iWharfe

IMPROVING WATER QUALITY ON THE RIVER WHARFE FROM OUGHTERSHAW TO THE OUSE: A CITIZEN SCIENCE PROJECT

Identifying sources of faecal bacteria in the River Wharfe in Upper Wharfedale 2021

Addingham Civic Society Environment Group

Ilkley Clean River Group

Yorkshire Dales Rivers Trust

Interreg North Sea Region WaterCoG

European Regional Development Fund

EUROPEAN UNION

iWHARFE_21

Improving water quality on the River Wharfe from Oughtershaw to the Ouse: a citizen science project

Identifying sources of faecal bacteria in the River Wharfe in Upper Wharfedale 2021

Rick Battarbee[1,2,3] and Malcolm Secrett[1]

[1]Addingham Environment Group, [2]Ilkley Clean River Group, [3]University College London

Introduction

The iWharfe project is a citizen science project concerned with water quality in the River Wharfe. It was designed by the Yorkshire Dales Rivers Trust (YDRT), the Ilkley Clean River Group (ICRG) and the Addingham Environment Group (AEG). In the summer of 2020, working together with the Environment Agency and with funding from local councils, charities and private donations, we organized a field survey to take water samples from the river from its headwaters in Langstrothsdale down to its confluence with the River Ouse at Cawood.

Low water in the R. Wharfe below Scargill House on the 26th April 2021

The survey involved five teams sampling at 60 sites from the river and from selected tributaries on the morning of Monday, 24th August. Samples were analysed for faecal bacteria and for nutrient chemistry. The faecal bacteria data for the sites on the main river are shown in Figure 1.

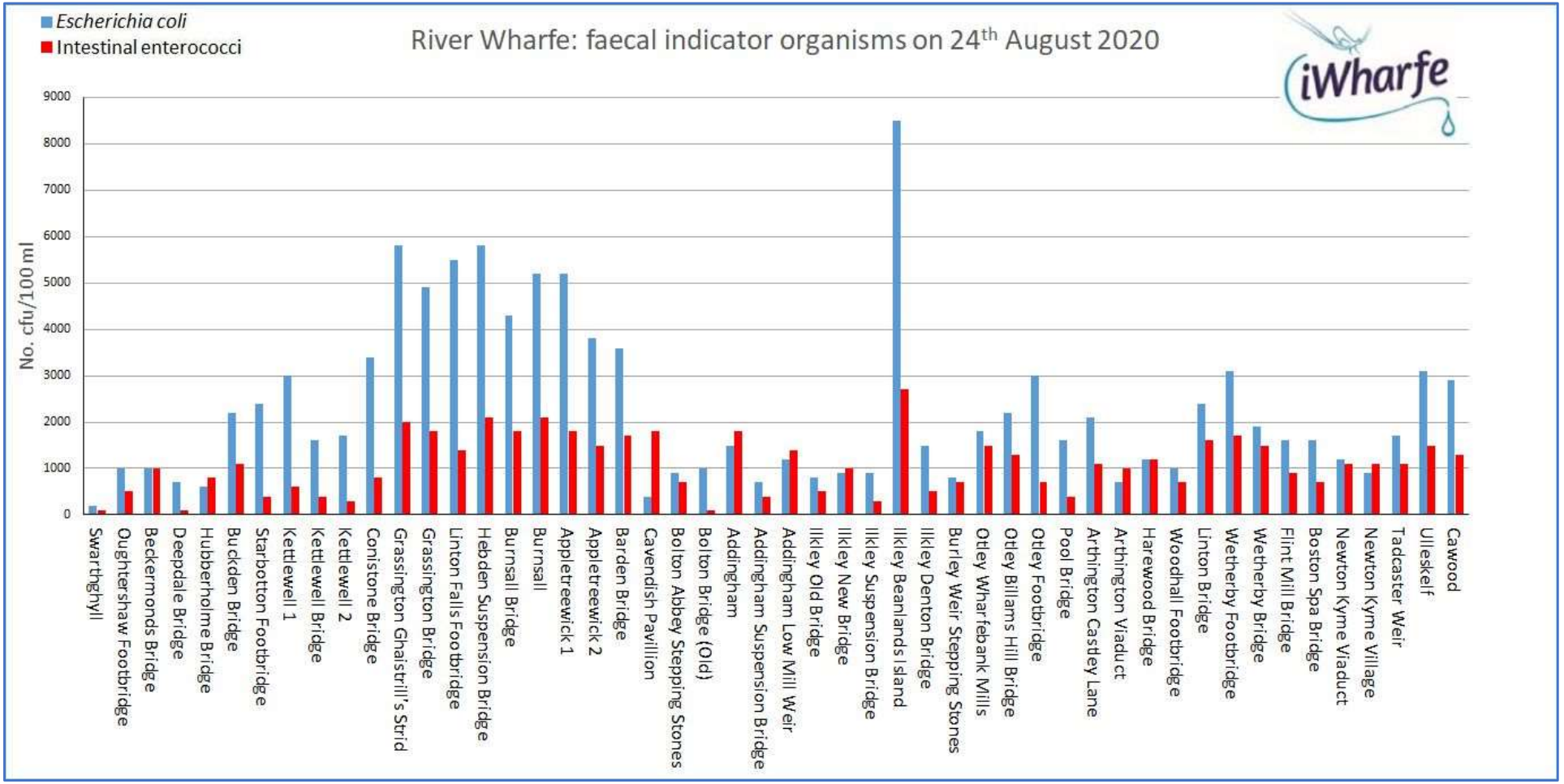


Figure 1. Faecal bacteria concentrations (cfu/100 ml) for sites on the River Wharfe for August 24th 2020. Blue = Escherichia coli, red = Intestinal Enterococci

River levels on the day of sampling were high. We consequently expected to see high concentrations of faecal bacteria at sites downstream of Ilkley, but the high concentrations at sites upstream in Upper Wharfedale, especially between Buckden and Barden Bridge (Fig. 1), were unexpected.

Most of the high values throughout this stretch of the river probably reflected a combination of faecal bacteria washed in from agricultural land and faecal bacteria discharged in the treated effluent from a succession of STWs serving the villages of Buckden, Starbotton, Kettlewell, Kilnsey, Conistone, Grassington, Threshfield, Linton, Burnsall and Appletreewick.

Not all the data were easy to explain. We observed a steep increase in faecal bacteria concentration between Conistone Bridge and Ghaistrill's Strid above Grassington (Fig. 1). It could have been due to the effluent from Conistone STW but we speculated that it could also have been caused by effluent discharge from the private sewage treatment facility serving the Long Ashes Caravan Park.

We also speculated that fish farms might be a source of faecal bacteria, not directly from fish but possibly from birds and/or small mammals attracted to the farms.

The iWharfe_Upper project described here was therefore designed as a follow-up study to identify causes of faecal bacteria pollution in Upper Wharfedale by taking samples upstream and downstream of STWs and upstream and downstream of other potential point sources, both on the main river and on a number of tributary becks.

Three surveys were conducted, in April, June and July of 2021 respectively. However, in marked contrast to 2020, riverflow on each of the 2021 survey dates was very low (Fig. 2). Consequently, whilst the data afforded valuable insights into faecal bacteria patterns in dry weather, low flow conditions we were unable to answer some of our specific questions, as set out below, which depended on sampling during average to high flow conditions.

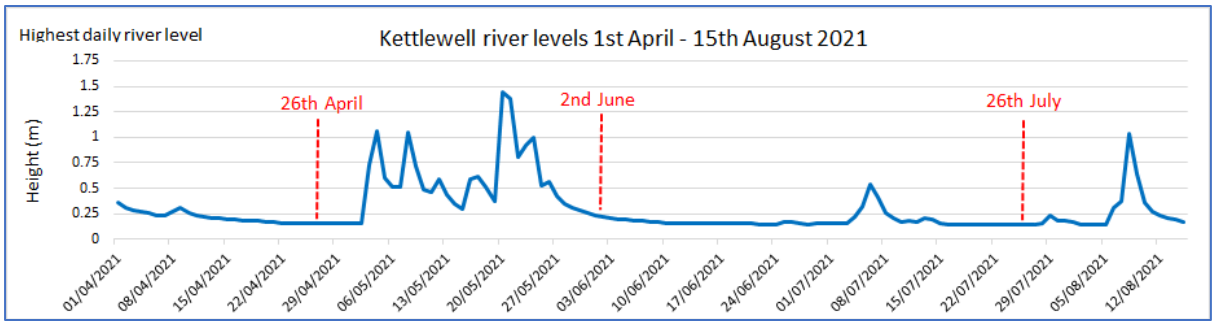


Figure 2. River levels during the survey period at Kettlewell

Kettlewell

Bolton Abbey (Cavendish Pavilion)

Sites

The sites chosen for sampling are shown in Figure 3. They extend from Hubberholme downstream to the Cavendish Pavilion at Bolton Abbey.

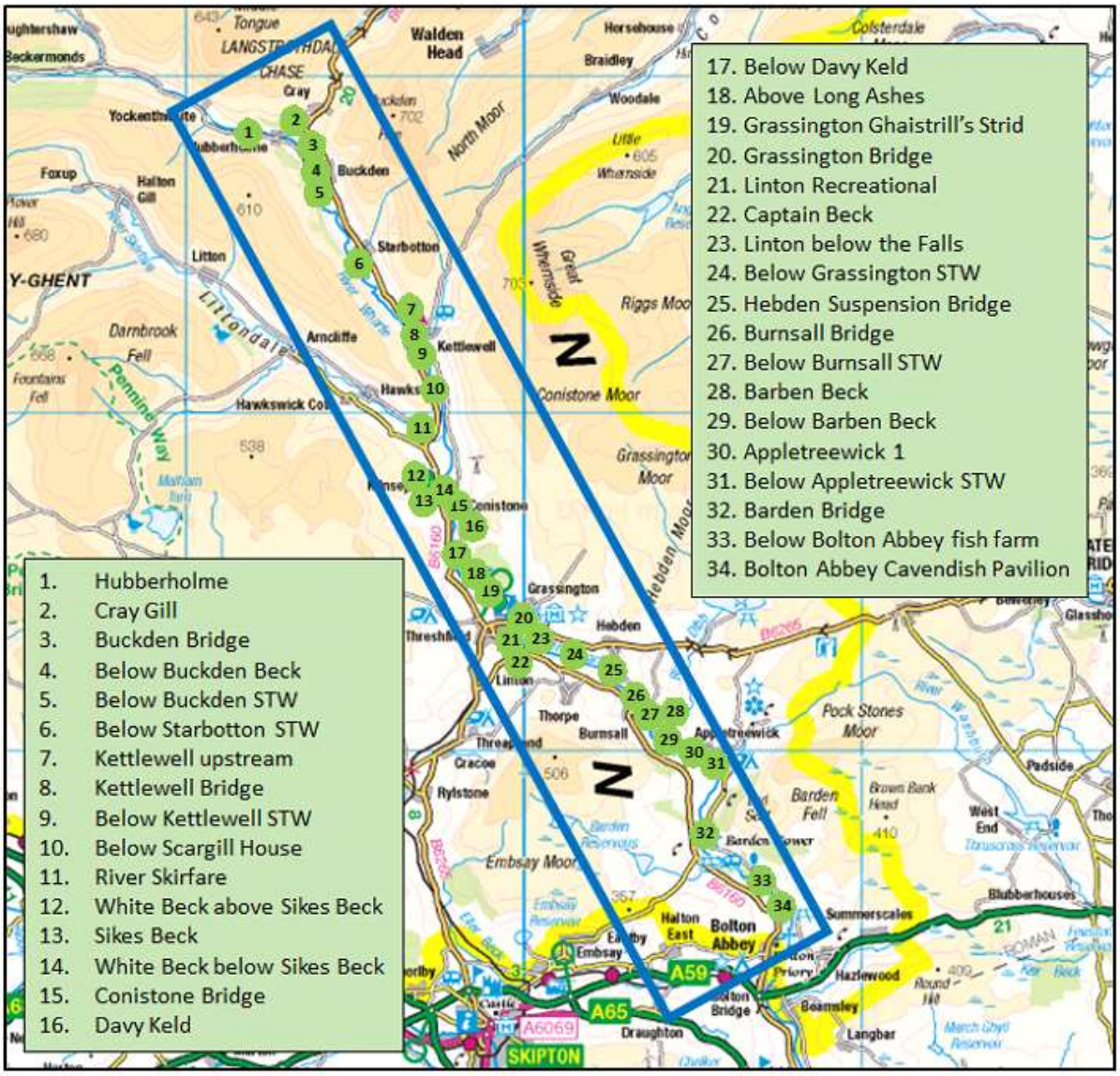


Figure 3. The sample sites

The rationale for site selection was as follows:

1. As *E. coli* concentrations in Langstrothdale upstream of Hubberholme were low in the iWharfe20 survey but increased significantly between Hubberholme and Buckden we used Hubberholme as the upstream starting point of the survey;
2. In an attempt to explain the increase in *E. coli* concentration between Hubberholme and Buckden (Fig. 1) we inserted a site on Cray Gill. We added Buckden Beck as a potential faecal bacteria source, a site on the main river below the entry point of the beck but above the Buckden STW, and a site downstream of the Buckden STW final effluent pipe;
3. The site sampled in 2020 downstream from Starbotton STW was retained, as were the three sites in Kettlewell designed to identify the contributions from Kettlewell Beck and Kettlewell STW;

4. Below Kettlewell a site was added on the main river downstream of Scargill House, a 70-bed residential centre, to detect any influence of the private sewage treatment plant serving the house;
5. Between Scargill House and Conistone Bridge the main inflow is the River Skirfare. The Skirfare is a major tributary with several small communities in its catchment. It was sampled from the road bridge close to its junction with the Wharfe just north of Kilnsey. Further downstream a site on Sikes Beck downstream from the Kilnsey Fish Farm was added as were two sites on White Beck, upstream and downstream from the Sikes Beck inflow, respectively. These sites were selected to identify potential contamination from the fish farm (on Sikes Beck) and from North Cote Farm (on White Beck) respectively;
6. In the 2020 iWharfe survey no sites were sampled between Conistone Bridge and Grassington Ghaistrill's Strid. In this study three were added, two to identify the impact of the Conistone STW on the river by sampling just downstream from the STW on the Davy Keld and just downstream of the junction of the Davy Keld and the main river, and one on the main river upstream of the Long Ashes Caravan Park.
7. As the 2020 survey showed consistently high values of *E. coli* from Grassington to Barden (Fig. 1) we inserted additional sites along this stretch in an attempt to identify more closely the potential sources of faecal pollution especially from tributary becks. The first of these is Captain Beck. We sampled on the main river at Linton above the Falls and upstream of the Captain Beck confluence, Captain Beck itself and on the main river at Linton below the Falls. We also added a site just downstream from the Grassington STW outfall, and we re-sampled Barben Beck (as in 2020) but added a site on the main river just downstream of the Barben Beck confluence. Barben Beck brings in water from Grimwith Reservoir as a compensating supply for water pumped from the Wharfe downstream at Lob Wood near Addingham.
8. Finally, we added a site just upstream of Bolton Abbey fish farm. Fish farms are unlikely to be sources of *E. coli* contamination but our objective, as for the Kilney Fish Farm, was to confirm this assumption by comparing *E. coli* concentrations at this site with data from the Cavendish Pavilion site a short distance downstream.

Methods

All methods were based on those successfully adopted for the iWharfe 2020 survey[1]. In this study we divided the river from Hubberholme to Cavendish Pavilion into three zones and used three field teams to take samples in each respective zone on the same day at approximately the same time on three separate dates, April 26th, June 2nd and July 26th. Sampling began in each zone in the early morning and was completed by early afternoon.

Each team was provided with identical equipment including sterile sample bottles and cool bags to keep the samples between 2 and 8° C. Samples were collected from the downstream side of bridges using a sample bottle on a lead-weighted rope or directly by hand in the river. The samples were then taken to ALS Ltd in Wakefield in the afternoon for delivery to ALS Coventry for microbiological analysis. Analysis of all samples began within 24 hours of collection.

Results

All the data from the three survey dates are shown together in Figure 4. Data for the individual dates can be seen in Appendix B. Here we describe the results from each stretch of the river from Hubberholme downstream to the Cavendish Pavilion.

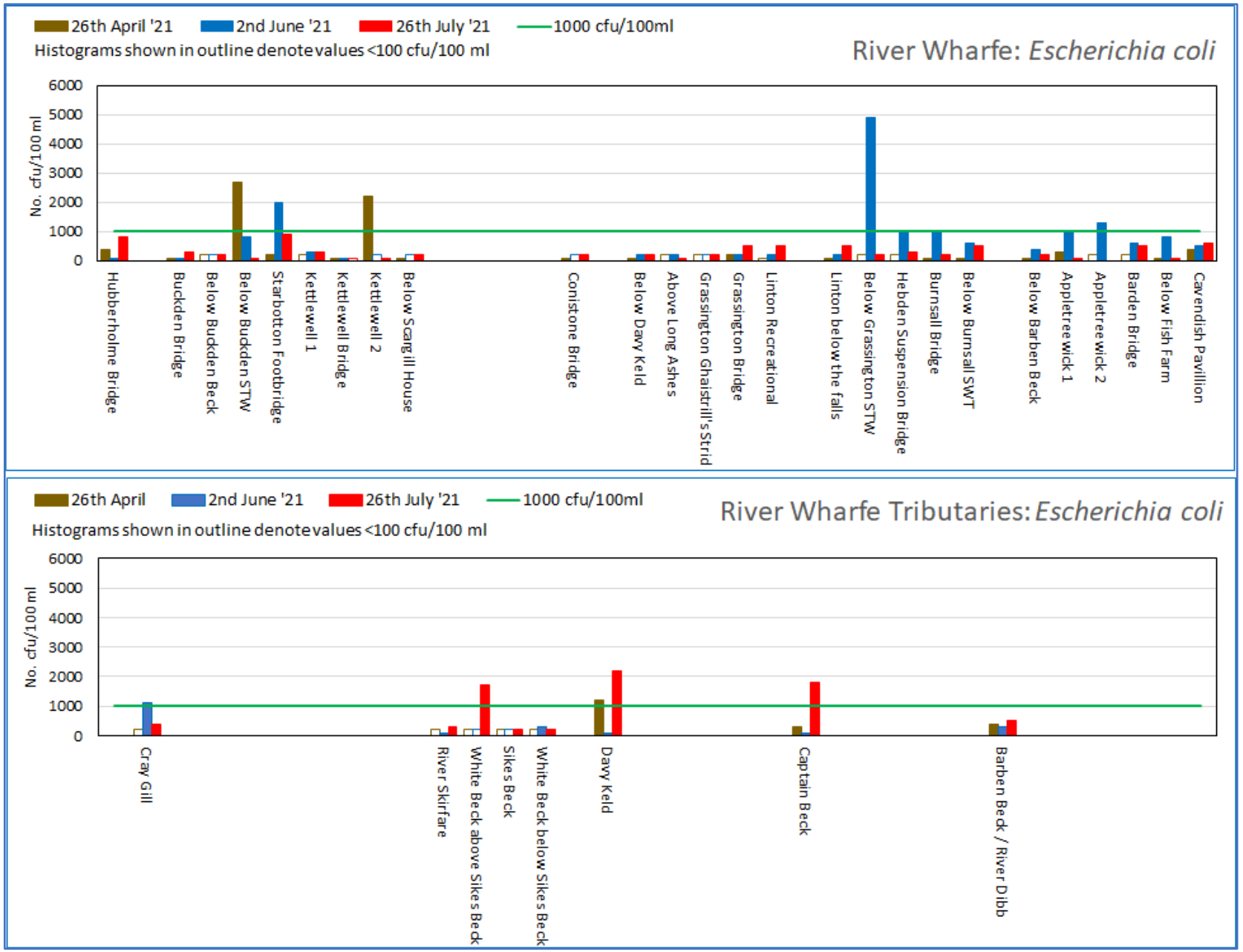


Figure 4. E. coli data for the River Wharfe and selected tributaries from Hubberholme to Bolton Abbey (Cavendish Pavilion).

1. *Hubberholme to Buckden*. No sampling for this project was carried out upstream of Hubberholme on the assumption, based on iWharfe 2020 data, that serious faecal bacteria pollution sources were unlikely to be found there. Of the three samples from Hubberholme Bridge taken, however, the July 26th sample had quite high values (800 cfu/100 ml). One of the three samples from the tributary Cray Gill was also high (1,100 cfu/100 ml), although all three samples from Buckden Bridge and at a sample point just downstream from the inflow of Buckden Beck were very low (100-300 cfu/100 ml). The data taken together with the data from iWharfe20 when river levels were high, suggest that elevated levels of faecal bacteria do occur upstream of Buckden probably associated with septic tank effluents in dry weather, low flow conditions and agricultural livestock in wet weather, high flow conditions.

Buckden STW outflow

2. *Buckden STW*. A small pipe discharges treated effluent into the main river from the Buckden STW. On the 26th April the *E. coli* concentration of the sample from the site just downstream showed a high value (2,700 cfu/100 ml). Of the samples from the same site on the two following occasions one was moderately high (800 cfu/100 ml) and one low (100 cfu/ml). The higher values are clearly caused by the faecal bacteria from the incoming treated effluent. The lowest value is more difficult to explain. On all three sample dates the river level was very low, so the difference in values is unlikely to be due to differences in dilution by the river. One possibility is that the small STW serving Buckden does not discharge continuously.

3. *Starbotton STW*. Starbotton is served by a small STW of a similar size to Buckden. The three samples taken on the main river just below the outfall pipe also had varying values. However, in this case the high value sample occurred on June 2nd. The sample from the 26th April had a low value (200 cfu/100 ml). This observation contrasts with the value from Buckden upstream on the same day indicating rapid and almost complete die-off of faecal bacteria between Buckden and Starbotton.

4. *Kettlewell*. As for iWharfe20, three sites were sampled in Kettlewell on the main river: just upstream of the Kettlewell beck inflow, by Kettlewell Bridge and just below the Kettlewell STW final effluent outfall. The values for both sites upstream of the STW were low on all occasions (100 – 300 cfu/100 ml) indicating no impact of the Starbotton peak of 2nd June and little or no contamination from Kettlewell Beck.

   Data from the site below the STW in Kettlewell are very similar to the sites below the Buckden and Starbotton STWs (above) with one high sample (2,200 cfu/100 ml on 26th April) and two very low samples. The impact of the STW discharge is clear for the high sample but it is unclear why the other two samples should be so low, given near identical weather and river level conditons on all sampling days unless the discharge from the STW itself varies significantly within and between days or it discharges only intermittently, as suggested above in the cases of Buckden and Starbotton.

5. *Scargill House*. Scargill House is a residential community centre capable of accommodating 70 people. We assume it has its own sewage treatment facilities creating effluent that could

potentially contaminate the river a few kilometres downstream from Kettlewell. The three samples taken from a site immediately downstream of the House were all very low (0-200 cfu/100 ml) indicating that this property is not a source of faecal pollution. Again these low values indicate rapid die-off in the water column as there is no evidence for the high numbers of bacteria seen in the Kettlewell 2 samples on the 2nd June reaching this site on that day.

6. *Kilnsey*. There are several fish farms on the Wharfe. Although fish as cold-blooded animals are not expected to contribute *E. coli* directly to the water column *E. coli* could be present in fish pond sediments or introduced by birds. No *E. coli* was detected in the Sikes Beck samples, but one sample from White Beck upstream of the Sikes Beck inflow had a high concentration (1,700 cfu/100 ml), the most likely source being a local farm.

Kilnsey Fish Farm

7. *Conistone*. The Conistone STW serves both Conistone and Kilnsey. Unlike all other small STWs in Upper Wharfedale the Conistone STW discharges to a small stream, the Davy Keld, and not to the main river. Of the three samples taken downstream of the outfall one had a low concentration of *E. coli* (200 cfu/100 ml) and two had high concentrations (2,200 and 1,200 cfu/100 ml). However, concentrations on the main river just below the junction of the Davy Keld and the Wharfe were very low (100 – 200 cfu/ml) indicating that the Conistone STW on these occasions had little impact on the main river. Despite the low flow in the main river this was probably due to dilution, although some die-off between the sample point on the Davy Keld and the confluence may also have occurred.

Conistone STW

8. *Long Ashes*. During the iWharfe20 survey in August 2020 the sample collected from Ghaistrill's Strid showed an unexpecrtedly high concentration of *E. coli* unrelated to any known nearby public STW source. We conjectured that the source was from a private sewage treatment plant serving the Long Ashes caravan park just a short distance upstream. Consequently in this study we collected samples just upstream of Long Ashes and at Ghaistrill's Strid downstream. Values at both upstream and downstream locations were extremely low indicating little or no impact of effluent from the Park under these dry weather, low flow conditions. Whilst this rules out treated effluent as a source of contamination the possibility that the high values from August 2020 in samples collected under high flow conditions was caused by spills of untreated effluent from the Park remains. So far it has not been possible to obtain information on how Long Ashes treats sewage and what arrangements are made to cope with storm water.

9. *Grassington and Captain Beck*. The Grassington STW serves the communities of Threshfield and Linton as well as Grassington. Consequently samples taken at Grassington Bridge and Linton upstream of the STW had expected low concentrations of *E. coli* on all sampling occasions. One sample from Captain Beck that joins the Wharfe at Linton Falls had a relatively high value of 1800 cfu/100 ml on the 26th July. The reason for this is unknown at present.

Samples taken downstream of Grassington STW had low concentrations on two occasions but a high concentration of 4,900 cfu/100 ml on the 2nd June. This high value is almost certainly owing to the discharge of treated effluent from the Grassington STW on that date. It is, however, surprising that samples taken on the other two dates were not equally as high given that flow conditions and the time of sampling were very similar on all three occasions. It is highly unlikely that flow from the STW is intermittent given the size of the local population served by the STW, but just as for the small STWs upstream, treated effluent discharge from the Grassington treatment works must vary considerably on a daily or even hourly basis.

10. *Hebden and Burnsall*. Concentrations of *E coli* in the main river downstream of the Grassington STW on the 2nd June decrease but remain relatively high, perhaps reflecting a slower rate of die-off along this stretch of the Wharfe compared to stretches upstream where water may be less turbid and UV radiation thereby more effective. *E. coli* levels at the site downstream from the Burnsall STW were somewhat elevated on two of the three survey dates probably due to the influence of treated effluent from the STW.

11. *Barben Beck*. Barben Beck joins the Wharfe between Burnsall and Appletreewick. Flow in the beck is dominated by discharge from Grimwith Reservoir, a Yorkshire Water reservoir designed to provide water to the main river to compensate for water pumped out of the river further downstream at Lob Wood. Concentrations of *E. coli* in the beck and in the river downstream from the confluence were low on all three sampling occasions. Although it is not an important source of faecal bacteria it introduces water with a high concentration of dissolved organic carbon (DOC) into the main river (see picture) and discolours the main river (at least in low flow conditions), for several kilometres downstream.

High concentration of dissolved organic carbon

12. *Appletreewick*. The Appletreewick 1 and 2 sites both had quite high concentrations on the 2nd June 2021 but not on other dates. There is no clear reason for the high value at Appletreewick 1 site, although it is situated close to a large campsite. Appletreewick 2, however, is situated downstream from the Appletreewick STW which is the most probable source of pollution.

13. *Barden and Bolton Abbey*. The stretch of river from Barden Bridge to the Cavendish Pavilion at Bolton Abbey had low concentrations of *E. coli* on all three sampling visits indicating little or no contamination of the river by the Bolton Abbey fish farm under these flow conditions. This is consistent with the findings at Kilnsey noted above.

Discussion

E. coli concentration and riverflow

Low flow at Buckden

On August 24th 2020 we collected water samples along the full length of the River Wharfe from its headwaters in Langstrothdale to its confluence with the Ouse at Cawood. The data showed that on that day, a day when river flow was high, high concentrations of faecal bacteria were present in samples from Buckden to Barden Bridge (Fig. 1). The current project was designed to explain those results by sampling along the Upper Wharfedale stretch of river more intensively and locating additional sampling sites upstream and downstream of potential pollution sources (Fig. 3). By conducting the survey three times over three months we hoped our pre-planned dates would fall on days with differing river flow and would include one low-flow day and one high-flow day. However, the spring/early summer period of 2021 was exceptionally dry. River flow was very low and much of the bed of the channel in the upper reaches was dry. Consequently whilst we were able to describe low flow conditions we were unable to capture conditions at medium or high flows (cf. Fig. 2).

Based on our work elsewhere[2] high flows after rainfall events are associated with the in wash of faecal bacteria from agricultural land and with discharges of untreated effluent from combined sewer overflows (CSOs). In low flow very little mobilisation of faecal bacteria occurs from field systems and none from CSOs, but the impact of discharges of treated effluent from STW outfalls is accentuated due to the lack of dilution by river water. As a result, one of our objectives to identify the source of the high concentration of faecal bacteria at Ghaistrill's Strid observed in August 2021, has not been met. Further work sampling upstream and downstream of the Long Ashes Caravan Park under high flow conditions is needed.

Variable impact of treated effluent discharges from STWs

In general, the data presented in Figure 4 show low values both in the river and in the tributaries selected for sampling on all three survey dates. This indicates that little contamination of watercourses by diffuse agricultural sources in these dry weather low-flow conditions was occurring. Almost all the high values shown are from samples taken immediately downstream of treated effluent outfalls. These include Buckden, Starbotton, Kettlewell, Grassington, Conistone (into the Davy Keld) and Appletreewick.

Unexpectedly there is very considerable variation at these downstream sites between sample dates, despite river flow being more or less constant and despite the samples being taken on all three occasions at approximately the same time of day. As yet we have no adequate explanation. Possibilities include discharges being made intermittently due to the design of the treatment works and/or major variations in the hourly flow of foul water into and through the works.

E. coli die-off rates

A striking feature of the data from all sites where high concentrations were observed is the evidence for rapid downstream die off of *E. coli*. In all four cases (Buckden and Kettlewell on the 26th April, and Starbotton and Grassington on the 2nd June) samples taken at the next site downstream within approximately 30 minutes on the same day have much lower values. In the absence of any diluting

inflows between the upstream and downstream sites in these four cases (Table 1) the only simple explanation for the differences is rapid die-off. The slow-flowing, shallow, clear water conditions of the river along the reach from Buckden to Kettlewell on the days of sampling would have been especially favourable for die-off via UV radiation.

Die-off rates	Peak site cfu/100ml	Downstream site cfu/100ml	Decrease cfu/100 ml	Distance m	% decrease
26th April: Buckden below STW - Starbotton Footbridge	2700	200	2,500	3,420	93
26th April: Kettlewell 2 - Scargill House	2200	100	2,100	2,390	95
2nd June: Starbotton Footbridge - Kettlewell 1	2300	300	2,000	3,410	87
2nd June: Grassington below STW - Hebden Suspension Bridge	4900	1000	3,900	1,450	80

Table 1: Decrease in E. coli concentration downstream

Evidence for rapid die-off has been seen on many occasions along the river, it is a key process central to tracking pollution in faecal bacteria transport models. A better understanding of die-off rates under different physical conditions in river environments is urgently needed.

Non-STW pollution sources

The sample site selection was designed to identify potential pollution sources additional to STWs. These included fish farms, the Long Ashes caravan park and Scargill House. Samples taken upstream and downstream of two fish farms (at Kilnsey on Sikes Beck and Bolton Abbey on the Wharfe, respectively) showed no evidence of faecal bacteria pollution and the sample taken on the Wharfe below Scargill House likewise showed no elevated faecal bacteria concentration compared with the samples from the Kettlewell site upstream. Samples from the Wharfe below the Long Ashes caravan park also showed no pollution occurring. However, anecdotal evidence from local residents in the Grassington area suggests that untreated storm discharges from this community do occur during wet weather, consistent with the results of our survey in August 2020 when river flow was high. A more detailed study of the private sewage treatment facility and its operation at Long Ashes coupled with further sampling on the Wharfe in wet weather conditions is needed.

Finally, we show data from various tributaries, some sampled for the first time. The condition of the tributaries and their influence on the main river varies considerably. The Skirfare, draining the Littondale catchment is a major tributary and contributes signicantly to flow in the main river. However, it carries more or less the same faecal bacteria load so its inflow causes no increase in faecal bacteria concentration in the Wharfe itself. In contrast tributaries such as the Davy Keld and Captain Beck often have high concentratios of faecal bacteria but their influence on the main river is not detectable as their inflows are very small and their pollution load is strongly diluted by the volume of water flowing in the main river.

Further work is needed to identify sources of faecal bacteria in tributary catchments.

Summary and Conclusions

In August 2020 we conducted a citizen science survey of faecal bacteria concentration at sites along the full length of the River Wharfe on a day when river levels were high. On that occasion, amongst other observations we found high concentrations of faecal bacteria in the stretch of the river from Buckden to Barden Bridge. Our aim in the project described here was to replicate those findings and to identify the sources of pollution giving rise to those high concentrations of faecal bacteria. We selected additional sampling sites and carried out the survey on three occasions. However, flow conditions were very different from 2020. On all three occasions in 2021, April 26, June 2nd and July

26th, river levels were very low and concentrations of faecal bacteria were quite different. Consequently some of our objectives were not met. The results, however, have provided valuable insights into patterns and sources of faecal bacteria pollution in dry weather and low flows, as follows:

- High values of *E. coli* were quite rare. Values greater than 1,000 cfu/100 ml were recorded only 10 times in the 102 samples taken;
- Seven of these 10 samples were taken immediately downstream of a STW final effluent outfall;
- Surprisingly *E. coli* concentrations at these sites immediately downstream of STWs were often very low. These observations are difficult to explain unless effluent discharge was extremely variable or occurring intermittently;
- In all 10 cases where a high value of *E. coli* was recorded, concentrations at the next sample in the series (between one and four kilometres downstream) were not significantly different from background levels. These observations indicate that in these low flow conditions *E. coli* dies-off rapidly in the river;
- Although three of the high value samples may have been caused by agricultural pollution, possibly directly from farmyards, background levels of *E. coli* are very low indicating that diffuse sources of *E. coli* from cattle and sheep contribute little to faecal bacteria levels in the main river in such low flow conditions.

Our results from this 2021 study taken together with the data from the iWharfe 2020 survey indicate how dependent *E. coli* concentrations are on riverflow conditions and on die-off rates in the water column. They also show how difficult it is using standard techniques of sampling and analysis to capture the range of variability in faecal bacteria behaviour needed to identify pollution sources. For Upper Wharfedale much progress has been made but additional sampling under different flow conditions upstream and downstream of suspected pollution sources is still required to determine the causes of the high *E. coli* concentrations recorded in the 2020 iWharfe survey.

Acknowledgements

We thank our iWharfe volunteers, John Fontana, Wendy Fontana, Jan Hindle, Steve Fairbourn, Kathleen Roberts, Steve Cheetham, Gill Battarbee and John Rishworth for helping to collect the water samples, Graham Weston of Yorkshire Water for information on Upper Wharfedale STWs, Dave Kay for helpful comments on the text, the Yorkshire Dales National Park Authority for funding and Charlotte Simons and Marie Taylor of the Yorkshire Dales Rivers Trust for their continuing support.

References

[1]Battarbee, R.W., Secrett, M., Malby, R., Shackleton, K., Taylor, M. & Simons, C. 2020. iWharfe, improving water quality on the River Wharfe from Oughtershaw to the Ouse: a citizens science project. Faecal bacteria data from samples collected on the 24th August 2020.

[2] Battarbee, R.W. & Secrett, M. 2022. iWharfe, improving water quality on the River Wharfe from Oughtershaw to the Ouse: a citizens science project. Faecal bacteria data from tributary becks between Bolton Abbey and Ilkley on the 23rd August 2021.

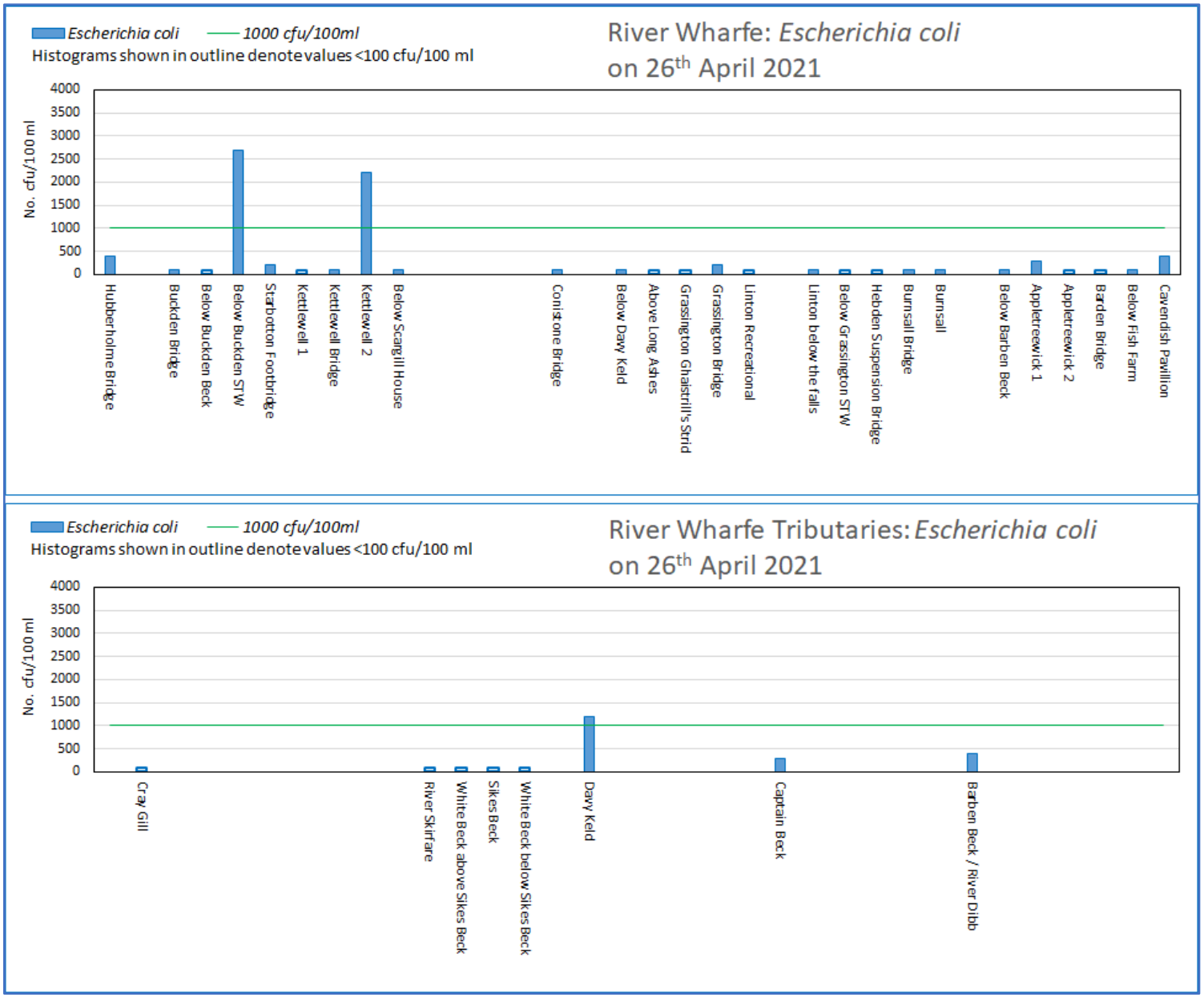
Appendices

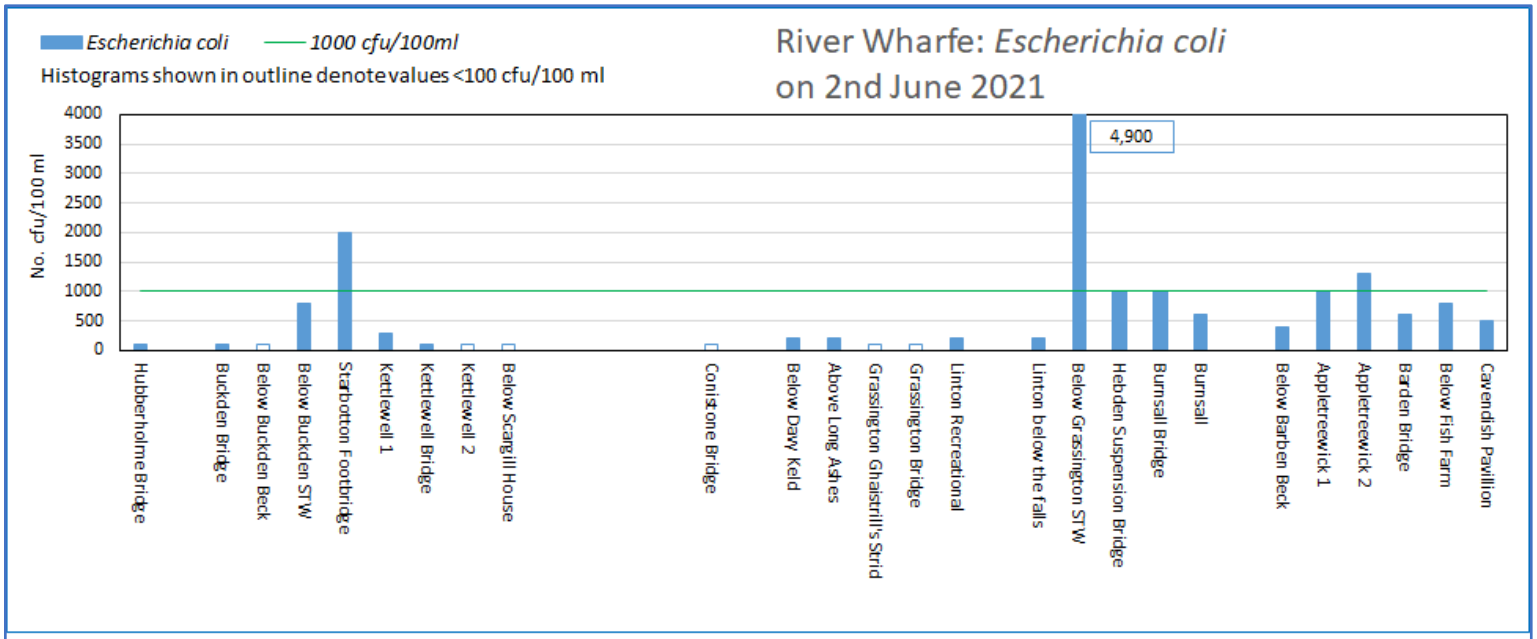
Appendix A: *E. coli* concentrations (cfu/100 ml) on three dates in 2021 for sites in Upper Wharfedale

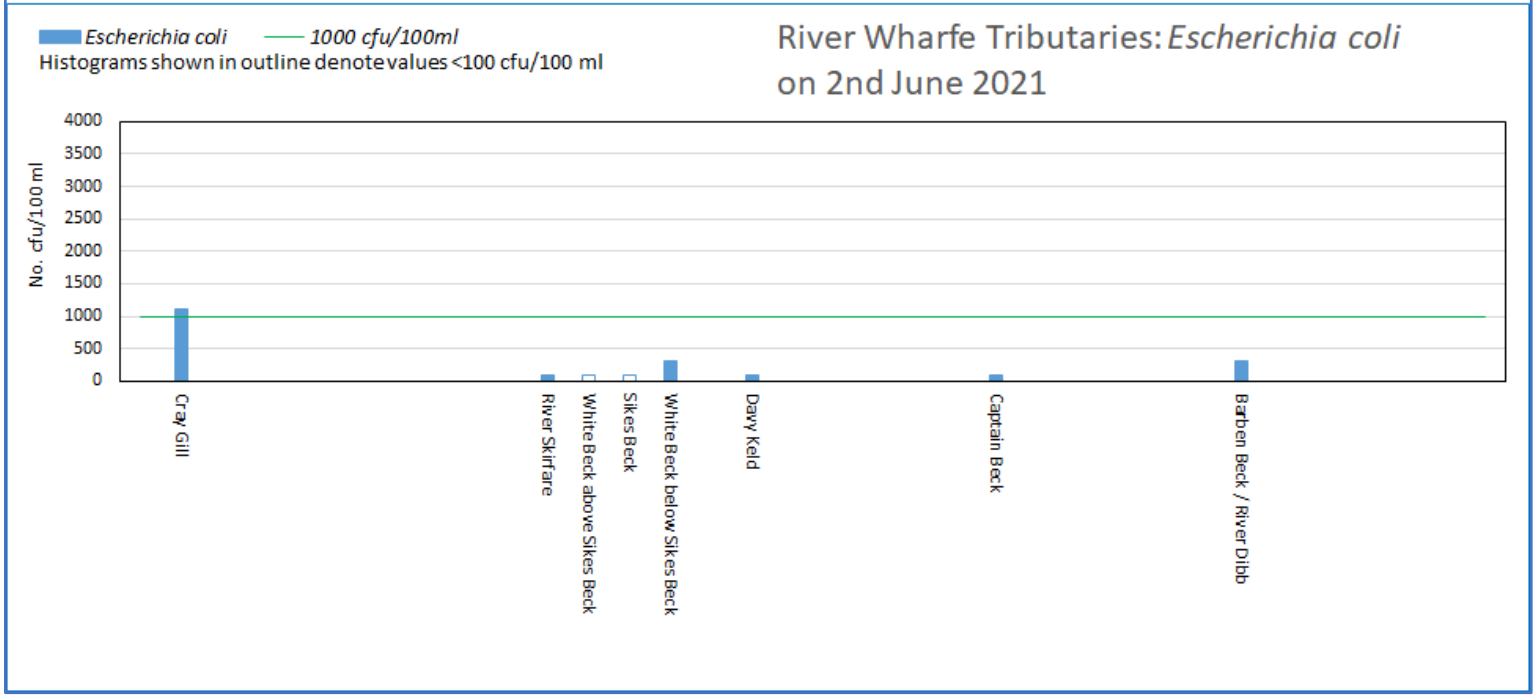
				E coli concentrations cfu/100ml		
No.	**Site name**	**Location**	**Type**	**26th April**	**2nd June**	**26th July**
1	Hubberholme Bridge	54.19966,-2.11469	River	400	100	800
2	Cray Gill	54.20154,-2.10326	Tributary	<100	1100	400
3	Buckden Bridge	54.19143,-2.09360	River	100	100	300
4	Below Buckden Beck	54.18827,-2.09520	River	<100	<100	200
5	Below Buckden STW	54.18647,-2.09299	River	2700	800	100
6	Starbotton Footbridge	54.16625,-2.07619	River	200	2000	900
7	Kettlewell 1	54.14779, -2.05062	River	<100	300	300
8	Kettlewell Bridge	54.14581,-2.05098	River	100	100	1000
9	Kettlewell 2	54.14188, -2.04581	River	2200	<100	100
10	Below Scargill House	54.12697,-2.03864	River	100	<100	200
11	River Skirfare	54.11837,-2.04493	Tributary	<100	100	300
12	White Beck above Sikes Beck	54.10470, -2.03946	Tributary	<100	<100	1700
13	Sikes Beck	54.10470, -2.03946	Tributary	<100	<100	<100
14	White Beck below Sikes Beck	54.10470, -2.03946	Tributary	<100	300	200
15	Conistone Bridge	54.10340,-2.03367	River	100	<100	200
16	Davy Keld	54.09774, -2.03019	Tributary	1200	100	2200
17	Below Davy Keld	54.09375,-2.03312	River	100	200	200
18	Above Long Ashes	54.08162, -2.02785	River	<100	200	100
19	Grassington Ghaistrill's Strid	54.07548,-2.01129	River	<100	<100	200
20	Grassington Bridge	54.07065,-2.00447	River	200	<100	500
21	Linton Recreational	54.06641,-2.00103	River	<100	200	500
22	Captain Beck	54.06583, -2.00079	Tributary	300	100	1800
23	Linton below the falls	54.06541, -1.99851	River	100	200	500
24	Below Grassington STW	54.06103,-1.98329	River	<100	4900	200
25	Hebden Suspension Bridge	54.05714,-1.96260	River	<100	1000	300
26	Burnsall Bridge	54.04641,-1.95163	River	100	1000	200
27	Burnsall	54.04538, -1.94772	River	100	600	500
28	Barben Beck / River Dibb	54.04436,-1.94033	Tributary	400	300	500
29	Below Barben Beck	54.03934,-1.93816	River	100	400	200
30	Appletreewick 1	54.03724,-1.93126	River	300	1000	100
31	Appletreewick 2	54.03218,-1.91488	River	<100	1300	Lab error
32	Barden Bridge	54.01260,-1.92186	River	<100	600	500
33	Below Fish Farm	54.00697,-1.91342	River	100	800	100
34	Cavendish Pavillion	53.99366,-1.88319	River	400	500	600

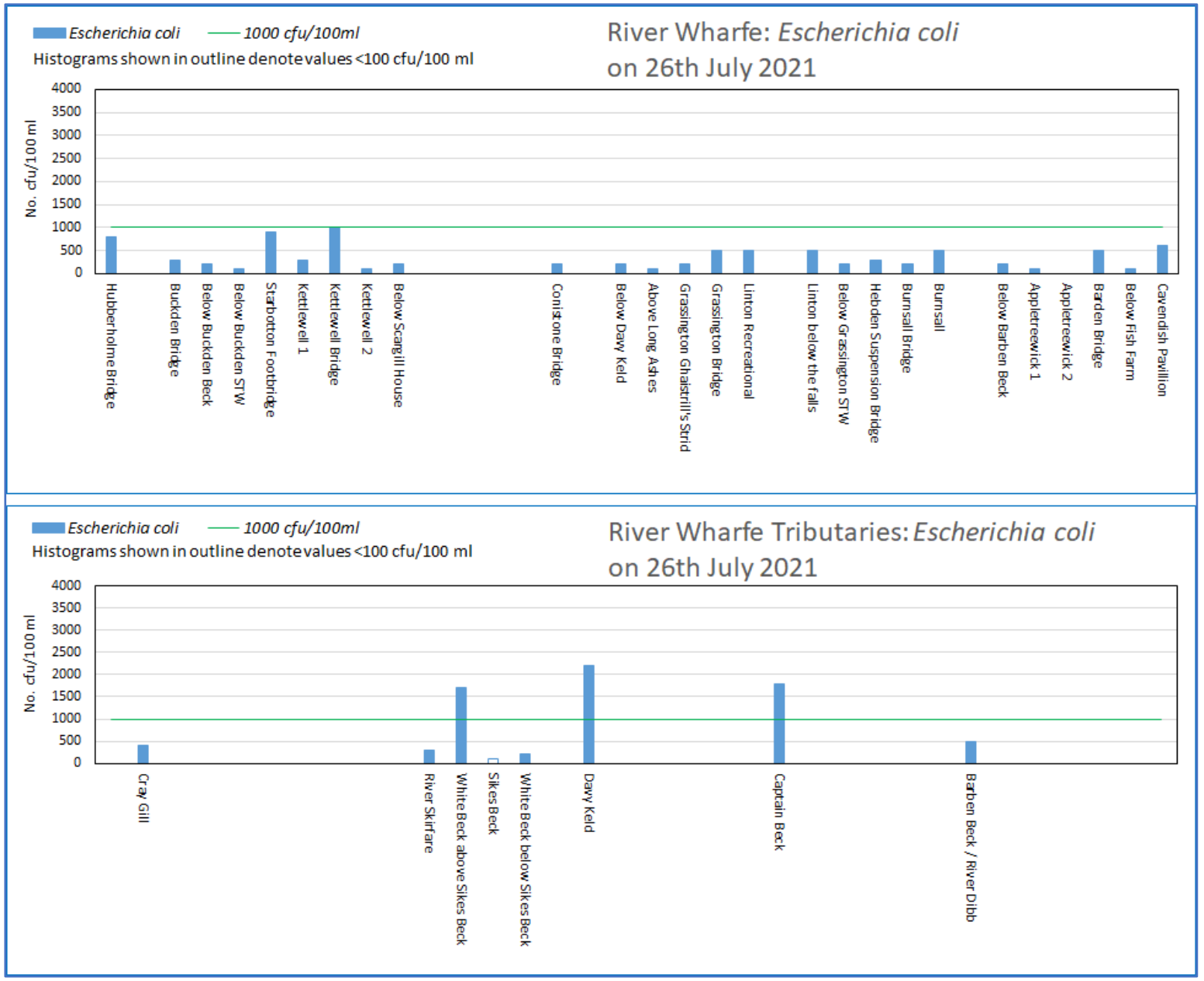
Appendix B:

E. coli concentrations (cfu/100 ml) for three dates in 2021 for sites in Upper Wharfedale




Escherichia coli
1000 cfu/100ml
Histograms shown in outline denote values <100 cfu/100 ml
River Wharfe: Escherichia coli
on 2nd June 2021
No. cfu/100 ml
4000
3500
3000
2500
2000
1500
1000
500
0
4,900
Hubberholme Bridge
Buckden Bridge
Below Buckden Beck
Below Buckden STW
Starbotton Footbridge
Kettlewell 1
Kettlewell Bridge
Kettlewell 2
Below Scargill House
Coniston Bridge
Below Dawy Keld
Above Long Ashes
Grassington Ghaistrill's Strid
Grassington Bridge
Linton Recreational
Linton below the falls
Below Grassington STW
Hebden Suspension Bridge
Burnsall Bridge
Burnsall
Below Barben Beck
Appletreewick 1
Appletreewick 2
Barden Bridge
Below Fish Farm
Cavendish Pavillion


Escherichia coli
1000 cfu/100ml
Histograms shown in outline denote values <100 cfu/100 ml
River Wharfe Tributaries: Escherichia coli
on 2nd June 2021
No. cfu/100 ml
4000
3500
3000
2500
2000
1500
1000
500
0
Cray Gill
River Skirfare
White Beck above Sikes Beck
Sikes Beck
White Beck below Sikes Beck
Dawy Keld
Captain Beck
Barben Beck / River Dibb


Escherichia coli
1000 cfu/100ml
Histograms shown in outline denote values <100 cfu/100 ml
River Wharfe: Escherichia coli on 26th July 2021
No. cfu/100 ml
4000
3500
3000
2500
2000
1500
1000
500
0
Hubberholme Bridge
Buckden Bridge
Below Buckden Beck
Below Buckden STW
Starbotton Footbridge
Kettlewell 1
Kettlewell Bridge
Kettlewell 2
Below Scargill House
Conistone Bridge
Below Davy Keld
Above Long Ashes
Grassington Ghaistrill's Strid
Grassington Bridge
Linton Recreational
Linton below the falls
Below Grassington STW
Hebden Suspension Bridge
Burnsall Bridge
Burnsall
Below Barben Beck
Appletreewick 1
Appletreewick 2
Barden Bridge
Below Fish Farm
Cavendish Pavillion
Escherichia coli
1000 cfu/100ml
Histograms shown in outline denote values <100 cfu/100 ml
River Wharfe Tributaries: Escherichia coli on 26th July 2021
No. cfu/100 ml
4000
3500
3000
2500
2000
1500
1000
500
0
Cray Gill
River Skirfare
White Beck above Sikes Beck
Sikes Beck
White Beck below Sikes Beck
Davy Keld
Captain Beck
Barben Beck / River Dibb

Appendix C: Sample collection