case at Kettlewell (see above).
- Samples downstream of the Viaduct at Harewood Bridge and Woodhall Footbridge have quite low values probably reflecting a combination of die-off and the lack of major STW discharges in this stretch of the river. More work, however, is required to identify potential sources in this region of rich agricultural land populated by numerous farms, small villages and the Harewood Estate itself.

Zone 5: Linton to Cawood

- Changes in faecal bacteria downstream in Zone 5 are not easy to interpret. On the day of sampling concentrations from Linton through Wetherby and Boston Spa were relatively low, probably reflecting the diluting effect of the main river on the discharges from STWs at Wetherby, Thorp Arch and Tadcaster. Discharges from CSOs may also play a role, although there was no evidence of spills occurring on the day of sampling.
- Overall, however, concentrations tend to be higher in the more densely populated region of Wetherby and Boston Spa and decrease probably due to die-off downstream through Newton Kyme to Tadcaster .

Zone 5: Wetherby Bridge (photo: Mike Gadd)

- The reasons for the somewhat higher values beyond Tadcaster at Ulleskelf and Cawood are not known. However, there is a strong possibility that they are influenced by conditions in the River Ouse as well as upstream sources. Although samples were not collected from the Ouse, the confluence with the Wharfe is situated only a few km downstream of the main York STW at Naburn.

Exposure to faecal bacteria at recreational sites

A second major objective of iWharfe was to assess the potential exposure of the general public to faecal bacteria at sites regularly used for recreation along the river. Following a consultation exercise we identified 33 recreational sites from the headwaters in Langstrothsdale down to Tadcaster Castle (Table 1). On the 9th August using a team of volunteers we conducted a head count of visitors at each site. Sunday 9th August at the time of counting was cloudy and dull. The numbers recorded therefore are likely to underestimate the numbers of people visiting the different recreational sites on warm and sunny days. For example, the data for Ilkley of 145 at the stretch upstream of the Suspension Bridge on the 24th August 2020 contrasts with counts from 2019 showing that on sunny days the river can attract up to 1750 visitors. The data, nevertheless, for the day of the iWharfe count are comparable between sites and therefore likely to be a true reflection of the relative popularity of the different sites.

Code	Sample Site	E.coli Cfu/100 ml	IE Cfu/100 ml	Visitor No.	Lat / Long	Grid Ref
Z1-3	Langstrothdale Chase	*700*	*100*	2	54.21671,-2.17795	SD88493 80123
Z1-3	Yockenthwaite	*700*	*100*	40	54.20894,-2.15260	SD9014479255
Z1-4	Hubberholme Bridge	*600*	*800*	3	54.19970,-2.11400	SD92660 78222
Z1-5	Buckden Bridge	*2200*	*1100*	0	54.19143,-2.09360	SD9399077300
Z1-6	Starbotton	*2400*	*400*	2	54.16553,-2.07556	SD9516474417
Z1-7	Kettlewell 1	3000	600	6	54.14668, -2.05023	SD9681672321
Z1-9	Kettlewell 2	1700	300	0	54.14369, -2.04904	SD9689371987
Z2-1	Grassington Ghaistrill's Strid	5800	2000	31	54.07548,-2.01129	SD9935964395
Z2-3	Linton Falls	*5500*	*1400*	321	54.06650,-2.00198	SD9996863396
Z2-6	Burnsall Loup Scar	*4300*	*1800*	184	54.05179,-1.95656	SE0294261760
Z2-7	Burnsall	5200	2100	727	54.04476,-1.95161	SE0326660978
Z2-8	Appletreewick 1	5200	1800	60	54.03724,-1.93126	SE0460060142
Z2-9	Appletreewick 2	3800	1500	14	54.03218,-1.91488	SE0567259579
Z2-10	Barden Bridge	*3600*	*1700*	222	54.01215,-1.92181	SE0522257351
Z3-1	Bolton Abbey	*400*	*1800*	315	53.99421,-1.88372	SE0772155359
Z3-2	Bolton Abbey Stepping Stones	900	700	354	53.98327, -1.88626	SE0755654141
Z3-5	Addingham	1500	1800	25	53.94983,-1.87673	SE0818750421
Z3-7	Addingham Suspension Bridge	*700*	*400*	20 *	53.94547,-1.87437	SE0834449937
Z3-11	Ilkley Langbar Road	*800*	*500*	25	53.92950,-1.83359	SE1102448165
Z3-14	Ilkley Suspension Bridge	*900*	*300*	145	53.93222,-1.81539	SE1221948471
Z3-15	Ilkley Beanlands Island	8500	2700	20 **	53.93222,-1.81539	SE1221948471
Z4-1	Burley Weir Stepping Stones	800	700	31	53.92267,-1.74934	SE1655947422
Z4-4	Otley Gallows Hill	*3000*	*700*	38	53.91042,-1.67891	SE2119046077
Z4-9	Arthington Castley Lane	2100	1100	2	53.90925,-1.59859	SE2646845974
Z4-11	East Keswick	*1000*	*700*	0	53.91359,-1.43758	SE3704146529
Z5-1	Linton	*2400*	*1600*	65	53.91213,-1.40840	SE3895946382
Z5-3	Wetherby 1	*3100*	*1700*	2	53.92789,-1.38983	SE4016448146
Z5-4	Wetherby 2	*1900*	*1500*	40	53.92661,-1.38566	SE4043948006
Z5-5	Boston Spa Jackdaw Crag	*1600*	*900*	9	53.91253,-1.35773	SE4228746455
Z5-5	Boston Spa Weir	*1600*	*900*	18	53.90767,-1.34678	SE 4301145921
Z5-7	Newton Kyme Viaduct	*1200*	*1100*	5	53.90364,-1.32012	SE4676045020
Z5-9	Tadcaster Viaduct	*1700*	*1100*	21	53.88858,-1.26408	SE4846743850
Z5-9	Tadcaster Castle	*1700*	*1100*	31	53.88695, -1.26336	SE4851543670

*Table 1. Sample sites, faecal bacteria data from the 24th August and visitor numbers for recreational sites on the R. Wharfe from the 9th August 2020. Italic script indicates sites where data are taken as proxies from close by crossing point sites (see Appendix A). *Data from August 7th, **Data estimated from 2019 counts for similar weather conditions.*

As a guide to the quality of the water at different sites for swimming we use the values defined by the EU Bathing Waters Directive for "good quality". The values for the 95 percentile values of *E.coli* and IE are 1000 cfu/100 ml and 400 cfu/100 ml respectively (Table 2). The Directive also allows a "sufficient" category (Table 2) which uses a somewhat less demanding 90 percentile to define the upper boundary. We have used the data from our single samples collected on the 24th August to estimate both the likely 95 and 90 percentile values for each site for both *E. coli* and IE. These calculations make several assumptions that: (i) our on-the-day sample represents the geometric mean of a much larger number of monitoring samples taken over the bathing water season; (ii) that the values in the theoretical data-set are normally distributed after $\log_{10}$ transformation; and that (iii) the standard deviation of the data is 0.4 (David Kay, personal communication). These data are presented in Appendix A. Here we only present the primary data (Table 1, Figures 4 & 5).

Parameter	Excellent quality[1]	Good quality[1]	Sufficient[2]
Intestinal enerococci (cfu/100 ml)	200	400	330
Escherichia coli (cfu/100 ml)	500	1000	900

Table 2. Bathing Water Quality Directive 2006/7/EC of the European Parliament and of the Council (February 2006). [1]95 percentile, [2]90 percentile.

Zone 3: The Wharfe in Ilkley, upstream of the Old Bridge

In the survey counts were made of the number of children and adults present and a record made of their activity (e.g. swimming, paddling, canoeing). Table 1 shows the faecal bacteria concentrations and total visitor numbers for the different iWharfe sites whilst Appendix D shows visitor numbers also by age and activity. The counts of *E. coli* and IE are from samples taken directly from the recreational sites, although in some cases they are from crossing point sites closeby where the water quality could be assumed to be the same because of the lack of obvious inflows between the sites. These are called "recreational proxy" sites (Appendix A).

As pointed out above since we have data only for one day the results presented here should not be used as a guide to safe bathing or to define the status of any particular site. However, it is clear from the data in Figures 4 and 5 that on the day in question, 24th August 2020, few sites achieved this standard either for *E. coli* or for both *E. coli* and IE. Ilkley's Beanlands Island site stands out as the one with the highest concentration and all the popular recreational sites in Upper Wharfedale experienced high concentrations of both types of bacteria on the 24th August. The safest sites with respect to *E coli* were those in Langstrothsdale and those from Bolton Abbey to the Ilkley Suspension Bridge. The only sites with values of *E. coli* less than 1000 cfu/100 ml and IE less than 400 cfu/100 ml on the whole river on the day were the Deepdale, Addingham Suspension Bridge and Ilkley Suspension Bridge sites.

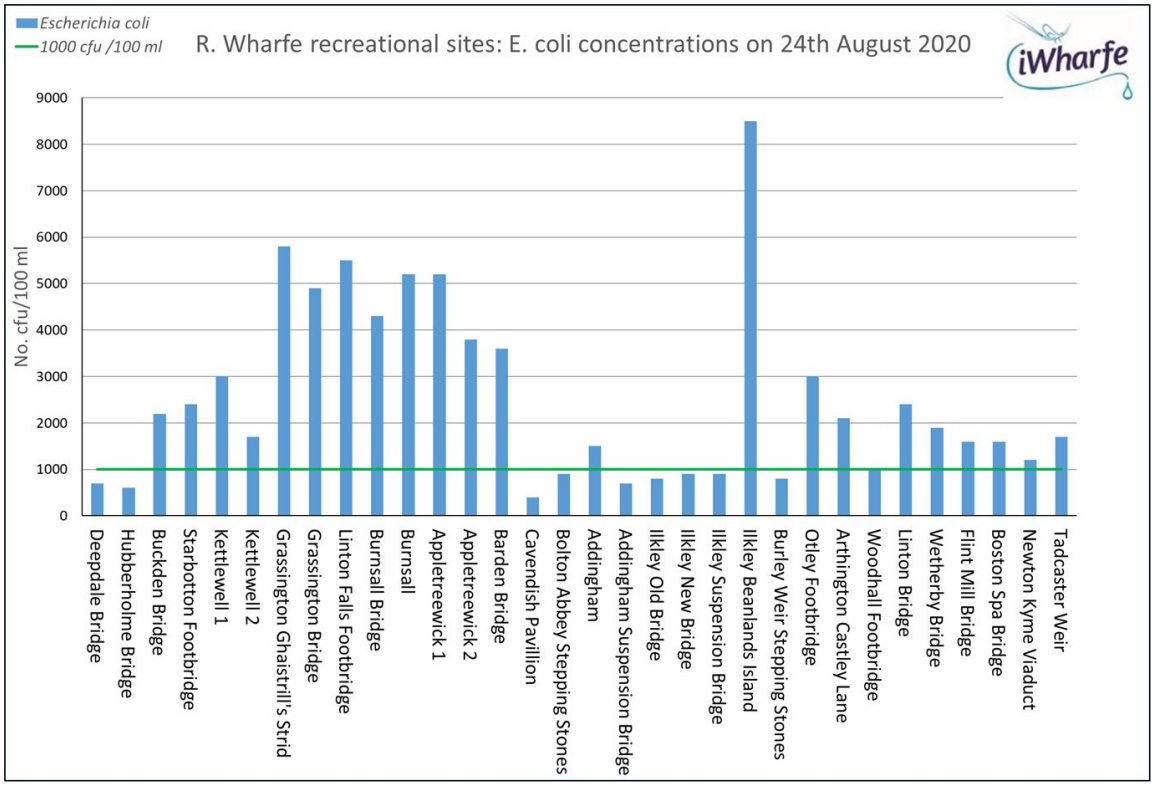

Figure 4. E. coli concentrations for recreational sites (or close by proxy site, cf. Table 1). The horizontal green line represents the upper 95 percentile boundary (1000 cfu/100 ml) for a good quality bathing

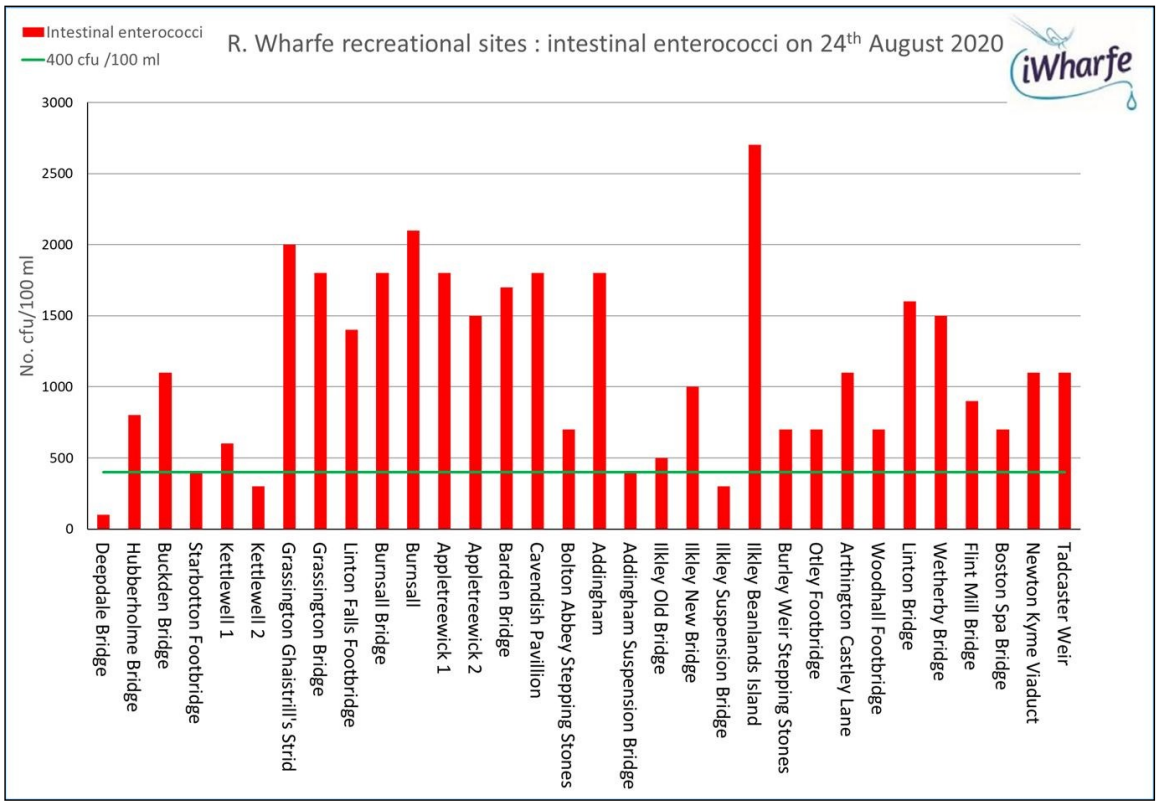

Figure 5. Intestinal enterococci concentrations for recreational sites (or their close by proxy, cf. Table 1). The horizontal green line represents the upper 95 percentile boundary (400 cfu/100 ml) for a good quality bathing water.

Conclusions and further work

Strengths and limitations of the data

The concentration of faecal bacteria in rivers in time and space is inherently variable depending principally on variations in the strength of contributions from different pollution sources, rates of downstream die-off and variations in riverflow. Of these, riverflow 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 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.

Sources of faecal bacteria

The iWharfe data indicate that in most situations treated effluent discharges from STWs were the dominant source of faecal bacteria in the river on the day of sampling.

There is evidence that inputs from agricultural land also contribute to the faecal bacteria load but these are likely to be of lesser importance as there are no cases where the concentration of *E coli* downstream of a tributary beck inflow is greater than in the concentration in the beck itself.

The clearest evidence for the importance of STW discharges is in Ilkley where the peak in values of both *E. coli* and IE at Beanlands Island, compared to the values upstream at the Ilkley Suspension Bridge, indicates the polluting role of treated effluent from the Ashlands STW. This observation has been made for these two sites on several previous occasions in the course of an earlier study by the Ilkley Clean River Group.

It is also highly probable that STW effluent is responsible for the high concentrations of faecal bacteria at most sites in Upper Wharfedale from Grassington to Barden Bridge.

However, there are some significant increases in concentration that are difficult to account for. These include the doubling of values between Hubberholme and Buckden and a further doubling between Conistone and Grassington. In the case of Buckden the increase may be explained by a combination of septic tank and livestock inputs from Hubberholme and Cray. The increase at Ghaistrill's Strid north of Grassington is less easy to explain. Potential sources of contamination upstream of Ghaistrill's Strid include Conistone STW but inflows from private sewage treatment plants may also be important.

In the lower Wharfe from Burley downstream identifying sources is less easy due to the variability of the data (see below).

Die-off

Concentrations of faecal bacteria do not consistently increase downstream. Bacterial populations die off in the water column albeit at different rates. *E. coli* has a more rapid die-off rate than IE and the difference in *E. coli* and IE concentrations at some sites may be due to these differential losses.

An example of die-off is well illustrated by the difference between the concentrations from Beanlands Island and Denton Bridge in Ilkley, a distance of only one kilometre, where we know from this

and previous studies losses of 80% can occur. Equally it seems very likely that the reason for the low concentration of *E. coli* at the Bolton Abbey Cavendish Pavilion site is due to die-off downstream from Barden Bridge. Here the river is bounded by woodland for almost the whole stretch and there are no significant sources of *E. coli* in the immediate catchment to compensate for the die-off.

Although some faecal pathogens may be more persistent this observation indicates that *E. coli* exposure along the river is driven chiefly by local upstream rather than distant upstream sources. It is unlikely, for example, that contamination of the recreational site in Ilkley upstream of the Suspension Bridge is caused by faecal bacteria sources upstream much above Addingham.

Unexplained variability

The data for the Wharfe downstream of Ilkley are more variable than upstream. *E coli* values fluctuate between 700 and 3100 cfu/100 ml from Burley down to Cawood. IE concentrations are quite high at all sites. However there are no sites with concentrations as high as those in the upper Wharfe despite the presence of a higher human population density and richer agricultural land in the catchment.

Sites with higher concentrations of faecal bacteria are associated with sites on the river running through the main towns of Otley and Wetherby and sites with lower values occur mainly between these towns suggesting that human populations are the dominant source. However, there is much unexplained variability. The observed concentrations on the day of sampling probably reflects a mixture of factors at any one site including differences in the efficiencies of STWs, inwash from agricultural land, septic tank discharges, die-off patterns, dilution capacity of the river and input of relatively clean water from tributary streams. It is notable, for example, that concentration of faecal bacteria in the River Washburn, a major tributary inflowing between the Otley Footbridge and the Pool Bridge sites is significantly lower than the main river.

Faecal bacteria concentrations at recreational sites

On the day of sampling many of the recreational sites were contaminated by high concentrations of faecal bacteria, although some sites, in Langstrothdale and in the stretch from Bolton Abbey to the Ilkley Suspension Bridge, had relatively low concentrations. However, based on the calculations presented in Appendix A even these three sites would not be compliant with the criteria of the Directive for either “good” or “sufficient” status if judged against monitoring data collected over the length of a single or multiple bathing seasons.

On the 24th August visitor numbers were low, as the river was fast flowing and the shingle banks used as access points were underwater. Consequently few members of the public would be exposed to the high faecal bacteria concentrations in such high flow conditions. Nevertheless, it is probable that visitors to some of the most popular sites for recreation along the river for swimming, paddling, canoeing and angling in low flow conditions would be exposed to poor water quality conditions owing to the proximity of these sites to the treated effluent outfalls of local STWs.

Future work

The results of iWharfe are valuable in raising awareness about river water quality and in highlighting some of the principal sources of faecal bacteria pollution along the river. However, many of the conclusions reached here are based on a very limited set of observations. These conclusions need examination by further work. Priorities include one or more repeat surveys in low flow conditions, identification of unknown point sources and more focused sampling upstream and downstream of STW final effluent outlets and tributary inflows.

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[1]Addingham Environment Group, [2]Ilkley Clean River Group, [3]Yorkshire Dales Rivers Trust, [4]Dales to Vale River Network

Appendix A: Main river sample sites and faecal bacteria data

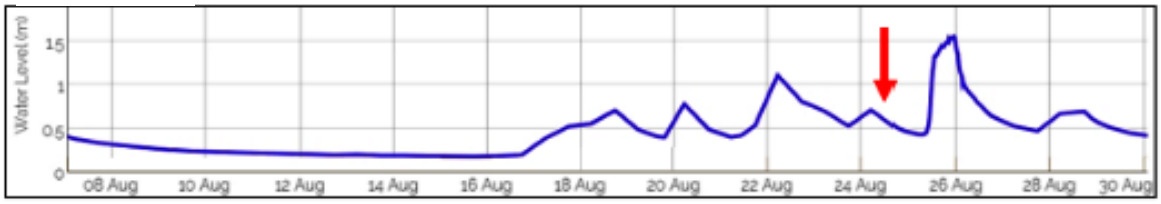
The table shows sample bottle code, site names, distances between downstream sites and the uppermost site sampled, distances between sites, location, type of sample (R = recreational; RP = recreational proxy), *E. coli* and IE concentrations, and *E. coli* and IE concentrations calculated for the 95 % ile and 90 %ile boundaries were the observational data to be the mean of a lognormal distribution of values with a 0.4 SD. These data were provided by David Kay.

Code	Sample Site	km from start	km from last	Lat / Long	Type	*E.coli* cfu/100 ml	IE cfu/100 ml	*E. coli* cfu/100 ml GOOD	IE cfu/100 ml GOOD	*E. coli* cfu/100 ml SUFFICIENT	IE cfu/100 ml SUFFICIENT
Z1-0	Swarthghyll	0.0		54.23546,-2.23566	Bank	200	100	914	457	651	326
Z1-1	Oughtershaw Footbridge	3.3	3.3	54.22867,-2.20046	Footbridge	1000	500	4,571	2,285	3,257	1,628
Z1-2	Beckermonds Bridge	4.6	1.4	54.21806,-2.19429	Footbridge	1000	1000	4,571	4,571	3,257	3,257
Z1-3	Deepdale Bridge	6.7	2.1	54.21303,-2.16645	Bridge (RP)	700	100	3,200	457	2,280	326
Z1-4	Hubberholme Bridge	10.6	3.9	54.19966,-2.11469	Bridge (RP)	600	800	2,743	3,657	1,954	2,605
Z1-5	Buckden Bridge	12.6	2.0	54.19143,-2.09360	Bridge	2200	1100	10,056	5,028	7,165	3,583
Z1-6	Starbotton Footbridge	16.7	4.1	54.16625,-2.07619	Footbridge	2400	400	10,970	1,828	7,816	1,303
Z1-7	Kettlewell 1	20.2	3.4	54.14668, -2.05023	Bank (R)	3000	600	13,713	2,743	9,771	1,954
Z1-8	Kettlewell Bridge	20.3	0.2	54.14581,-2.05098	Bridge	1600	400	7,313	1,828	5,211	1,303
Z1-9	Kettlewell 2	20.6	0.3	54.14369, -2.04904	Bank (R)	1700	300	7,770	1,371	5,537	977
Z1-11	Conistone Bridge	25.7	5.1	54.10340,-2.03367	Bridge	3400	800	15,541	3,657	11,073	2,605
Z2-1	Grassington Ghaistrill's Strid	29.8	4.1	54.07548,-2.01129	Bank (R)	5800	2000	26,511	9,142	18,890	6,514
Z2-2	Grassington Bridge	30.6	0.8	54.07065,-2.00447	Bridge (RP)	4900	1800	22,397	8,228	15,959	5,862
Z2-3	Linton Falls Footbridge	31.3	0.7	54.06591,-1.99985	Footbridge (RP)	5500	1400	25,140	6,399	17,913	4,560
Z2-4	Hebden Suspension Bridge	34.3	3.0	54.05714,-1.96260	Footbridge	5800	2100	26,511	9,599	18,890	6,839
Z2-6	Burnsall Bridge	36.0	1.7	54.04641,-1.95163	Bridge (RP)	4300	1800	19,655	8,228	14,005	5,862
Z2-7	Burnsall	36.5	0.6	54.04476,-1.95161	Bank (R)	5200	2100	23,769	9,599	16,936	6,839
Z2-8	Appletreewick 1	38.5	2.0	54.03724,-1.93126	Bank (R)	5200	1800	23,769	8,228	16,936	5,862
Z2-9	Appletreewick 2	39.6	1.1	54.03218,-1.91488	Bank (R)	3800	1500	17,369	6,856	12,376	4,885
Z2-10	Barden Bridge	42.0	2.5	54.01260,-1.92186	Bridge (RP)	3600	1700	16,455	7,770	11,725	5,537
Z3-1	Cavendish Pavillion	45.7	3.6	53.99366,-1.88319	Footbridge (RP)	400	1800	1,828	8,228	1,303	5,862
Z3-2	Bolton Abbey Stepping Stones	47.3	1.6	53.98327, -1.88626	Stepping stones	900	700	4,114	3,200	2,931	2,280
Z3-3	Bolton Bridge (Old)	48.8	1.5	53.97195,-1.89161	Bridge	1000	100	4,571	457	3,257	326
Z3-5	Addingham	51.9	3.2	53.94983,-1.87673	Bank (R)	1500	1800	6,856	8,228	4,885	5,862
Z3-7	Addingham Suspension Bridge	52.5	0.5	53.94532,-1.87451	Footbridge (RP)	700	400	3,200	1,828	2,280	1,303
Z3-9	Addingham Low Mill Weir	53.5	1.1	53.93964,-1.86203	Bank	1200	1400	5,485	6,399	3,908	4,560
Z3-11	Ilkley Old Bridge	56.8	3.3	53.92906,-1.83043	Bridge (RP)	800	500	3,657	2,285	2,605	1,628
Z3-13	Ilkley New Bridge	57.3	0.5	53.92806,-1.82349	Bridge (RP)	900	1000	4,114	4,571	2,931	3,257
Z3-14	Ilkley Suspension Bridge	58.1	0.8	53.93234,-1.81494	Footbridge (RP)	900	300	4,114	1,371	2,931	977
Z3-15	Ilkley Beanlands Island	58.6	0.4	53.93106,-1.80850	Bank (R)	8500	2700	38,852	12,341	27,683	8,794
Z3-16	Ilkley Denton Bridge	59.6	1.1	53.92929,-1.79260	Bridge	1500	500	6,856	2,285	4,885	1,628
Z4-1	Burley Weir Stepping Stones	63.5	3.9	53.92267,-1.74934	Stepping stones	800	700	3,657	3,200	2,605	2,280
Z4-2	Otley Wharfebank Mills	67.4	3.9	53.90423, -1.71318	Bank (R)	1800	1500	8,228	6,856	5,862	4,885
Z4-3	Otley Billams Hill Bridge	68.8	1.4	53.90854,-1.69514	Bridge	2200	1300	10,056	5,942	7,165	4,234
Z4-4	Otley Footbridge	69.6	0.8	53.91059,-1.68469	Footbridge (RP)	3000	700	13,713	3,200	9,771	2,280
Z4-6	Pool Bridge	74.1	4.5	53.90514,-1.63063	Bridge	1600	400	7,313	1,828	5,211	1,303
Z4-9	Arthington Castley Lane	76.5	2.4	53.90925,-1.59859	Bank (R)	2100	1100	9,599	5,028	6,839	3,583
Z4-8	Arthington Viaduct	77.2	0.6	53.90470, -1.60076	Bank	700	1000	3,200	4,571	2,280	3,257
Z4-10	Harewood Bridge	84.6	7.4	53.90980,-1.52626	Bridge	1200	1200	5,485	5,485	3,908	3,908
Z4-11	Woodhall Footbridge	90.8	6.2	53.90946,-1.44608	Footbridge (RP)	1000	700	4,571	3,200	3,257	2,280
Z5-1	Linton Bridge	94.2	3.4	53.91252,-1.40986	Bridge	2400	1600	10,970	7,313	7,816	5,211
Z5-3	Wetherby Footbridge	96.8	2.6	53.92860,-1.39503	Footbridge	3100	1700	14,170	7,770	10,096	5,537
Z5-4	Wetherby Bridge	97.7	0.9	53.92654,-1.38607	Bridge (RP)	1900	1500	8,685	6,856	6,188	4,885
Z5-5	Flint Mill Bridge	100.4	2.7	53.91964,-1.35839	Footbridge (RP)	1600	900	7,313	4,114	5,211	2,931
Z5-6	Boston Spa Bridge	102.8	2.4	53.90615,-1.34400	Bridge (RP)	1600	700	7,313	3,200	5,211	2,280
Z5-7	Newton Kyme Viaduct	104.8	1.9	53.90312,-1.32178	Bank (RP)	1200	1100	5,485	5,028	3,908	3,583
Z5-8	Newton Kyme Village	109.2	4.5	53.89865, -1.28756	Bank	900	1100	4,114	5,028	2,931	3,583
Z5-9	Tadcaster Weir	112.1	2.8	53.88758,-1.26371	Bank (R)	1700	1100	7,770	5,028	5,537	3,583
Z5-10	Ulleskelf	118.7	6.6	53.85414, -1.20442	Bank	3100	1500	14,170	6,856	10,096	4,885
Z5-11	Cawood	127.3	8.6	53.84516, -1.13091	Bank	2900	1300	13,256	5,942	9,445	4,234

Appendix B: 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

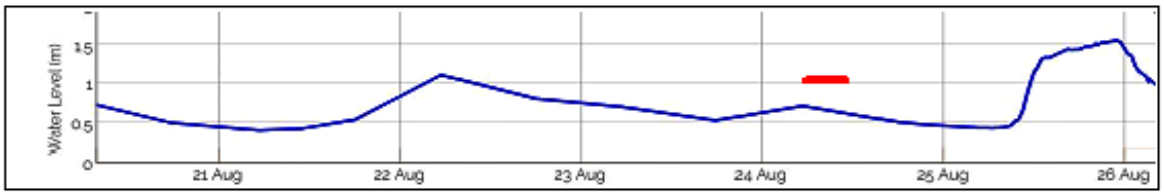
Otley

Collingham

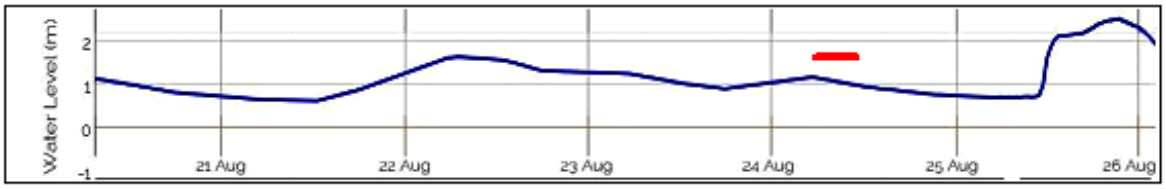
Appendix C: River levels at five EA hydrometric monitoring sites on the River Wharfe

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).

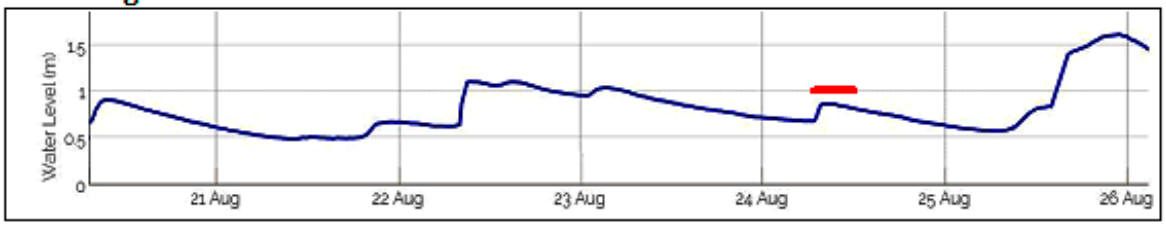
Kettlewell



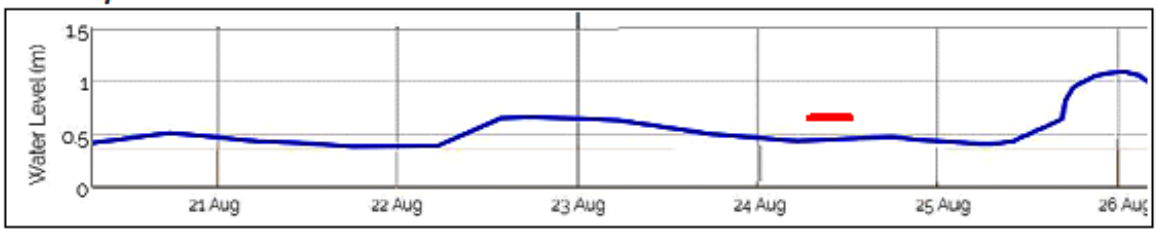
Netherside Hall



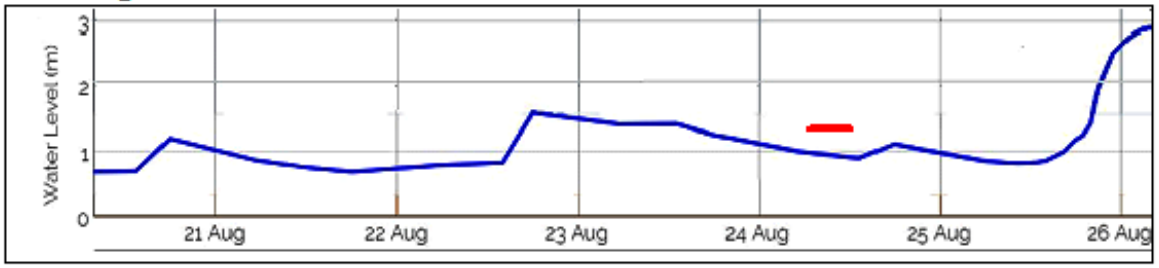
Addingham



Otley



Collingham



Appendix D: Visitor counts at recreational sites on Sunday 9th August

	Total Visitors	ADULTS				CHILDREN			
		Swim	Paddle	On the water (e.g. in boats)	Using the riverbank	Swim	Paddle	On the water (e.g. in boats)	Using the riverbank
Langstrothdale Chase	2	0	0	0	2	0	0	0	0
Yockenthwaite	40	0	1	0	29	0	1	0	9
Hubberholme Bridge	3	0	0	0	1	0	0	0	2
Buckden Bridge	0	0	0	0	0	0	0	0	0
Starbotton	2	0	0	0	2	0	0	0	0
Kettlewell 1	6	0	0	0	5	1	0	0	0
Kettlewell 2	0	0	0	0	0	0	0	0	0
Grassington Ghaistrill's Strid	31	0	4	0	16	0	5	1	5
Linton Falls	321	3	18	8	209	3	12	2	66
Burnsall Loup Scar	184	8	7	4	110	7	8	7	33
Burnsall	727	6	17	15	388	17	79	38	167
Appletreewick 1	60	2	0	0	24	5	10	0	19
Appletreewick 2	14	2	0	0	10	0	0	0	2
Barden Bridge	222	0	0	0	155	0	4	0	63
Bolton Abbey	315	1	17	0	169	1	46	0	81
Bolton Abbey Stepping Stones	354	1	22	0	184	4	53	1	89
Addingham	25	8	2	2	6	2	4	0	1
Addingham Suspension Bridge	20 *								
Ilkley Langbar Road	25	0	0	0	9	5	4	0	7
Ilkley Suspension Bridge	145	10	11	1	74	2	22	6	19
Ilkley Beanlands Island	20 **								
Burley Weir Stepping Stones	31	1	0	17	0	4	2	0	7
Otley Gallows Hill	38	0	10	0	12	4	6	2	4
Arthington Castley Lane	2	2	0	0	0	0	0	0	0
East Keswick	0	0	0	0	0	0	0	0	0
Linton	65	0	2	0	28	0	4	0	31
Wetherby 1	2	0	1	0	0	1	0	0	0
Wetherby 2	40	0	0	0	29	0	3	0	8
Boston Spa Jackdaw Crag	9	1	0	1	5	0	0	0	0
Boston Spa Weir	18	0	1	0	15	0	0	0	2
Newton Kyme Viaduct	5	0	2	0	1	2	0	0	0
Tadcaster Viaduct	21	0	1	0	14	1	3	0	2
Tadcaster Castle	31	0	2	0	23	1	2	0	3

**Data from 7th August; **Data from 2019 counts on a similar day*

Appendix E: FIO Team leaders

Acknowledgements

Our thanks to Ben Statham, Sara Spillett and Mike Gadd for permission to use their photographs, Trish Smith for permission to sample at Flint Mill and to all those who provided valuable comments on an earlier draft of this report. Special thanks are due to David Kay, University of Aberystwyth, for suggesting how our single data points could be used illustratively to calculate the upper 95%ile and 90%ile values of a typical set of monitoring data for each site under the EU Bathing Waters Directive. Finally we are most grateful to the whole iWharfe Citizen Science community including our Consortium Partners, Funders, Field Teams, Visitor Survey Team, Advisory Group and Management Group for their help and encouragement throughout the project.

Consortium Partners

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Yorkshire Dales National Park Authority
Ilkley Clean River Group
Addingham Environment Group
Upper Wharfedale Field Society
Friends of the Dales
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Otley 2030
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Boston Spa, Wetherby & Villages Community Green Group
Dales to Vale River Network
The Rivers Trust

Funders

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Ilkley Town Council
Wetherby Ward Councillors
Wharfedale Naturalists Society
Salmon & Trout Conservation UK
Patagonia
EU WaterCog
Alan and Penny Jerome
97 people who donated through Crowdfunding

Field Teams

Steve Cheetham, Christine Cheetham, John Rishworth, Steve Fairbourn, Kathleen Roberts, Rick Battarbee, Gill Battarbee, Malcolm Secrett, Jan Hindle, Karl Ridley, Charlotte Ridley, Tom Raper, Ruth Raper, Mike Gadd, Lee Reutens, Mark Barrow, Sara King, Jack Hirst, Charlotte Simons, Conor Scholey, Marie Taylor, Tim Harris, Josh Tinsley, Fran Hooley, Louise Brustad, Emily Lewis, Kim Bailey

Visitor Survey Team

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Advisory Group

Andrew McKeon, Andy Boyle, Ben Statham, Becky Malby, Ben Aston, Mark Barrow, Charlotte Simons, Martin Christmas, Conor Scholey, David Asher, Emily Lewis, Fran Hooley, Graham Weston, Jack Hirst, Janet Hindle, John Rishworth, Jon Grey, Karen Shackleton, Karl Ridley, Kathleen Roberts, Keith Berrington, Kim Bailey, Kirsty Breaks, Louise Brustad, Malcolm Secrett, Marie Taylor, Martin Bamforth, Mick Bradley, Mike Gadd, Owen Wells, Penny Stables, Rick Battarbee, River Six, Steve Cheetham, Steve Fairbourn, Steve Robinson, Tom Raper, Tim Harris, Josh Tinsley, Tony Serjeant, Victoria Prest

Management Group

Marie Taylor, Charlotte Simons, Karen Shackleton, Becky Malby, Malcolm Secrett, Rick Battarbee

http://www.yorkshiredalesriverstrust.com/projects/iwharfe/
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Environment Agency

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