UPSTREAM THINKING IN ACTION: ARGAL AND COLLEGE RESERVOIRS

- Algal blooms and eutrophication related issues are a major problem in the catchment. Monitoring has mostly focused on nutrient inputs (as a driver for eutrophication), algae content and metaldehyde detections.
- The monitoring results at sub-catchment scale highlight the need to focus intervention efforts on the Antron Stream sub-catchment, as it is a higher nutrient contributor to the reservoir than the Argal Stream.
- Efforts should focus on reducing P input, as peaks are concomitant with blue-green algal blooms.
- Passive sampling showed that metaldehyde detections were consistently below 100 ng L^{-1} in the catchment and at the WTW, and decreased between autumn deployment periods.
- Upstream Thinking interventions have the potential to hold the line against environmental degradation.

About the catchment

Background site information

Argal and college reservoirs are within South West Water's Colliford Strategic Supply Area (Figure 1). They are located within the Fal EA Operational catchment, which itself falls within the wider Cornwall West and Fal EA Management Catchment. Abstraction from College No. 4 reservoir stopped in 2007; Argal reservoir is currently the only source used to supply approximately 15,000 homes around Penryn and Falmouth.

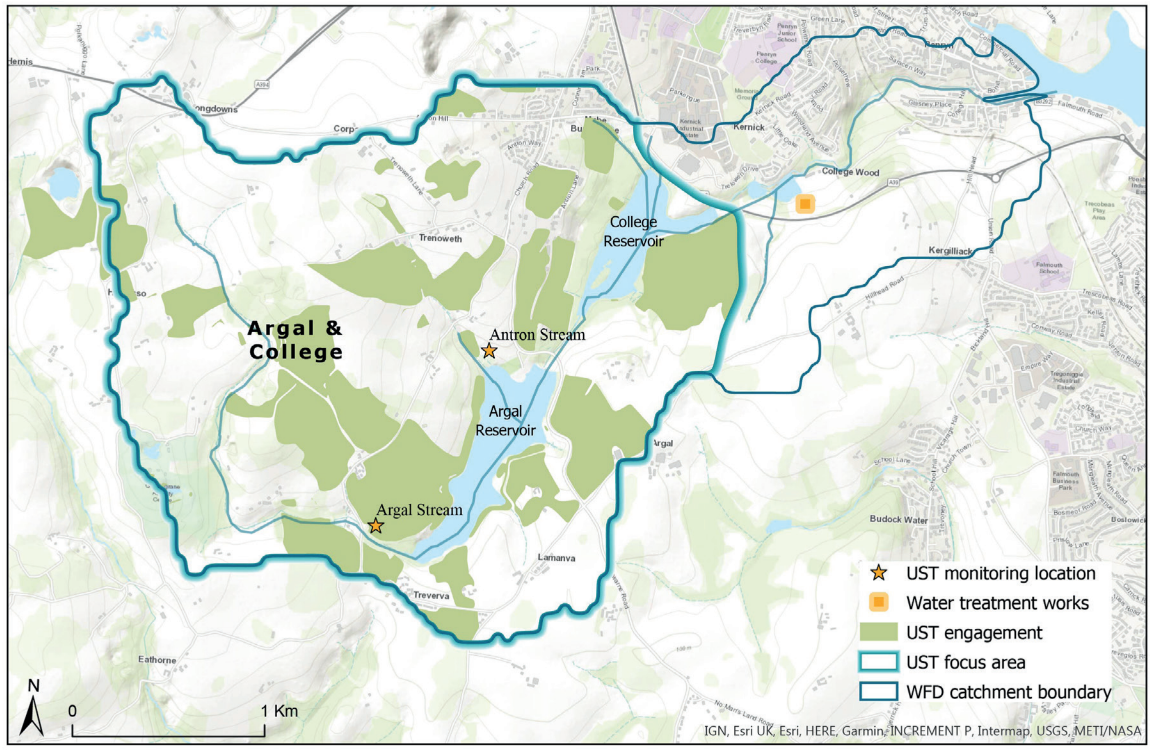


Figure 1 Map of engagement by the CWT as part of Upstream Thinking in the Argal and College catchment.

Catchment Challenges

Argal and College reservoirs were identified as at risk for: algae (total and blue-green), geosmin, MIB, ammonia and metaldehyde.

Catchment Activities

During Upstream Thinking 2 (2015-2020), **Cornwall Wildlife Trust** (CWT) engaged with farmers in the Argal and College catchment to offer advice and capital grants aimed to improve farming practices and to reduce ammonium and pesticide runoff from farms. They also supported farm businesses into Countryside Stewardship schemes to undertake better management for the reduction of soil and nutrient runoff into the reservoir. Areas of semi-natural habitat were brought into better management for water and wildlife benefits.

Figure 1 illustrates the level of farm engagement in UsT2 within the Argal and College reservoirs catchment. As of May 2019, 33% of the catchment focus area has been engaged in the programme, including such things as farm visits by an advisor, the provision of a farm plan or physical interventions and behaviour changes.

Physical interventions completed via Upstream Thinking, which were quantifiable within the Farmscoper software, amounted to a cumulative total of 22 ha. The interventions most frequently used were re-siting gateways away from high risk areas and minimising the volume of dirty water produced (and sent to dirty water store). It should be noted, however, that numerous additional interventions have occurred that are less easy to quantify or that have happened as a result of the Countryside Stewardship joint working, and are therefore not covered in this assessment.

Water quality in the Argal catchment

Nutrient content in feeder streams

Since 2012, Argal reservoir consistently falls in the "poor" Water Framework Directive (WFD) water quality classification. This is due to Total Phosphorus (TP) and phytoplankton issues that are attributed to agriculture and land management issues. In order to investigate the input to the reservoir, water quality sampling (rainfall events) was conducted in the two feeder streams to Argal reservoir (Figure 2): the Argal Stream and the Antron Stream. Monitoring focused more particularly on nutrient inputs to the reservoir, as these can be a driver for algal blooms. Both sites show concentrations of Soluble Reactive Phosphorous (SRP) and Total Oxidised Nitrogen (TON) frequently above the targets set by the EA and SWW for (TP) and TON, indicating overall high nutrient contribution from the catchments to the reservoir (Figure 3). It is worth noting that our measurements were of inorganic P solely (i.e. SPR) when the regulatory limit is that of TP. As TP also contains organic and inorganic P, the exceedance of this limit by SRP alone confirms the high values that would be even higher if TP had been measured.

Figure 2 Pictures showing the main tributaries to Argal reservoir: Argal stream (left) and Antron stream (right) (photos by Emilie Grand-Clement).

For the events monitored, nutrient concentrations measured in the Antron Stream are consistently higher than that coming from the Argal stream (Figure 3). Despite lower stream flow in the Antron Stream (Figure 3), higher concentrations mean that the total instantaneous load (i.e. mass of nutrients at any one time) input to the reservoir tends to be higher than that from the Argal Stream (Figure 4), making this sub-catchment a higher contributor of diffuse pollution. The lack of significant change between years indicate that no deterioration has occurred during the course of the project which is a positive result. In the wider landscape, it is unfortunately clear that environmental degradation is still worsening. This work demonstrates that more interventions are required to reverse the diffuse pollution problems both in these reservoirs and wider landscape.

Argal reservoir within the catchment (photos by Emilie Grand-Clement).

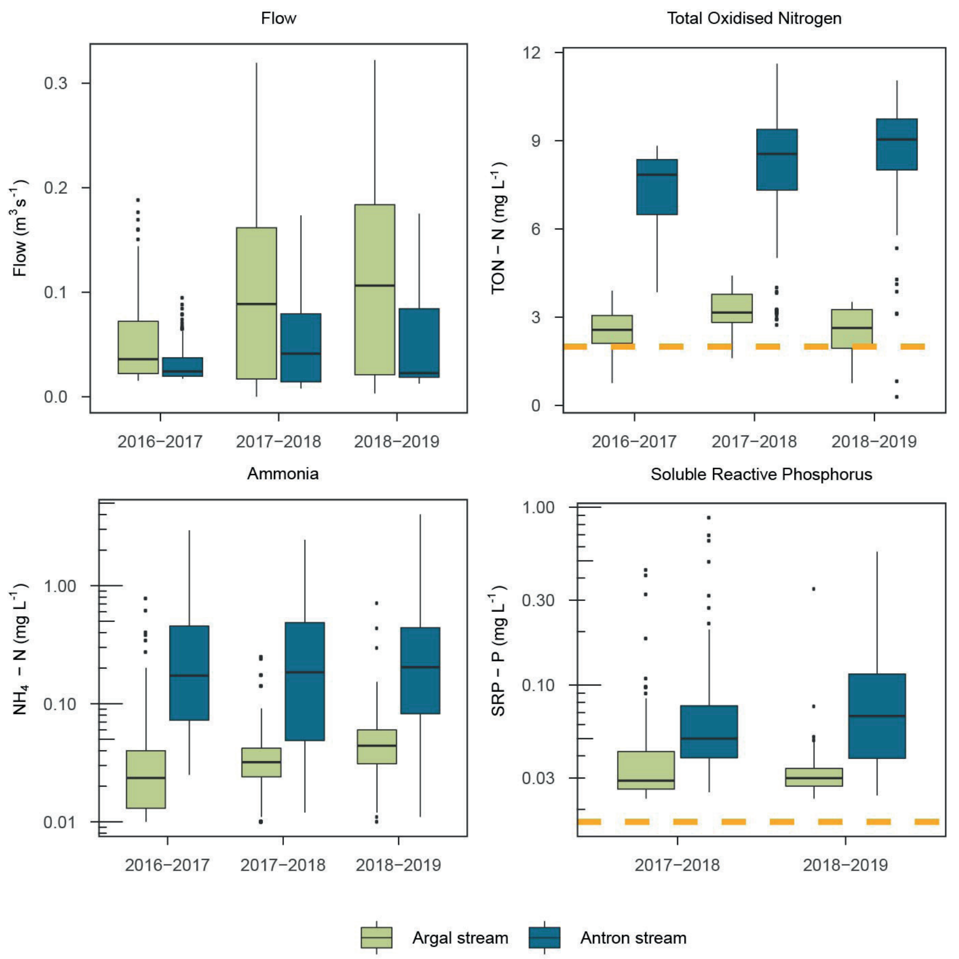
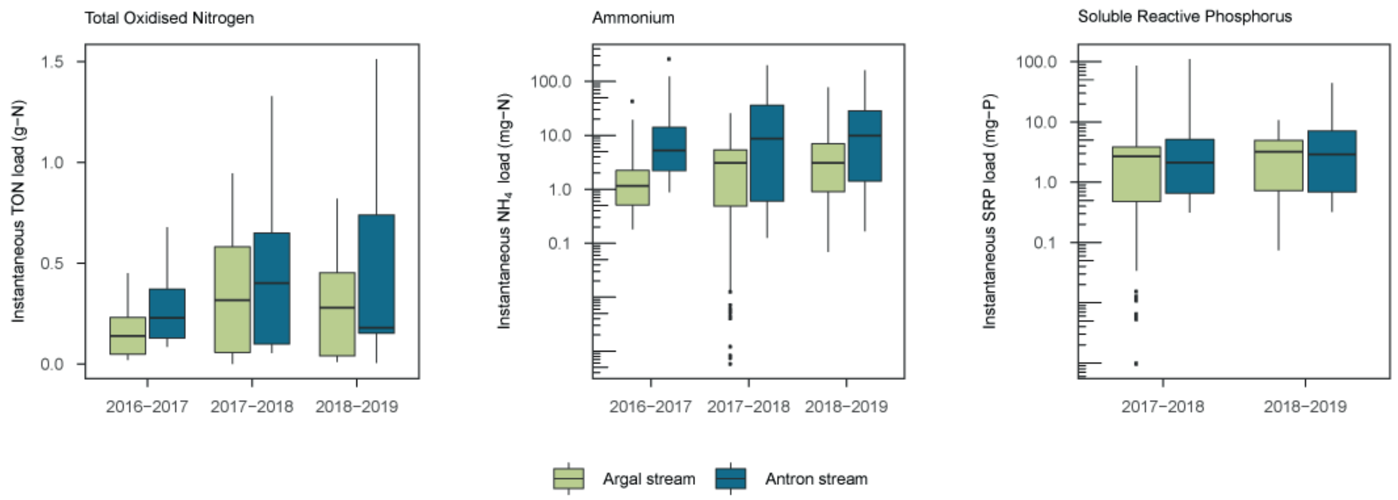


Figure 3 Flow ($m^3 s^{-1}$), Total Oxidised Nitrogen, ammonium and Soluble Reactive Phosphorus concentrations in feeder streams to Argal lake, with the Antron Stream experiencing worse water quality consistently than the Argal Stream. For both sites, concentrations are consistently above the orange lines representing SWW's limit of 2 mg L^{-1} for Total Oxidised Nitrogen, and the Water Framework Directive good status limit of 0.017 mg L^{-1} for Total Phosphorus in the reservoir, both used as a target for quantifying impacts of the project.

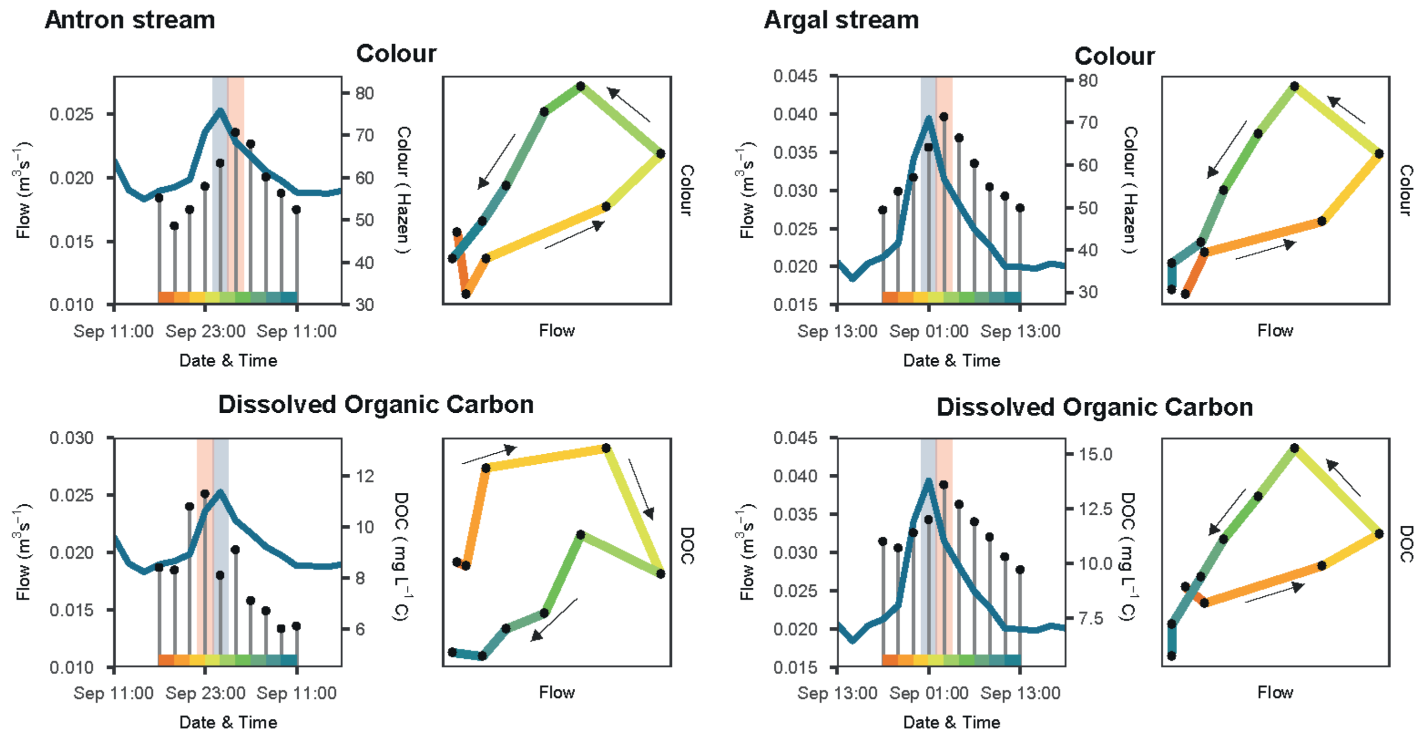
Figure 4 Total Oxidised Nitrogen (mg-N), ammonium (mg-N) and Soluble Reactive Phosphorus (mg-P) loads measured by the project in the two feeder streams to Argal lake between 2016-2017 and 2018-2019: despite lower streamflow, nutrients loadings at the Antron Stream are significantly higher for all nutrients due to particularly high concentrations.



Water quality and diffuse pollution during rainfall events

In addition, the hysteresis behaviour of DOC and colour between sites during rainfall events gives interesting information on the origin of pollution during storms within the catchment. In the Argal Stream, the maximum concentration (highlighted in red) of both DOC and colour occurs soon after the maximum stream flow (highlighted in blue) (Figure 5A), which is materialised by two similar anticlockwise hysteresis loops. However, in the Antron Stream, the peak of DOC is desynchronised and occurs earlier than that of colour, as shown by a clockwise loop (Figure 5B). It is likely that DOC peaks earlier because it originates from a different and closer source than colour, for example fields or farmyard hard standings close to the reservoir. However, in the Argal Stream, it is likely that the source of both DOC and colour is the same and further away from the reservoir. This is useful information to investigate pollution sources within catchments, as it allows the project partners to target the most problematic areas.

Figure 5 Relationship between flow ($m^3 s^{-1}$) and water quality parameters (i.e. Dissolved Organic Carbon (DOC) and colour in mg L^{-1}) for both Argal feeder streams for one storm event, with associated hysteresis loop: the events considered show an anticlockwise loop for colour and a clockwise loop for DOC at the Antron stream, whereas both hysteresis loops are anticlockwise for the Argal stream, highlighting a difference of behaviour for DOC losses between the two streams.



Blue-green algae and nutrient content in the reservoir

Blue-green algal blooms are a major problem for Argal reservoir (Figure 6). The study of algae content is coupled with that of nutrients in the reservoir (Figure 7) as these are a major driver for eutrophication. Overall, data from Argal reservoir shows that this reservoir experiences some of the worst blooms across the region (see Figure 4 p23), with concentrations going up to 1,500,000 cells mL^{-1}. Overall, all parameters show a seasonal pattern, although these do not always coincide with algal blooms. TON concentrations in the reservoir reach their maximum around April and exceed the 2 mg L^{-1} target set by SWW as evidence of successful impact of in-catchment measures for part of the year, making spring the most at-risk period for the treatment of water. Overall, most TP samples collected since 2014 show concentrations higher than the WFD good status targets for total phosphorus. Phosphorus tends to peak in autumn (i.e. October) (Figure 7, middle), although this seasonal trend is less clear. As blue-green algal blooms generally occur in summer/autumn (Figure 7 bottom and Figure 8), blooms are concomitant with P concentrations but not N. In-catchment efforts to limit nutrient input to the reservoir should therefore focus on the reduction of P to reduce blue-green algal blooms, and the significant costs and risks to health that they pose.

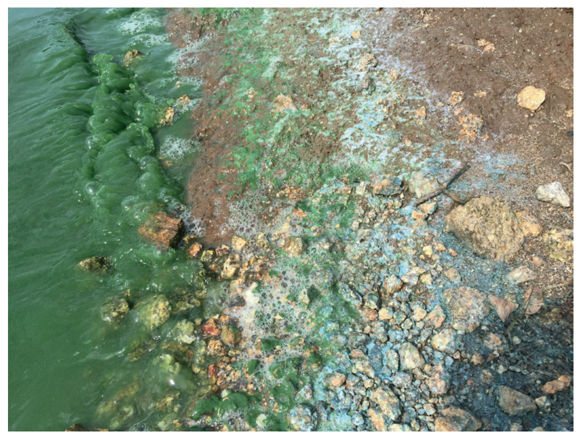


Figure 6 Detail of blue-green algal bloom in Argal reservoir, with marks left on the shore (photo by Emilie Grand-Clement).

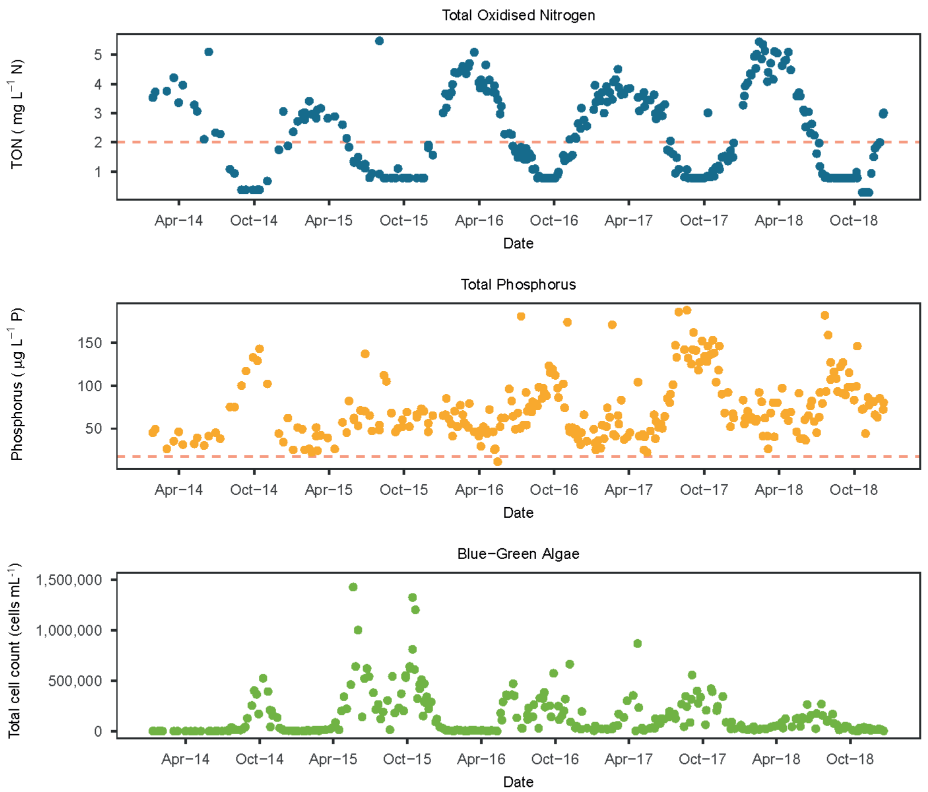


Figure 7 Total Oxidised Nitrogen (TON-N, top), Total Phosphorus PO4-P, (middle) and blue-green algae cell count (bottom) between 2014 and 2018 in raw water at Argal WTW; red lines indicate the target limits for each nutrient concentrations in the reservoir.

Figure 8 highlights not only the high cell counts of cyanobacteria (i.e. blue-green algae) that can be experienced in Argal Lake during algal blooms (e.g. peaks of monthly mean cell count of ca 800,000 cells mL^{-1} in 2015), but it also shows the overwhelming proportion that blue-green algae make amongst the total algal and diatoms species. This is particularly problematic for the treatment of water, but also for the risk posed by the production of toxins and taste and odour compounds by cyanobacteria. The problems experienced at Argal Lake are particularly challenging and indeed costly for SWW and drinking water production. These results show the need to use catchment management to decrease nutrient input, but also to consider in-reservoir dynamics to understand and predict future blooms, and thus when water is very costly to treat.

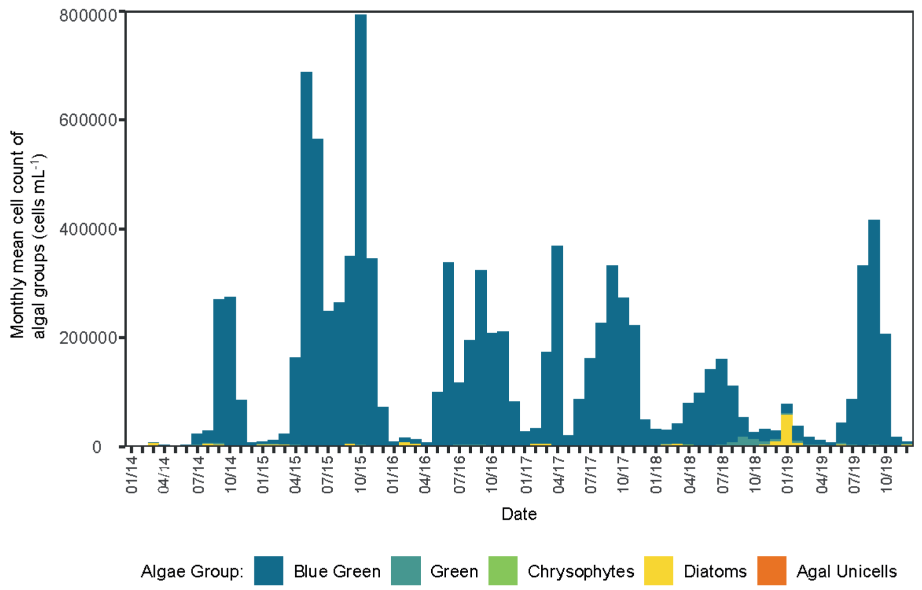


Figure 8 Monthly mean cell count of algae per group species between 2014 and 2018 Argal reservoir.

The Argal stream (photo by Emilie Grand-Clement).

In-situ monitoring equipment by UoE within the Argal catchment (photo by Emilie Grand-Clement).

Pesticides detections within the reservoirs

Another water quality issue in the catchment is pesticides. In particular, metaldehyde was highlighted by the EA as a pesticide of specific concern. This compound is particularly difficult to remove from raw water. These concerns are confirmed by the results from the passive sampling deployment campaigns (Figure 9). Measurements show that metaldehyde was detected in all locations (i.e. both feeder streams and at the WTW) during each spring and autumn deployment periods. More precisely, detections in the streams feeding the reservoirs show an input of metaldehyde at the time of deployment in the catchment whilst measurements at the WTW (i.e. in reservoir water) show the persistence of the compounds in the water body. This explains the higher concentrations being measured at WTW compared to input to the reservoir, which is a serious problem and costly for water treatment.

The maximum concentrations detected in the passive samplers are generally low (i.e. below 35 ng L^{-1}), and well below the regulatory 100 ng L^{-1} limit per compound. However, these are averaged over a period of time, and are therefore likely to hide short-lived spikes that might have occurred during each deployment period, as the pesticides were washed off the farmland that they had been applied to.

Finally, a consistent decrease in concentrations between autumn deployments can be observed across all sites and monitoring years, including at the reservoir. This is a very positive result as it shows the potential for changes in the practical application of pesticides to improve water quality. However, variability in the general period of metaldehyde application (i.e. start and end of usage) and that of monitoring periods might also have prevented the detection of the compound in these locations. More work is clearly needed to reduce the input of pesticides from agriculture in such catchments.

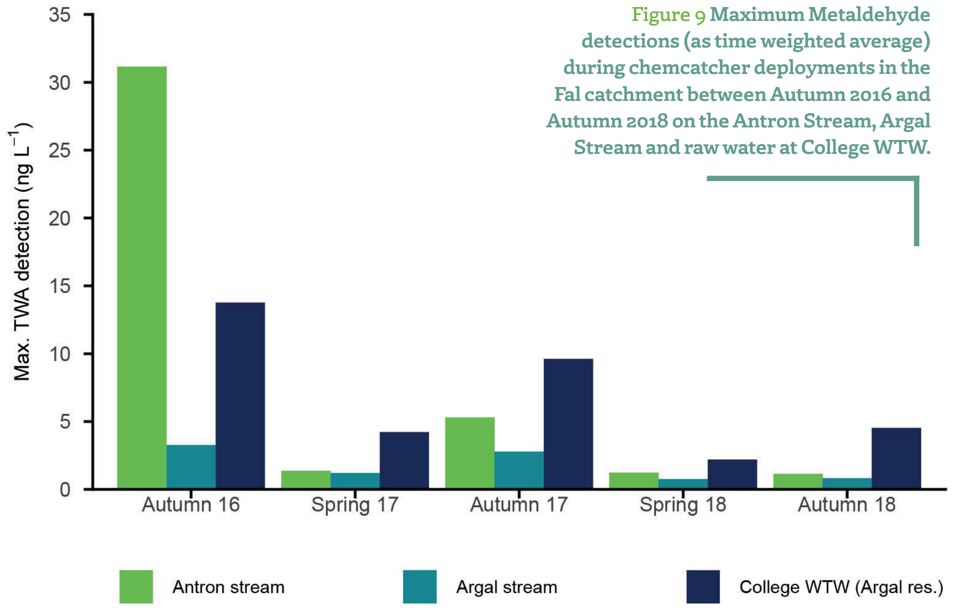


Figure 9 Maximum Metaldehyde detections (as time weighted average) during chemcatcher deployments in the Fal catchment between Autumn 2016 and Autumn 2018 on the Antron Stream, Argal Stream and raw water at College WTW.

Argal reservoir (photos by Emilie Grand-Clement)

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