River Yealm water quality: findings from Westcountry Rivers Trust Citizen Science Investigations between July 2022 and October 2023

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Presented on behalf of the Yealm Dippers, River Yealm Water Quality Group and Yealm Estuary to Moor Project,
in partnership with the Westcountry Rivers Trust

Contents

1. Context, acknowledgements and qualifications

Volunteers studying long term river health on the River Yealm are known as "Yealm Dippers".

Yealm Dippers contribute to:

- water quality measures designed to monitor background water quality on an approximate monthly basis, as part of the Westcountry Rivers Trust's (WRT) Citizen Science Investigationrt.org.uk) (CSI);
- management of an automated instrument, the "Yealm Sonde", which monitors water quality continuously, alerting to transient events whilst defining our rivers chemistry and physics; and
- measures of aquatic insect diversity as indicators of ecological health, in partnership with Wildfish's Smartrivers Riverfly Census.

As such, Yealm Dippers receive associated training and support from both WRT and WildFish.

Equipment and consumables have been afforded by funding from the riparian Parish Councils of Wembury, Newton Ferrers, Noss Mayo, Yealmpton, Brixton and Sparkwell, plus one significant anonymous donor, coordinated through the River Yealm Water Quality Group (RYWQG), which is comprised of representatives from each of those councils.

The Yealm Estuary to Moor Project (yemcorridor.com) (YEM) further supports this CSI through additional funding, and by helping to engage and coordinate local volunteers.

This report has been prepared in partnership with WRT; on behalf of Yealm Dippers, the RYWQG and YEM.

Personal data of our volunteers is protected under the Data Protection Act 2018 (DPA) and the UK General Data Protection Regulation (UK GDPR).

We are grateful for invaluable support and advice from Lydia Ashworth, Holly Pearson, Anna Seal, Simon Browning and Nicola Rogers of WRT, including Lauren Harley, Sam Green, Matt Owen-Farmer and Richard Osmond of WildFish.

Additional interest and encouragement offered by Environment Agency officers, especially Rob Price and Robin Hooper, are also appreciated.

Neither the present authors nor any of the above organisations or individuals accept any form of liability or damage resulting from findings or associated interpretations as are reported below.

Interpretation and suggestions presented here in this report are those of the authors alone.

2. Aims

The WRT's Citizen Science Investigation is intended:

- to educate and engage people with the water environment;
- to help identify and locate persistent background pollution problems, producing data that can be used to help target remediation;
- to spot transient pollution events which can be dealt with as quickly as possible; and
- to create a network of catchment communities that are invested in their local environment.

3. Survey sites and frequencies

From initial training in July 2022 to 30th Oct 2023, 49 active volunteers logged 290 water quality surveys onto the Westcountry Rivers Trust's (WRT) Cartographer website (Figures 1 and 2). This report focusses upon survey sites for which three or more surveys were logged during that period. There were 28 such sites throughout the Yealm catchment, of which 22 are located on tributaries (Figure 3), thereby helping to help identify any cause for concern in associated sub-catchments, each faced with different environmental challenges as are illustrated in Figure 4.

From 1st July 2022 to 30th Oct 2023, the Environment Agency (EA) monitored a total of 7 sites (Figure 3).

Table 1 lists the names and locations of all sites surveyed from 1st July 2022 to 30th Oct 2023, including the number of surveys logged at each site, totalling 96 by the EA compared with 290 by Yealm Dippers (Table 1).

Figure 1. In July 2022, "Yealm Dippers" received initial training from Lydia Ashworth, Evidence and Engagement Officer for the Westcountry Rivers Trust.

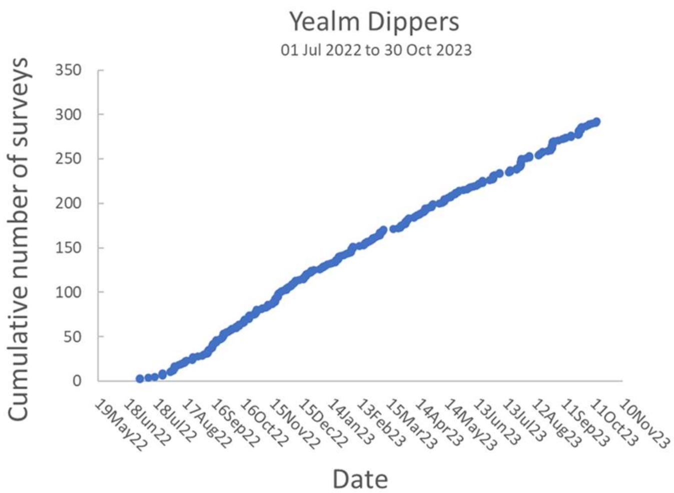


Figure 2. Cumulative number of surveys that have been successfully logged onto WRT's "Cartographer" website (https://cartographer.io/case-studies/wrt/) involving a total of 49 active volunteers from 1st July 2022 to 30th Oct 2023.

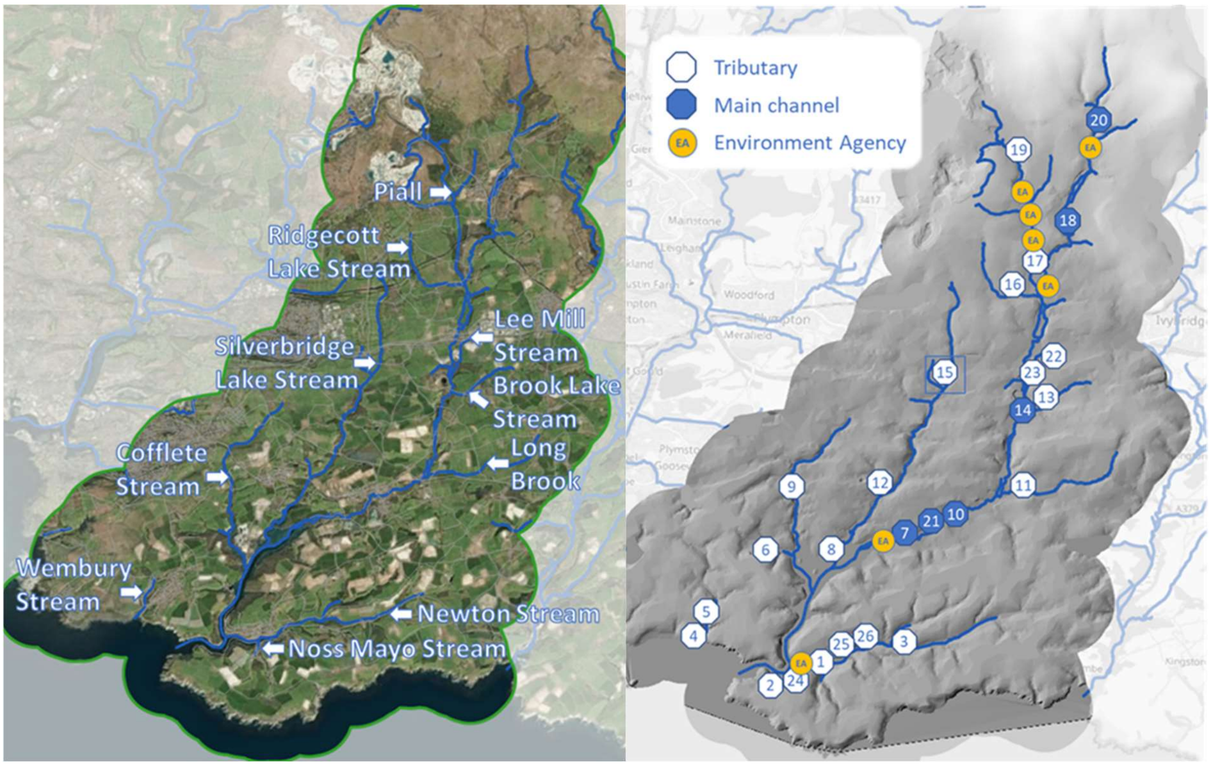


Figure 3. Locations of tributaries to the main channel of River Yealm, including all surveys undertaken by Yealm Dipper volunteers as part of the Westcountry Rivers Trust Citizen Science Investigations from 1st July 2022 to 30th Oct 2023. Sites in blue are located on the main channel, whereas sites in white are on tributaries. Sites monitored by the Environment Agency are illustrated in orange. The names and locations of each CSI site, including the number of surveys logged, are summarised in Table 1.

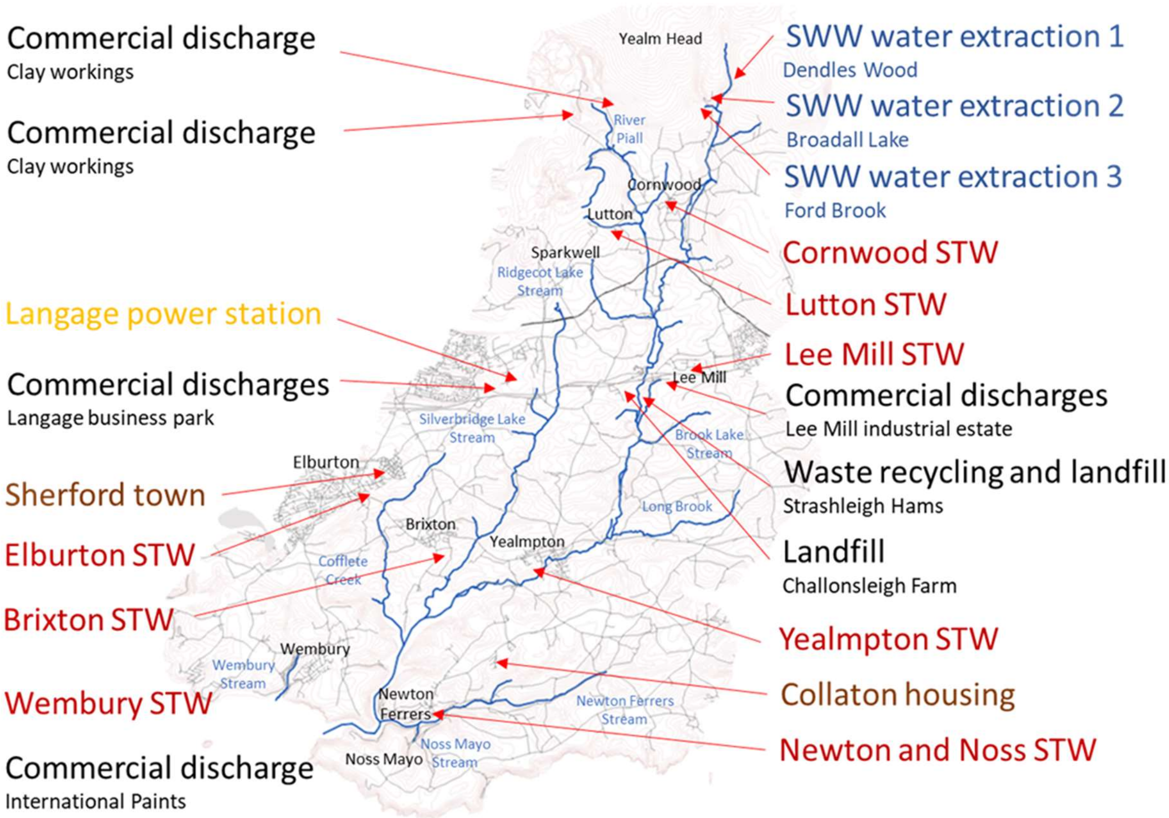


Figure 4. Environmental challenges throughout the Yealm Catchment.

Table 1. Names of sites and number of associated surveys undertaken by (i) Yealm Dipper volunteers as part of the Westcountry Rivers Trust (WRT) Citizen Science Investigations (CSI) and (ii) the Environment Agency (EA) from 1st July 2022 to 30th Oct 2023.

Site No.	WRT Survey Sites	No. of surveys
1	Noss Mayo Stream @ Tidal car park	11
2	Newton Stream @ Bridgend	24
3	Newton stream @ Preston	11
4	Wembury Stream @ Wembury beach footbridge	3
5	Wembury Stream @ Mill Meadow footbridge	23
6	Hollacombe Brook @ Traine Wood	4
7	Yealm @ Puslinch Bridge	31
8	Silverbridge Lake @ Kitley Lake outflow	6
9	Cofflete Stream @ Combe	6
10	Yealm @ Yealm Bridge	14
11	Long Brook @ Yealm Bridge	14
12	Silverbridge Lake @ Gorlofen	13
13	Brook Lake @ Rubys wood near Popples Bridge	7
14	Yealm @ Popple's Bridge	11
15	Silverbridge Lake @ Barn Park (Smithaleigh)	5
16	Ridgecott Lake @ Three Streams	8
17	Piall @ Marks Bridge	8
18	Yealm @ Cornwood (Slade Mill)	11
19	Piall @ Quick Bridge	17
20	Yealm @ Wisdom Mill Bridge	3
21	Yealm @ The Borough	15
22	Lee Mill Stream @Lee Mill	6
23	Lee Mill Stream @ New England Nature Reserve	9
24	Coffin Stream @ Bridgend	11
25	Collaton Stream East, Preston	8
26	Collaton Stream West, Preston	7
27	Brusheshill Stream @ Brusheshill Wood	2
28	Trescan Brook @ Wembury Wood	2
		290

	EA Monitoring Sites	No. of surveys
	Newton Stream @ Bridgend	13
	Yealm @ Puslinch Gauging Station	13
	Yealm @ Fardel Mill Farm Bridge	13
	Yealm @ Hele Cross	15
	Piall @ Marks Bridge	14
	Piall @ Slade Bridge	16
	Piall @ Almhouse Bridge	12
		96 (54 from Jan-Nov 23)

4. Observations and measures

Surveys are recorded by Yealm Dippers on an approximate monthly basis, thereby helping to identify and locate persistent background pollution problems.

Each survey makes use of a manual kit and form provided by WRT, as illustrated in Figure 5, involving the observations and measures summarised in Figure 6.

Reasons for each measure and where appropriate, Upper Safe Limits (USL) above which animal or plant health is compromised, are summarised as follows:

4.1 Observational and contextual data

Observations of wildlife such as may include birds, dragonflies, damselflies, otters, mink and voles are primary indicators of ecosystem health.

Problem species, such as knotweed, hogweed, balsam and waterweeds, may cause issues for the biodiversity of the watercourse by shading out other plant species.

Evidence of pollution sources and/or recent pollution such as industrial outfalls, farm runoff, road runoff, litter, smell, sewage, smothering algae, foam or oil; any of which may help to explain or justify measures of water quality and ecological impact.

4.2 Phosphate

Phosphate occurs naturally within the river ecosystem, but in very low levels under 0.05 mg/l. Higher levels may indicate anthropogenic input. Phosphate is found in animal and human waste, cleaning chemicals, industrial runoff and fertiliser so this can be a good indicator of pollution. Having raised levels of phosphate can lead to increases in plant growth within the watercourse. This leads to a depletion of oxygen due to the plant's aerobic respiration during the night. Without oxygen aquatic species cannot survive and the river ecosystem collapses. It is important to note that phosphate is taken up by plants. You may get a low reading but high plant growth, indicating eutrophication.

In 1986, the U.S. Environmental Protection Agency (EPA) recommended phosphate levels of no more than 0.1 mg/l (100 ppb) for streams that do not empty into reservoirs; no more than 0.05 mg/l (50 ppb) for streams discharging into reservoirs; and no more than 0.024 mg/l (24 ppb) for reservoirs.

The above recommendations are consistent with ranges on the diagnostic colour chart for WRT's CSI test kit as follows:

0 – 100 ppb: OK
200 – 300 ppb: HIGH
500 – 2500 ppb: TOO HIGH

We use 100 ppb = 0.1 mg/l as our upper safe limit (USL) for phosphate.

4.3 Temperature

Temperature is a vital parameter within the river ecosystem. It controls many of the aquatic species life cycles. Temperature fluctuates with the seasons; however, you do get variation within that, particularly in small rivers and streams. Another important reason to measure temperature is to track the impact of our warming climate on our waterbodies.

Survival in, and passage through, estuaries and rivers by returning adult salmon are influenced by temperature, especially where other water quality parameters are critical. Studies indicate that brown trout and Atlantic salmon are stressed, with long-term consequences for the population, at temperatures above 19.5 °C and 22.5° C, respectively (Brown trout and salmon (publishing.service.gov.uk)).

We use 19.5°C as the upper safe limit (USL) for temperature.

4.4 Turbidity

Turbidity is a measure of the optical clarity of the water. The more suspended particles in the water the lower the clarity and the higher the turbidity. You will often find your waterbody gets more turbid after heavy rainfall due to soil running off the fields and sediment being mixed into the water column. This loss of topsoil is both a problem for farmer and river. It can often contain chemicals from the fertiliser and pesticides used on the land. An increase in sediment level on the substrate of the river can cause smothering of habitat by removing light and oxygen. Aquatic wildlife such as the less mobile invertebrates and fish eggs struggle to survive in low oxygen conditions and without light, plants are unable to grow. It is a good idea to sample your river after different weather conditions to understand how it responds to rainfall or drought.

Turbidity is recorded in Nephelometric Turbidity Units (NTU). The relationship between NTU and suspended solids is as follows: 1 mg/l (ppm) is equivalent to 3 NTU. Therefore, 300 mg/l (ppm) of suspended solids is 900 NTU.

A review of literature indicates that NTU values of ≥100 are unsafe for most aquatic life.

The European Union (EU) Freshwater Fish Directive’s Guideline Standard is an annual mean of 25 mg/l, and which guideline standard is used by the U.K. Environment Agency to help set controls on discharges of inorganic material from quarries, open caste coal sites, and mines. This EU standard of 25 mg/l = 75 NTU annual mean.

We use 75 NTU = 25 mg/l as the upper safe limit (USL) for turbidity

4.5 Total dissolved solids

Total dissolved solids (TDS) is directly related to the conductivity of the water. The more minerals, salts and metals that are dissolved in the water the more conductive it gets. Geology will influence the normal level of conductivity in a watercourse. Low levels of dissolved solids in waters such as those on Dartmoor near to the source of the river are a result of very low levels of input from the surrounding landscape. As the river runs down to the sea it collects material from many different inputs, some natural and some man-made such as farms, sewage plants, factories and residential areas. This typically increases the amount of solids dissolved in the water leading to a higher reading. Harmful pollution from things like sewage, slurry and factory discharge will usually elevate TDS. However, some pollutants such as oil can lower conductivity. Therefore, whilst continuous or regular monitoring of TDS may allow the detection of pollution events, TDS should be used as a general indicator of water quality, rather than a specific measure of toxicity.

The U.S. Environmental Protection Agency (EPA) Secondary Regulations advise a maximum contamination level of 500mg/L (500 ppm) for total dissolved solids (TDS). When TDS levels exceed 1000mg/L it is considered unfit for human consumption. Most commonly, high levels of TDS are caused by the presence of potassium, chlorides and sodium. Changes in the amount of dissolved solids determines the flow of water in and out of an organisms cell, thereby affecting growth or causing death. A level of 400ppm = 400 mg/l is recommended for most freshwater fish.

Whilst still getting to know our river, we use 300 ppm = 300 mg/l as the upper safe limit (USL) for total dissolved solids.

Figure 5. Illustration of the kit and form used by Yealm Dippers when undertaking surveys of water quality as part of the Westcountry Rivers Trust (WRT) Citizen Science Investigation (CSI).

Observational and contextual data
- Wildlife, as indicators of ecosystem health
- Problem plants, often invasive
- Evidence of pollution (litter, odour, foam, sewage, oil)
- Pollution sources (outfalls, land runoff, fly tipping)

Phosphate
- From fertilisers and waste
- Stimulates plant growth, but which may choke watercourse and reduce oxygen levels
- Upper safe limit < 100 ppb = 0.1 mg l^{-1}

Temperature
- Influenced by season and climate change
- Direct effects on development, growth and survival
- Indirect effects through dissolved oxygen levels
- Upper safe limit = 19.5 °C

Turbidity (suspended solids)
- From soil erosion and waste
- Reduces light and vision, smothering membranes
- Upper safe limit is an average of 25 mg l^{-1} = 75 NTU

Total dissolved solids
- Natural levels elevated by waste
- Useful indicator of pollution events
- Excess affects membrane function, growth and survival
- Upper safe limit = 300 mg l^{-1}

Figure 6. Summary of measurements that are being recorded by Yealm Dippers for the Westcountry Rivers Trust (WRT) Citizen Science Investigation (CSI), including likely influences upon and reasons for each measure, and Upper Safe Limits (USL) above which animal or plant health are considered to become compromised.

5. Classification of ecological health by the Westcountry Rivers Trust

Table 2 summarizes analysis by the WRT of survey data recorded within the Yealm catchment during 2022, both before and for six months after training of the Yealm Dippers in July 2022. This analysis suggests overall health had been (i) at best moderate in the Lower River Yealm and Newton Stream, each scoring badly for ecology, turbidity and/or phosphate; and (ii) good in Wembury Stream, where the lowest score was for phosphate.

Findings described in the present report include for 28 sites representing 12 tributaries to the main river channel. By this means, we aim to achieve greater spatial resolution than has previously been possible, helping to clarify where and when there may be specific areas of concern.

Table 2. Overall scores that are relevant to the Yealm catchment, selected from the Westcountry Rivers Trust's Scorecard Summary for 2022.

Waterbody	Overall Grade	Ecology Score	Pollution Score	TDS Score	Turbidity Score	Phosphate Score	Overall Score
Wembury Stream	B	60	80	65	82	43	66
Lower River Yealm	C	35	80	78	14	34	48.2
Newton Stream	C	58	76	59	14	23	46

River Health Scale	
A	80 - 100
B	60 - 80
C	40 - 60
D	20 - 40
E	0 - 20

6. River water levels

River water pollution from land run off and/or untreated sewage overflowing from sewage treatment plants is normally associated with rainfall. More continuous inputs of pollution, such as from industry and treated sewage, may also be diluted or concentrated according to rainfall. For which reasons, river water quality is inevitably influenced by rainfall throughout the catchment, as reflected by resulting river water levels.

River water levels are recorded in the main channel of River Yealm by the EA at Puslinch Gauging Station, located just above Puslinch Bridge (Site # 7 in Figure 3 and Table 1), about half a mile before the river enters the estuary below.

To help interpret water quality findings reported below, those recordings have been downloaded from River Yealm at Puslinch. Levels are illustrated in Figure 7; (a) from 1st July 22 to 30th October 23, (b) over the past ten years from 1st July 12 to 30th October 23 and (c) as a daily average (● ± 95% CL as grey line) calculated over 10 years from 2013 to 2023.

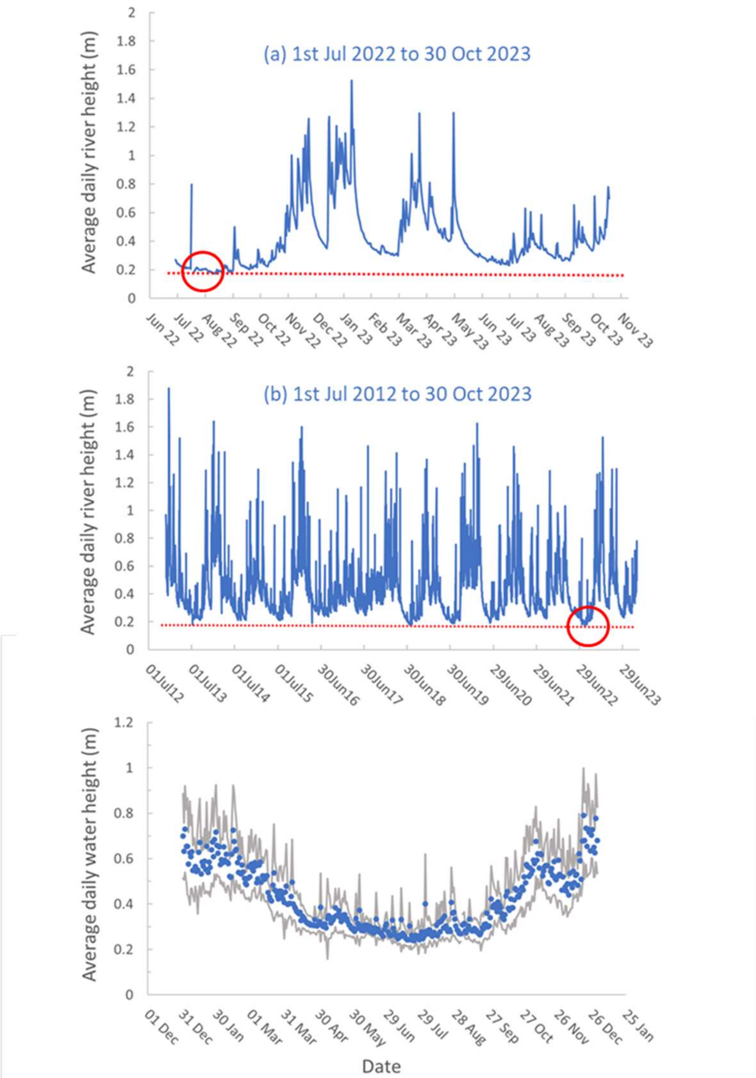


Figure 7. Height of River Yealm at Puslinch Bridge Gauging Station; illustrated (a) from 1st July 22 to 30th October 23, (b) over the past ten years from 1st July 12 to 30th October 23 and (c) as a daily average (● ± 95% CL as grey line) calculated over 10 years from 2013 to 2023. Red circles highlight the drought during summer of 2022, when daily river height dropped to the levels indicated by red dotted lines. Data have been downloaded from https://riverlevels.uk/river-yealm-yealmpton-puslinch

7. Water quality findings in the main channel

7.1 From moor to estuary

Figures 8 and 9 illustrate findings for water quality recorded from 1st July 22 to 30th October 2023 at six survey sites located in the main channel of River Yealm.

Survey sites range from Site # 20 at Wisdom Mill Bridge towards the top of river, to Site # 14 at Popple's Bridge in the middle reaches, and then on down to Sites # 10 (Yealm Bridge) and 21 (The Borough), both in Yealmpton, and finally to Site #7 at Puslinch Bridge below Yealmpton on the last stretch of fresh water before the river joins our estuary (Figure 3) (Table 1).

Findings show how average values of temperature, total dissolved solids and phosphate all increased progressively from Wisdom Mill Bridge in the upper reaches to Puslinch Bridge in the lower reaches of the River Yealm's main channel (Figure 8).

Within the main channel, temperature periodically equalled or exceeded the USL at sites downstream of and including Cornwood (Figure 8).

Most notably, concentrations of phosphate consistently exceeded the USL from the middle reaches at Popples Bridge down to the lowest reaches at Puslinch Bridge (Figure 8).

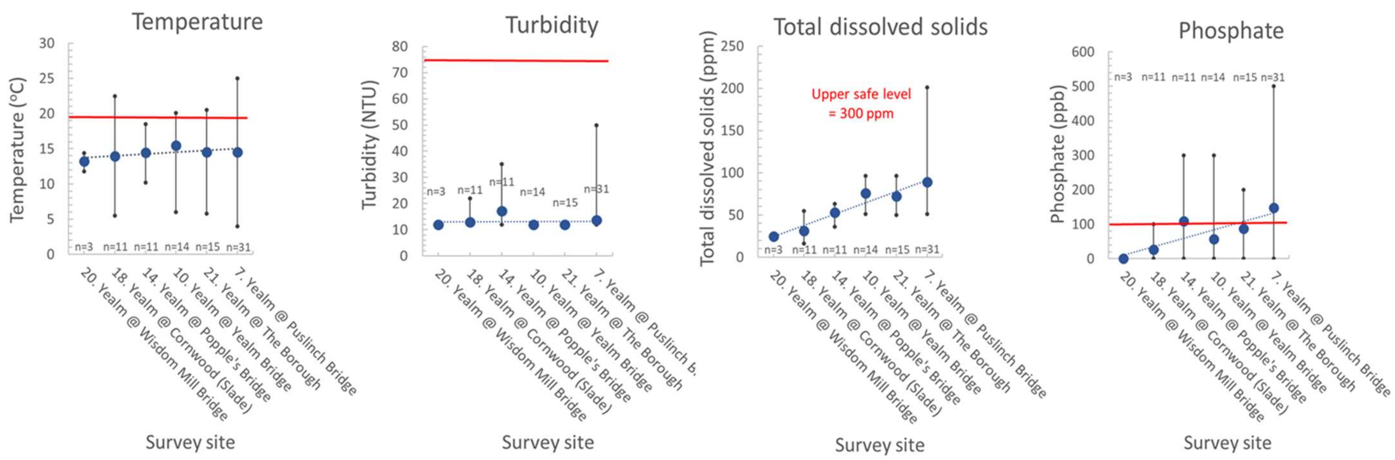


Figure 8. Average (●), minimum (●) and maximum (●) values of temperature, turbidity, total dissolved solids and phosphate at six sites located in the main channel of River Yealm, recorded from 1st July 22 to 30th Oct 23; where n = number of surveys for each site, solid horizontal red lines illustrate the upper safe levels (USL) and dashed blue lines illustrate trendlines fitted using linear regression. Sites are ordered from the top of main channel (20. Yealm @ Wisdom Mill Bridge) to bottom of river just above the estuary (7. Yealm @ Puslinch Bridge). Data are from the Westcountry Rivers Trust Citizen Science Investigations Project [Westcountry CSI - Westcountry Rivers Trust (wrt.org.uk)].

7.2 Seasonal differences

Comparison of Figures 7 and 9 illustrates how water quality in the main channel varied with river water height and thus by inference rainfall.

Highest levels of temperature, phosphate and dissolved solids occurred during summer months when water levels were low, suggesting inputs from sustained sources such as presumably included sewage and industry, in the relative absence of land runoff (Figures 7 and 9).

During summer months when water levels were low, phosphate concentrations in the main channel at Puslinch Bridge, situated below Yealmpton's sewage treatment works, were as much as five times the USL; which concentrations, together with those for total dissolved solids, consistently exceeded those measured one mile upstream at The Borough, immediately above Yealmpton's sewage treatment works (Figures 7 and 9).

In contrast, highest levels of turbidity occurred during winter and spring, when water levels were high, suggesting inputs from land runoff, industrial discharges such as from China clay workings, and/or sewage overflows (Figures 7 and 9).

Whilst low water levels in the summer of 2022 occurred during an official drought, they were not unusual compared with historic river levels which varied considerably over the previous 11 years (Figure 7). Such significant annual variation between summer water levels suggests that yearly variation in rainfall, including climate change, is likely to lead to significant annual differences in the degree to which pollutants are concentrated, and thus also in river health.

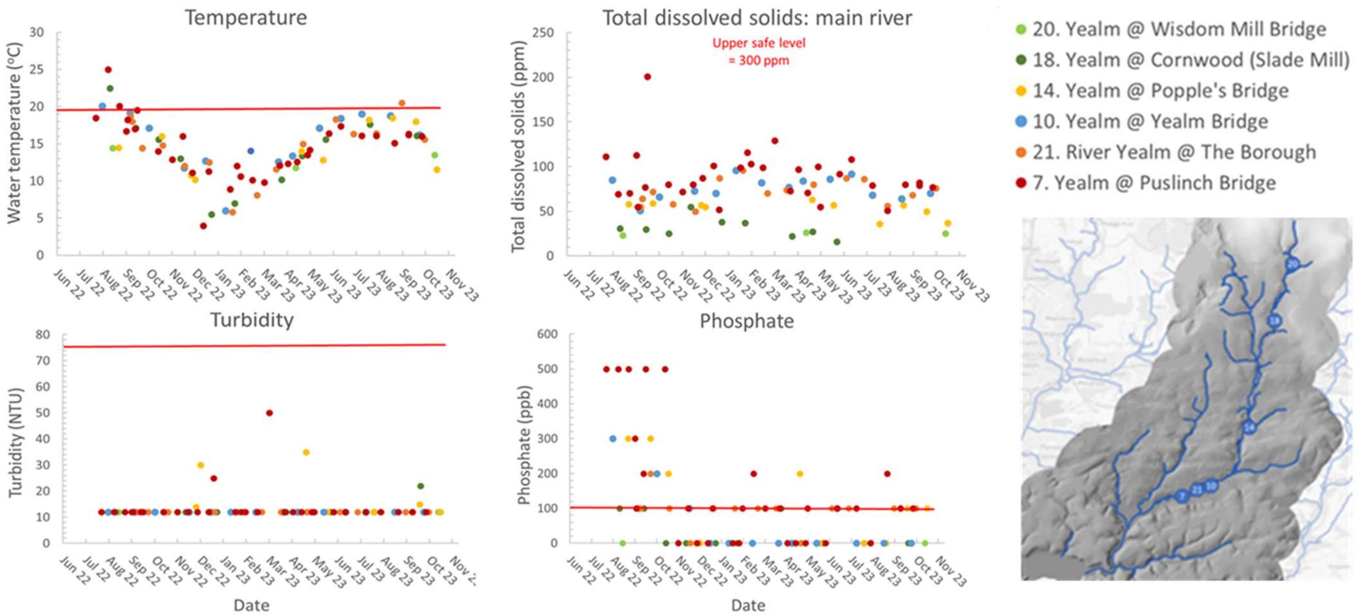


Figure 9. Temperature, turbidity, total dissolved solids and phosphate at six sites in the main channel of River Yealm, recorded from 1st July 22 to 30th Oct 23; where dashed horizontal red lines illustrate the upper safe levels (USL). Data are from the Westcountry Rivers Trust Citizen Science Investigations Project Westcountry CSI - Westcountry Rivers Trust (wrt.org.uk).

8. Water quality findings in tributaries

There are twelve tributaries within the River Yealm Operational Catchment as defined by the , named as follows: Wembury Stream, Hollacombe Brook, Silverbridge Lake Stream, Cofflete

Stream, Ridgecott Lake Stream, the Piall River, Brook Lake Stream, Lee Mill Stream, Long Brook Stream, Newton Stream, Coffin Stream, and Noss Mayo Stream (Figure 3).

Water quality measures recorded on the above 12 tributaries from 1st July 22 to 30th Oct 2023 are illustrated for 22 survey sites in Figures 10, 11, 12, 13 and 14.

As in the main channel, highest levels of temperature, phosphate and dissolved solids occurred during summer months when water levels were low, whereas highest levels of turbidity occurred during winter and spring when water levels were high (Figures 7, 10, 11, 12, 13 and 14).

To help resolve which of the above 12 tributaries are contributing most pollution to the progressive deterioration observed down main channel, Table 3 ranks:

(i) each measured water quality indicator on the basis of average values recorded at all survey sites on each tributary since 1st July 2022; and
(ii) each tributary, overall, from the average of rankings for each measured water quality indicator (Table 3).

On an overall ranking of 1 to 12, Hollacombe Brook appears the cleanest tributary, but with only 3 surveys to date, too few to be conclusive. With 15 surveys to date, Lee Mill Stream comes in a solid worst overall (Table 3).

Whilst overall rankings may help inform an initial assessment, environmental health in separate tributaries varied for different reasons. For example, worst temperatures and dissolved solids in Cofflete Stream, but worst turbidity in Lee Mill Stream and worst phosphate in Coffin Stream (Table 3). Therefore, to identify specific concerns, tributaries must be assessed separately, according to each different measure of water quality, including any further information as may include more than one survey site, potential pollution according to local circumstances and observed pollution events.

Major causes of pollution in our rivers and streams include:

(i) industrial waste, often as a liquid effluent released into the environment without any processing;
(ii) public sewage treatment works, dumping directly into the nearest body of water; and
(iii) contaminated surface runoff that is washed into bodies of water in times of heavy rainfall: originating from both rural and urban areas, often as contaminants which normally lie on land, such as include oil, chemicals and rubber particles from tyre abrasion; including as fertilisers, pesticides and other agricultural products such as contain nitrogen and phosphate, the latter resulting in an imbalance of nutrients.

To help interpret our collective findings, Table 4:

(i) groups sites according to whether they are on the main river or on individual tributary, represented by separate white and blue bands;
(ii) orders the above groups representing the main river or individual tributaries within further groups according to potential primary inputs from industry (i.e. Langage business park or Lee Mill industrial estate), public sewage treatment works (i.e. Cornwood, Lutton, Lee Mill, Yealmpton, Newton and Noss or Elburton) and/or surface runoff, each informed by local knowledge illustrated in Figure 4; and

(iii) uses ticks to illustrate multiples by which maximum recorded levels for each measured indicator exceeded respective USLs.

Drawing upon the above groupings and pollution levels (Table 4), each tributary will now be considered in turn below.

8.1 Tributaries subject to potential inputs from industry, sewage treatment works and/or surface runoff

Lee Mill Stream

- Temperatures of ≥ 20 °C, total dissolved solids ≥ USL, turbidity ≥ 3 x USL and phosphate ≥ 2 x USL collectively suggest possible water abstraction and/or the addition of warm water, including possible inputs from sewage, industry and/or surface runoff (Figures 11, 12, 13 and 14, and Table 4).
- Vulnerable to Lee Mill sewage treatment works, Lee Mill industrial estate and motorway road run off (Figure 4).

Silverbridge Lake Stream

- Phosphate of ≥ 5 x USL in the upper reaches at Smithaleigh suggests possible inputs from surface runoff and/or industry (Figure 14 and Table 4).
- Temperatures of ≥ 22 °C in the middle reaches suggest possible water abstraction and/or the addition of warm water (Figure 11).
- Dissolved solids of ≥ 2 x USL in the lower reaches at Kitley Lake outflow suggest possible sewage input (Figure 13 and Table 4)
- Vulnerable to potential influences from Langage Industrial Estate, Langage Power Station and Brixton sewage treatment works (Figure 5).

8.2 Tributaries subject to potential inputs from sewage treatment works and/or surface runoff

Newton Stream

- Exceptionally high phosphate of ≥ 28 x USL and total dissolved solids of ≥ 3 x USL suggest possible inputs from surface runoff and/or sewage (Figures 13 and 14, and Table 4).
- Vulnerable to Newton and Noss sewage treatment works, plus potential discharges and runoff from Collaton housing development (Figure 4).

Piall River

- Temperatures of ≥20 °C plus turbidity of ≥ 3 x USL in the upper reaches at Quick Bridge suggest possible discharges from clay settlement ponds (Figures 11 and 12, and Table 4).
- Phosphate of ≥ 2 x USL in the lower reaches at Marks Bridge suggests possible inputs from sewage or surface runoff (Figures 14, and Table 4).
- Vulnerable to two commercial clays workings, Cornwood sewage treatment works and Lutton sewage treatment works (Figure 4).

8.3 Tributaries subject to potential inputs from surface runoff alone

Coffin Stream

- Phosphate of ≥ 5 x USL and turbidity of ≥ USL (Figures 12 and 14, and Table 4).

Wembury Stream

- Average phosphate of ≥3 x USL and average temperature both increased significantly from Mill Meadow footbridge to Wembury Beach footbridge, suggesting significant interim phosphate input and/or water abstraction (Figures 11 and 14, and Table 4).

Ridgecott Lake Stream

- Turbidity of ≥3 x USL and phosphate ≥2 x USL (Figures 12 and 14, and Table 4).

Long Brook Stream

- Phosphate of ≥ 3 x USL and temperatures of ≥ USL (Figures 11 and 14, and Table 4).

Noss Mayo Stream

- Phosphate of ≥ 3 x USL and temperatures of ≥ USL (Figures 11 and 14, Table 4).

Brook Lake Stream

- Phosphate of ≥ 2 x USL and turbidity of ≥ USL (Figure 14 and Table 4).

Cofflete Stream

- Phosphate of ≥ USL, but with only six surveys to date, more required (Figure 14 and Table 4).

Table 3. Tributaries ranked (i) for each measured water quality indicator on the basis of average values recorded at all survey sites on each tributary since 1st July 2022; and (ii) overall, from the average of separate rankings for each measured water quality indicator.

Tributaries	Temperature	Total dissolved solids	Turbidity	Phosphate		Overall
Hollacombe Brook	1	3	1	1		1
Piall	3	1	10	3		2
Ridgecott Lake Stream	2	2	11	4		3
Brook Lake Stream	8	4	1	7		4
Long Brook	8	4	1	7		4
Noss Mayo Stream	7	7	1	9		6
Wembury Stream	6	9	1	10		7
Silverbridge Lake Stream	10	6	8	6		8
Cofflete Stream	12	12	6	2		9
Newton Stream	5	10	7	11		10
Coffin Stream	4	8	9	12		10
Lee Mill Stream	11	11	12	4		12

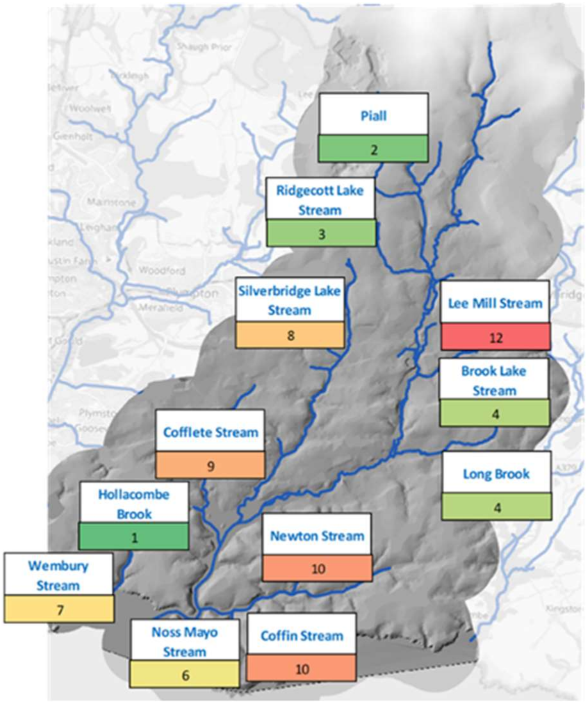


Table 4. All main river and tributary survey sites numbered as illustrated in Figure 3. Sites are grouped according to whether they are on the main river or on individual tributary, represented by separate white and blue bands. Each grouping as main river or tributary is then ordered according to primary potential inputs from sewage treatment works, industry and/or surface runoff (Section 9). The number of ticks (✓) for each water quality indicator represent multiples by which maximum recorded levels exceeded respective Upper Safe Levels (USL). For example, levels of phosphate recorded at Newton Stream @ Bridgend (Site # 2) reached 2500 ppb, which were thus 2500/100 = 25 times more than the USL for phosphate, for which survey site 25 ticks have therefore been entered.

Survey sites	Water quality indicator x USL				Potential influences
	Temperature	Total dissolved solids	Turbidity	Phosphate	
Main channel					
18. Yealm @ Cornwood (Slade)	✓			✓	Industry, sewage works and surface runoff
14. Yealm @ Popple's Bridge				✓✓✓	
10. Yealm @ Yealm Bridge	✓			✓✓✓✓	
21. Yealm @ The Borough	✓			✓✓	
7. Yealm @ Puslinch Bridge	✓			✓✓✓✓✓	
Tributaries					
22. Lee Mill Stream@Lee Mill	✓	✓	✓✓✓	✓✓	Industry, sewage works and surface runoff
23. Lee Mill Stream@ New England Nature Reserve	✓	✓	✓✓	✓✓	
15. Silverbridge Lake @ Barn Park (Smithaleigh)			✓	✓✓✓✓✓	
12. Silverbridge Lake @ Gorlofen Bridge	✓			✓✓	
8. Silverbridge Lake @ Kitley Lake outflow	✓	✓✓		✓	
2. Newton Stream @ Bridgend		✓✓✓		✓✓✓✓✓✓✓✓✓✓ ✓✓✓✓✓✓✓✓✓✓ ✓✓✓✓✓	Sewage works and surface runoff
26. Collaton Stream West, Preston				✓✓	
25. Collaton Stream East, Preston				✓✓	
19. Piall @ Quick Bridge	✓		✓✓✓	✓	
17. Piall @ Marks Bridge			✓✓✓	✓✓	
4. Wembury Stream @Mill Meadow footbridge				✓✓	Surface runoff
5. Wembury Stream @ Wembury beach footbridge				✓✓✓✓✓	
9. Cofflete Stream @ Combe				✓	
16. Ridgecott Lake @ Three Streams			✓✓✓	✓✓	
13. Brook Lake @ Rubys wood near Popples Bridge			✓	✓✓	
11. Long Brook @ Yealm Bridge	✓			✓✓✓	
24. Coffin Stream @ Bridgend			✓	✓✓✓✓✓	
1. Noss Mayo Stream @ Tidal Car Park				✓✓✓	

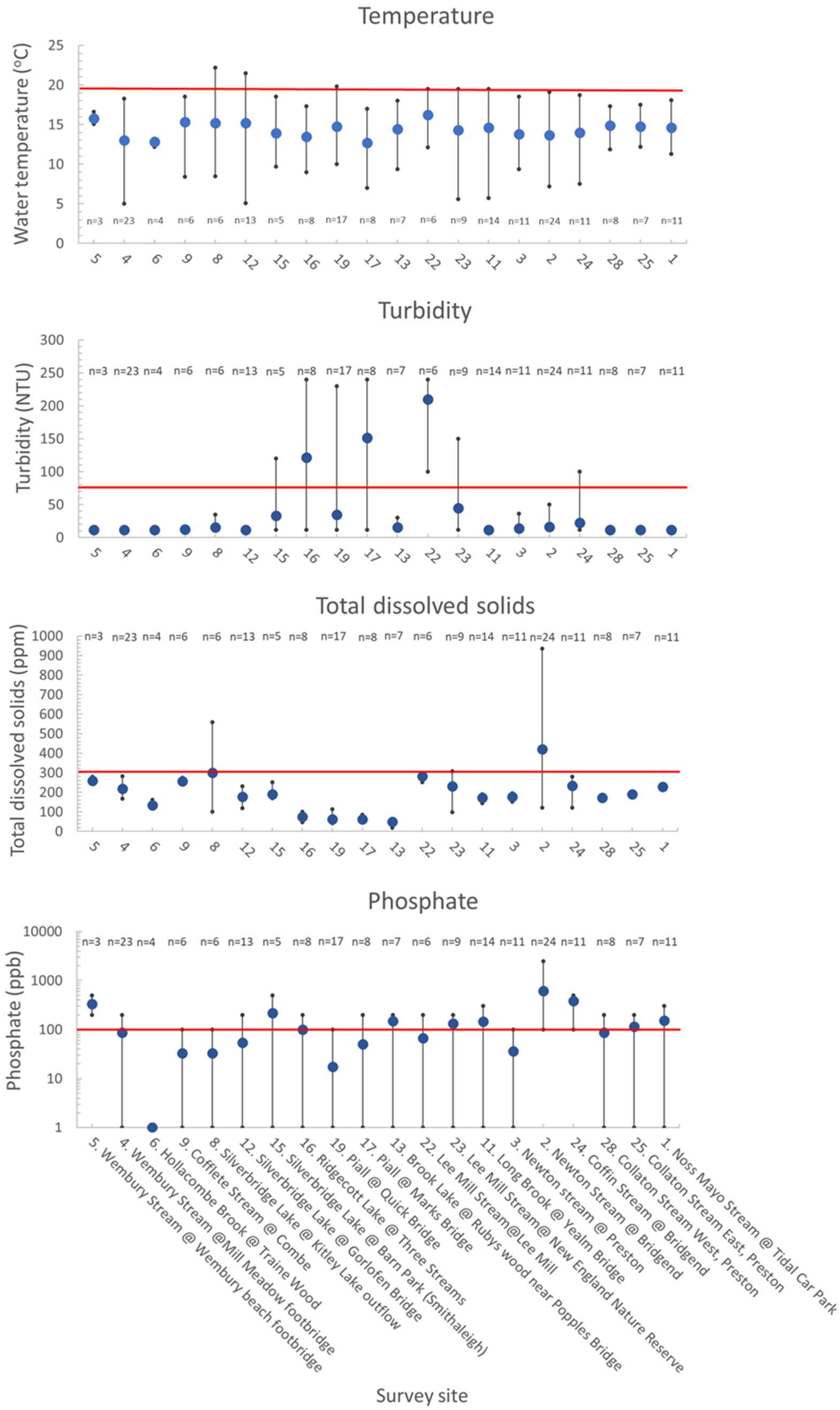


Figure 10. Average (●), minimum (●) and maximum (●) values of temperature, turbidity, total dissolved solids and phosphate at 20 sites on tributaries to the River Yealm, recorded from 1st July 22 to 30th October 2023; where n = number of surveys for each site and solid horizontal red lines illustrate the upper safe levels (USL). Sites are grouped according to tributary/location. Data are from the Westcountry Rivers Trust Citizen Science Investigations Project [Westcountry CSI - Westcountry Rivers Trust (wrt.org.uk)](https://wrt.org.uk).

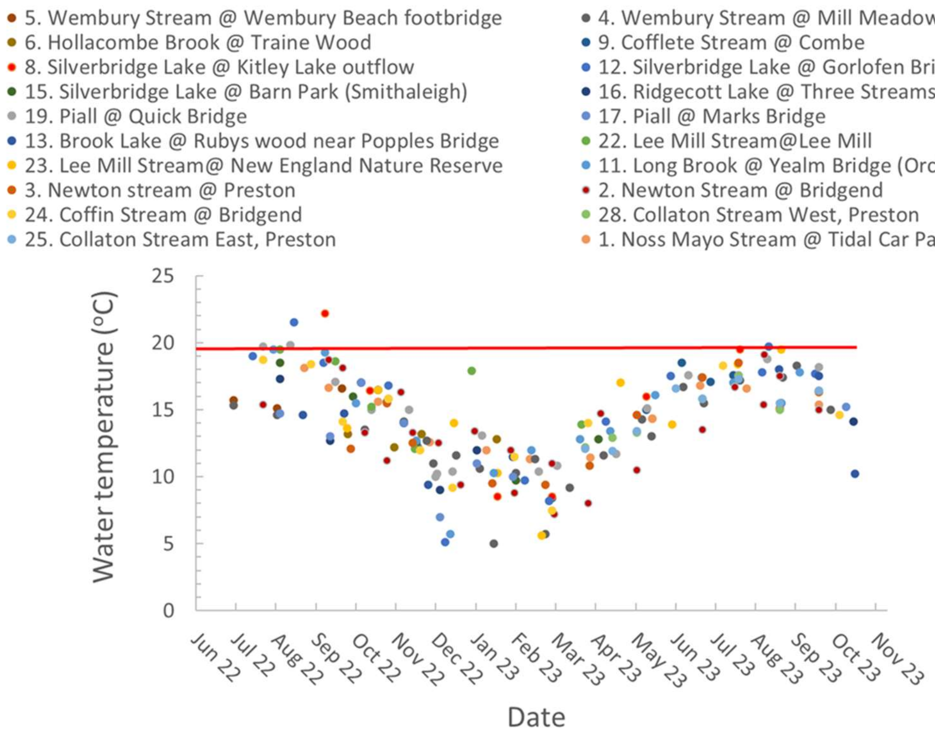


Figure 11. Temperature (°C) at 20 sites on tributaries to the River Yealm, recorded from 1st July 22 to 30th Oct 23; where the dashed horizontal red line illustrates the upper safe level (USL). Data are from the Westcountry Rivers Trust Citizen Science Investigations Project Westcountry CSI - Westcountry Rivers Trust (wrt.org.uk).

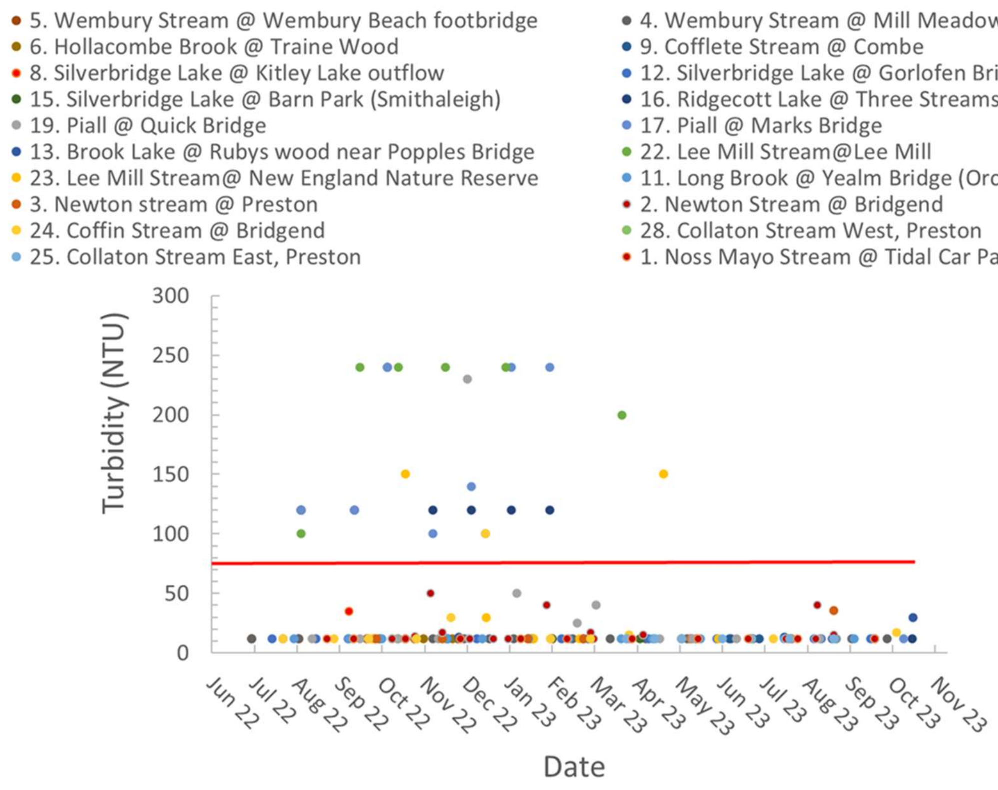


Figure 12. Turbidity (NTU) at 20 sites on tributaries to the River Yealm, recorded from 1st July 22 to 30th Oct 23; where the dashed horizontal red line illustrates the upper safe level (USL). Data are from the Westcountry Rivers Trust Citizen Science Investigations Project Westcountry CSI - Westcountry Rivers Trust (wrt.org.uk).

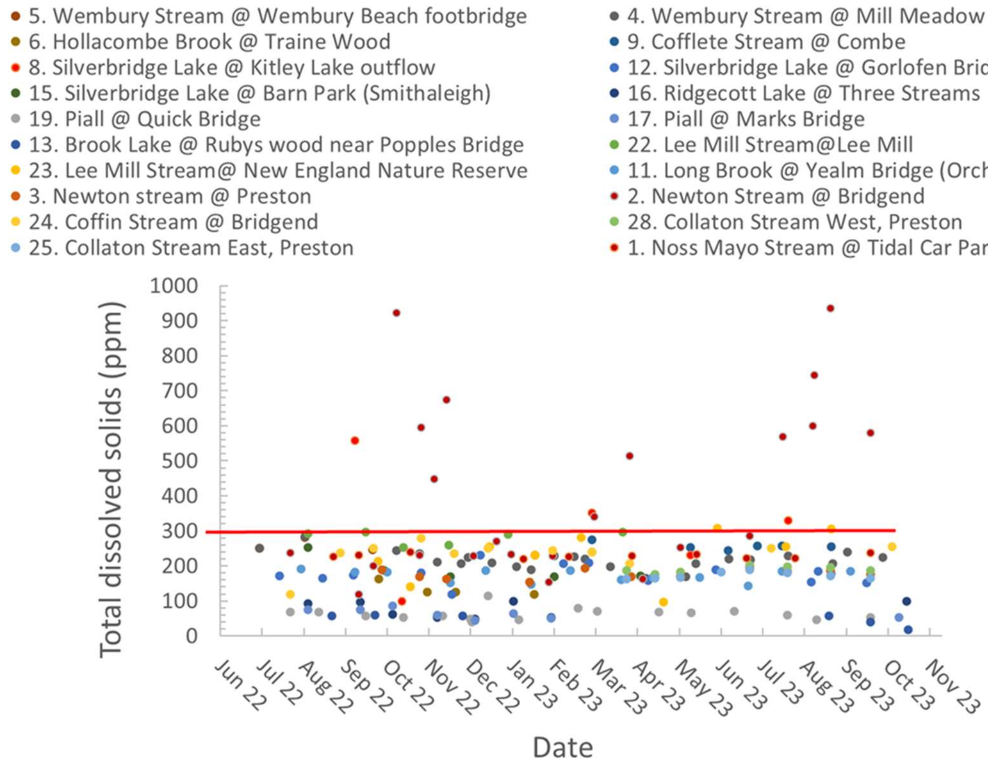


Figure 13. Total dissolved solids (ppm) at 20 sites on tributaries to the River Yealm, recorded from 1st July 22 to 30th Oct 23; where the dashed horizontal red line illustrates the upper safe level (USL). Data are from the Westcountry Rivers Trust Citizen Science Investigations Project [Westcountry CSI - Westcountry Rivers Trust (wrt.org.uk)].

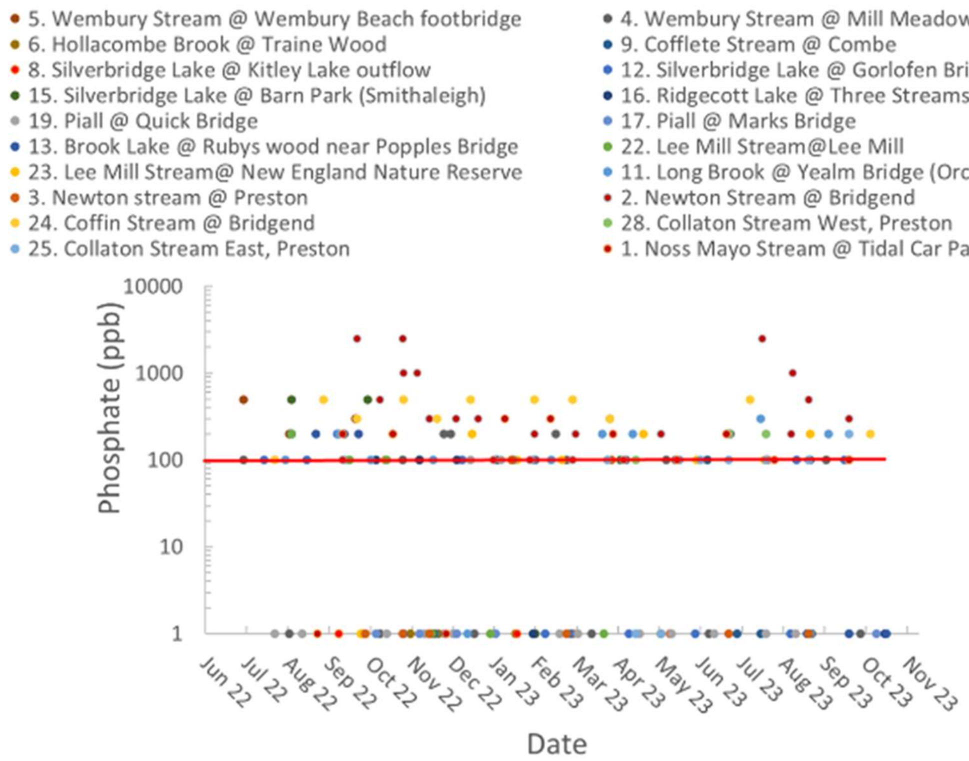


Figure 14. Phosphate (ppb) at 20 sites on tributaries to the River Yealm, recorded from 1st July 22 to 30th Oct 23; where the dashed horizontal red line illustrates the upper safe level (USL). Data are from the Westcountry Rivers Trust Citizen Science Investigations Project [Westcountry CSI - Westcountry Rivers Trust (wrt.org.uk)].

9. Pollution events reported to the Environment Agency

In addition to water quality surveys in partnership with WRT, Yealm Dipper volunteers have reported a notable number of pollution events to the Environment Agency. Since 1st July 2022 these have included 6 events illustrated in Figure 15 listed as follows:

a) Lee Mill Stream; eutrophic algal bloom on 16 Aug 2022;
b) Popple's Bridge; River Yealm discoloured on 6 Oct 2022;
c) Rivers Piall and Yealm, both throughout; discoloured with kaolin-like material on 05 December 2022; with resulting sediments that remained for more than 4 months;
d) Puslinch Bridge, localised stream of contaminant flowing into the River Yealm on 14 Feb 2023;
e) Lee Mill Stream, discoloured flow into the River Yealm on 11 May 2023; and
f) Newton Stream, discoloured flow with associated sediments at Bridgend on 11 Aug 2023.

Lee Mill Stream; eutrophic algal bloom on 16 Aug 2022

Puslinch Bridge; contaminant flowing into the River Yealm on 14 Feb 2023

Rivers Piall and Yealm; discoloured with kaolin-like material on 05 December 2022, with resulting sediments that smothered the riverbed for more than 4 months

Lee Mill Stream; discoloured flow into the River Yealm on 11 May 2023

Popple's Bridge; River Yealm discoloured on 6 Oct 2022

Newton Stream; discoloured flow and settlement at Bridgend on 11 Aug 2023

Figure 15. Selection of photographs submitted by Yealm Dipper volunteers to the Environment Agency since 1st July 2022 in associated reports of significant pollution events.

The above incidents in River Piall, Lee Mill Stream and Newton Stream each build upon water quality survey results which, described above, indicate cause for concern in those same tributaries (Section 9).

The most serious of these events involved kaolin-like pollution starting 05 December 2022. Early that day, an unusually high water flow saturated with kaolin-like material was seen above Quick Bridge on the River Piall in Cornwood Parish. The source was quickly identified as being from the direction of Headon China clay works. Leaving deposits more than 15 cm deep on the Piall, the River Yealm was discoloured along its entire length, the river bed covered with kaolin-like material for many miles downstream, depriving plant and animal life of both light and oxygen (Figure 15).

Drawing primarily upon evidence submitted by our CSI volunteers, a report 28 pages long with more than 30 photographs detailed the likely source, including how the riverbed was smothered for more than one month after the event, and associated fish mortality. That report was drafted on behalf of River Yealm Water Quality Group, comprised of nominated representatives from each of the riparian parish councils that border our river (Brixton, Yealmpton, Newton & Noss, Sparkwell and Cornwood), thereby helping inform councils make coincident representations to the EA, and was subsequently collected by the EA with an associated witness statement.

The EA has recently confirmed continued investigation into the above incident. Meanwhile, we are encouraged to be patient, when any suggestion of associated responsibility or guilt might incur a legal challenge which compromises the EA's ability to investigate further.

10. Wildlife

In no particular order, wildlife observed has included swans, geese, duck, oyster catchers, egrets, kingfisher, woodpeckers, dragon flies, damsel flies, dippers, wagtails and fish.

We have no recordings of otters or mink, but which are thought to be present.

11. Summary highlights

Since training in July 2022, as part of the WRT's CSI, 46 volunteers known as the Yealm Dippers have undertaken 290 surveys of river water quality at 28 sites which are focussed primarily upon 12 tributaries to the main channel of River Yealm, (Figures 2 and 3) (Table 1). Such focus provides greater spatial resolution than has previously been possible in classifications of ecological health (Section 6). To help visualise resolution achieved, Figure 16 illustrates all sites at which water quality measures exceeded USLs for temperature, turbidity, total dissolved solids and/or phosphate; encircled in red, blue, brown and/or green, respectively.

The present report presents and interprets associated findings, helping to clarify where there may be specific areas of concern, as opportunities to focus remediation.

Whilst still "early days", data collected over 15 months to date are beginning to help identify specific issues in space and time, as we get to know our river and catchment.

Highlights are summarised as follows:

a) Water quality varied with river water height and thus by inference rainfall; highest levels of temperature, phosphate and dissolved solids occurring during summer months when water levels were low, whereas highest levels of turbidity occurred during winter and spring when water levels were high (Figures 7 and 9).
b) Highest levels of turbidity when water levels were on average highest high seem likely to have resulted from industrial discharge such as from China clay workings, sewage and/or surface runoff.

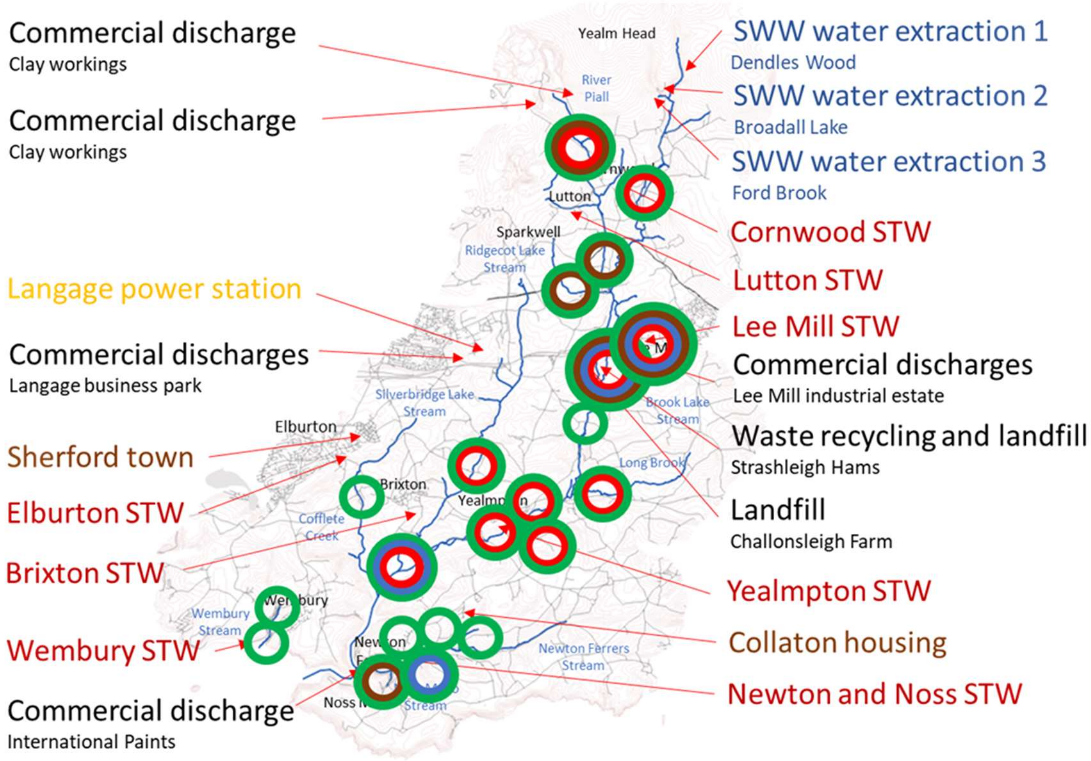


Figure 16. Sites surveyed by Yealm Dipper volunteers as part of the Westcountry Rivers Trust Citizen Science Investigation from 1st July 2022 to 30th Oct 2023 sites at which water quality measures exceeded upper safe levels for temperature, turbidity, total dissolved solids and/or phosphate; encircled in red, blue, brown and/or green, respectively.

c) Highest levels of phosphate when water levels were on average lowest suggest seasonal concentration of relatively continuous inputs that are independent of rainfall and land run off, such as from industry and/or sewage.
d) The influence of river water height means that considerable annual variation between summer water levels (Figure 7), according to each years' rainfall and climate change, is likely to be associated with significant annual variation in the degree to which pollutants are concentrated, and thus also in river health.
e) Average temperature, turbidity, total dissolved solids and phosphate all increased progressively in the main river channel from upper to lower reaches (Figure 8).
f) Within the main river channel, temperature, turbidity and total dissolved solids each periodically exceeded USLs. In contrast, concentrations of phosphate were consistently high, average values exceeding the USL from the middle to lowest reaches (Figure 8).
g) Phosphate levels of ≥ 3 x USL in the middle reaches of the main river channel at Popple's Bridge evidenced a clear deterioration in water quality(Figure 8). Such an abrupt deterioration appears associated with input from Lee Mill Stream; the only tributary where averages recorded for all four measures of water quality each exceeded respective USLs, and which ranked lowest among all 12 tributaries throughout our catchment (Figure 3, and Table 3). Potential influences include Lee Mill industrial estate, motorway road run off, Lee Mill sewage treatment works and/or surface runoff (Figure 4). An associated pollution event with photographic evidence was reported to the EA in December 2022 (Section 10 and Figure 15).

h) In the lower reaches of main river channel at Puslinch Bridge, situated about ¼ mile below Yealmpton's sewage treatment works, maximal phosphate of ≥ 5 x USL and total dissolved solids each consistently exceeded levels measured just one mile upstream at The Borough, located immediately above Yealmpton's sewage treatment works (Figure 9).
i) Phosphate exceeded USLs in each of our 12 surveyed tributaries (Table 4).
j) Total dissolved solids only exceeded the USL in tributaries that appear vulnerable to sewage treatment plants; as included Lee Mill Stream, Silverbridge Lake Stream and Newton Stream (Figure 4 and Table 4).
k) In Silverbridge Lake Stream, phosphate of ≥ 5 x USL in the upper reaches at Smithaleigh suggests possible inputs from industry, sewage and/or surface runoff (Figure 14 and Table 4). In the middle reaches at Gorlofen Bridge, temperatures of ≥22 ^{o}C suggest possible water abstraction and/or the addition of warm water (Figure 11). In the lower reaches at Kitley Lake outflow, TDS of ≥ 2 x USL suggest potential sewage input (Figure 13 and Table 4). Possible influences include Langage Industrial Estate, Langage Power Station Brixton sewage treatment works and/or surface runoff (Figure 4).
l) In Newton Stream, exceptionally high phosphate of ≥ 28 x USL, combined with TDS of ≥ 3 x USL, suggest very significant inputs from sewage and/or surface runoff (Figures 13 and 14, and Table 4). An associated pollution event with photographic evidence was reported to the Environment Agency in August 2023 (Section 10 and Figure 15).
m) In the River Piall, enhanced phosphate levels of ≥ 2 x USL in the lower reaches at Marks Bridge suggest possible inputs from sewage and/or surface runoff (Table 5). Possible influences include both Cornwood sewage treatment works and Lutton sewage treatment works (Figure 4).
n) Throughout the River Piall, from Quick Bridge in the upper reaches to Mark's Bridge in the lower reaches, turbidity was > 3 x USL. High turbidities are consistent with inputs from surface runoff and/or clay settlement ponds that drain from commercial workings into the upper reaches of River Piall (Figure 4). Certainly, it seems possible that the major pollution event which started on 5 December 2022, smothering the Piall and main channel of Yealm with kaolin-like material for at least one month, was associated with those commercial workings (Section 10 and Figure 15). That event was reported to the Environment Agency, who subsequently collected an associated report as evidence (Section 10 and Figure 15).
o) In the upper reaches of River Piall at Quick Bridge, maximal recorded temperatures of 20 ^{o}C were far higher than coincident temperatures of no more than 15 ^{o}C on the main river below (Figures 9 and 11). Such temperatures exceeded the critical threshold of 19.5 °C above which brown trout are stressed, and were close to the threshold of 22.5° C above which there are long-term consequences for salmon fry and adults (Section 4.3). More importantly, temperatures as high as 13.3 ^{o}C recorded during January 2023, and which were again far higher than coincident temperatures of no more than 7 ^{o}C on the main river below (Figures 9 and 11), exceeded the critical threshold of about 12 ^{o}C above which mortality and deformities increase markedly in salmon eggs, as are mainly deposited in the River Yealm during December and January (Thermal Biology-Atlantic Salmon). As for turbidity above, high temperatures are consistent with inputs from surface runoff and/or clay settlement ponds that drain from commercial workings into upper reaches of the River Piall (Figure 4).

p) Remaining tributaries that are not vulnerable to public sewage treatment works, nor to known industrial inputs, but with high temperature, phosphate and/or turbidity, implying possible inputs from surface runoff, include:
   - Coffin Stream, with phosphate of ≥ 5 x USL and turbidity of ≥ USL;
   - Wembury Stream; with phosphate of ≥ 5 x USL;
   - Long Brook Stream, with phosphate of ≥ 3 x USL and temperature of ≥ USL;
   - Noss Mayo Stream, with phosphate of ≥ 3 x USL and temperature of ≥ USL;
   - Ridgecott Lake Stream, with phosphate of ≥ 2 x USL and turbidity of ≥ 3 x USL,
   - Brook Lake Stream, with phosphate of ≥ 2 x USL and turbidity of ≥ USL; and
   - Cofflete Stream with phosphate of ≥USL (Figures 11, 12 and 14, and Table 4)

12. Areas of concern

12.1 Environment Agency designations

Table 5 summarises the current ecological status for each of five waterbodies designated within the Yealm Operational Catchment, as last presented by the EA in 2022 (YEALM | Catchment Data Explorer | Catchment Data Explorer). The worst waterbody status is "Moderate", defined as a "Moderate change from natural conditions". High concentrations of phosphate are identified as a common issue; hydrology (i.e. water levels) and algal growth (i.e. macrophytes) being of localised concern (Table 5).

The present report further confirms phosphate as an ecological indicator of widespread concern. Drawing upon our first annual survey from 28 sites that include 12 tributaries, we also identify specific areas of concern as have mostly been highlighted in Section 12 above.

Relevant to helping prioritise those areas of concern, the EA also designate the River Yealm as one of only 42 Principle Salmon Rivers within England, including as a Special Area of Conservation for which salmon are a qualifying species, with an associated Salmon Action Plan (River Yealm Salmon Action Plan). Salmon are in icon of our natural heritage; enhancing ecology, recreation, amenity value and commerce. Main historic salmon spawning and rearing habitats within our catchment include the River Piall, Ridgecott Lake Stream and the middle to lower reaches in main channel of River Yealm (River Yealm Salmon Action Plan).

12.2 Further prioritisation

In summary, present findings suggest the following:

a) Throughout the River Yealm catchment, phosphate represents a general benchmark upon which to improve.
b) Widespread concentration of phosphate and total dissolved solids at times of low water level, in the absence of rainfall and associated land run off, places a priority on reducing relatively continuous inputs such as from industry and/or sewage.
c) To uphold responsibilities for conservation of the Atlantic Salmon within known historic spawning and rearing habitats, there is a need to reduce inputs from industry, sewage and/or surface runoff to (i) the River Piall; (ii) Lee Mill Stream, compromising lower reaches

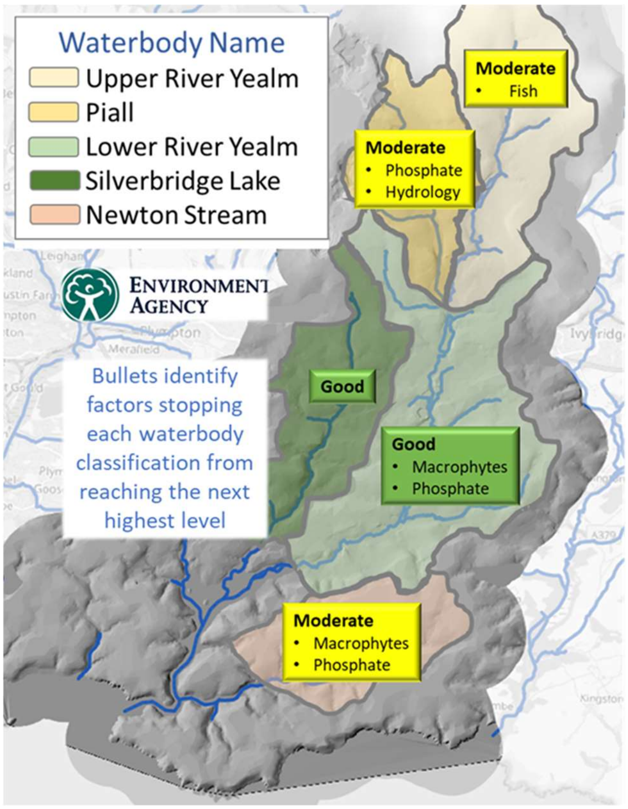
in the main channel of River Yealm; and (iii) the main channel of River Yealm between The Borough and Puslinch Bridge, spanning Yealmpton sewage works.

d) There is an urgent need to identify and act upon sources contributing to exceptional levels of phosphate and total dissolved solids in Newton Stream.

e) There is a need to identify and act upon sources or activities contributing to high levels of phosphate in the upper reaches of Silverbridge Lake Stream, including for high temperature in the middle reaches and high total dissolved solids in the lower reaches.

f) There is widespread potential to reduce inputs that appear most likely to be associated with surface runoff in Coffin Stream, Wembury Stream, Long Brook Stream, Ridgecott Lake Stream Noss Mayo Stream, Brook Lake Stream and Cofflete Stream.

Table 5. Waterbody designation and Ecological Status awarded through the Yealm Operational Catchment by Environment Agency in 2022 ([YEALM | Catchment Data Explorer | Catchment Data Explorer]()).



Status	Definition
High	Near natural conditions. No restriction on the beneficial uses of the water body. No impacts on amenity, wildlife or fisheries.
Good	Slight change from natural conditions as a result of human activity. No restriction on the beneficial uses of the water body. No impact on amenity or fisheries. Protects all but the most sensitive wildlife.
Moderate	Moderate change from natural conditions as a result of human activity. Some restriction on the beneficial uses of the water body. No impact on amenity. Some impact on wildlife and fisheries.
Poor	Major change from natural conditions as a result of human activity. Some restrictions on the beneficial uses of the water body. Some impact on amenity. Some impact on wildlife and fisheries.
Bad	Severe change from natural conditions as a result of human activity. Significant restriction on the beneficial uses of the water body. Major impact on amenity. Major impact on wildlife and fisheries with many species not present.

13. Future actions

Findings and areas of concern prioritised and reported here will be used to:

- inform and engage further community support;
- lobby for action through negotiated partnerships;
- leverage improvements on back of relevant river and land-based schemes, towards changing behaviour and reducing pollution; and
- collect evidence of resulting impacts.

To help ensure positive changes in the catchment by informing improvement work and raising public awareness, the Yealm Estuary to Moor Project (YEM) and River Yealm Water Quality Group (RYWQG) are each engaged with four additional partnerships as follows:

River Yealm Catchment Co-ordination Partnership (RYCCP)

The RYCCP is hosted by the EA and YEM, in partnership with RYWQG the WRT, Devon Wildlife Trust, Farming and Wildlife Advisory Group, Natural England, Yealm Estuary Management Group, South Devon Area of Outstanding Natural Beauty, University of Plymouth, Plymouth Marine Laboratory, South West Water and others. This RYCCP enables YEM and WRT to share evidence for areas of concern with industry, agencies and regulators, with a primary aim to help focus each members separate programs, towards the co-ordinated optimisation of future monitoring and remediation within the context of an agreed 5 -10 year plan.

South Devon Catchments Partnership (SDCP)

The SDCP is hosted by WRT, the EA, and South Hams District Council's unit for Area of Outstanding Beauty, bringing together a wider range of organisations from 5 Devon catchments which include the Teign, Dart, Erme, Yealm and Avon. YEM contributes with other community groups to share information and opportunities, whether through collaborative funding applications, or through the focussing of existing programs, towards appropriate remediation. (https://south-devon.org/).

South Devons River Champions (SDRC)

The SDRC network connects community groups, parish councils, farmers, landowners and businesses in South Devon catchment areas for the Rivers Yealm, Erme, Avon, Gara and Dart, plus Salcombe/Kingsbridge Estuary. SDRC also provides a welcome communication platform through the South Devon River Voices digital magazine and the River Voices e-newsletter, including the River Discovery Zone marquee at Devon County Show (South Hams England Catchment | Avon River Champions (south-devon-river-champions.org)).

Westcountry Rivers Collective (WRC)

The WRC is being developed by the WRT as a new Citizen Science model involving a tiered volunteering system where Yealm Dippers will be represented both within the River Guardians Network and as Coordinators. It is intended that this collective will afford a range of resources, including expertise that volunteers can refer to when training volunteers, developing catchment plans and targeting work in their area. Associated plans include more advanced data collection methods so that there is more evidence for the public, and the relevant agencies have more respect for the data, helping as an engagement tool for lobbying as well as when talking to the public and stakeholders. This includes establishing common contact points in the Environment Agency and South West Water through which levels of concern may be reported.

14. Value of Citizen Science

This “Yealm Dippers” Citizen Science Investigation is:

- providing regular measurements and the creation of long-term dataset for specific pollutants at sites where the EA and other official monitoring programs are not active;
- stimulating communication and outreach activities with our local community, thereby helping to inform wider audiences on the potential threats faced by riverine environments;
- helping to cement a relationship between our community and river system, at the same time encouraging learning opportunities for individuals that may not normally interact with nature; and
- empowering our community to make change, not only in our catchment, but also upon sharing knowledge and facilities with those working on other rivers.

As such, the value of citizen science is clear. “Yealm Dippers can take pride in helping to resolve the scale and location of background water quality issues through our catchment. We look forward to building our evidence base and further developing working collaborations, towards helping nurse the River Yealm back into better health.

All of this work is undertaken by volunteers. If you would like further information, or to help in any capacity; whether undertaking measures on the river, coordinating volunteers, data management and/or relations with the public and other organisations, please contact:

Tony Hawkins or Jane Pennington,
River Coordinators,
Yealm Estuary to Moor
Email: yemriver@gmail.com