UPSTREAM THINKING IN ACTION: UPPER TAMAR LAKE

- Upper Tamar Lake has been identified as "at-risk" for pesticides (in particular MPCA, mecoprop and metaldehyde) and blue-green algae caused by excess nutrients;
- Water quality investigations showed a decrease in turbidity in the feeder stream to the reservoir at high flow between 2016-2017 and 2018-2019; however, this reduction is not yet detectable in the overall turbidity of the raw water at the WTW;
- Two different rainfall event dynamics have affected the delivery of Soluble Reactive Phosphorus to the feeder stream, indicating the contribution of either a deep zone within the soil, or from a more distant, agricultural source further up catchment. This information is important to tackle sources of diffuse pollution;
- Algal blooms are not concomitant with nutrient input to the reservoir, and are therefore likely to be driven, to some extent, by climate combined with existing nutrient loads in reservoir;
- A number of high pesticide detections were observed in the catchment and reservoir (e.g. 2,4D, Fluroxypyr and Trichlopyr; the number of detections ranged between 6 and 18 per deployment period).

About the catchment

Background site information

The Tamar catchment is located along the boundary of Devon and Cornwall. The catchment drains an area of about 1,800 km^2. Upper Tamar Lake is a reservoir catchment located the north of the Tamar catchment (Figure 1). The area is predominantly rural. To the south are the Tamar estuary and the city of Plymouth where the majority of the population is based.

Catchment Challenges

Upper Tamar Lake at risk for pesticides (in particular MCPA and mecoprop), metaldehyde and blue-green algal blooms caused by excess nutrients.

Figure 1 Upper Tamar Lake; photo by Emilie Grand-Clement.

Catchment activities

Through Upstream Thinking, project partners have targeted the most polluting areas of the catchments and have focussed around activities such as farm track management, fencing off rivers and establishing buffer strips. As of May 2019, 77% of the Upper Tamar area has been engaged in Upstream Thinking by both **Westcountry Rivers Trust** (WRT) and **Devon Wildlife Trust** (DWT) (Figure 2).

Physical interventions completed via Upstream Thinking, which were quantifiable within the Farmscoper software, amounted to a cumulative area of almost 6,000 ha. The most commonly used interventions are shown in Figure 3. In addition, ca. 4 ha of culm, or species rich grassland, were restored in the catchment by DWT.

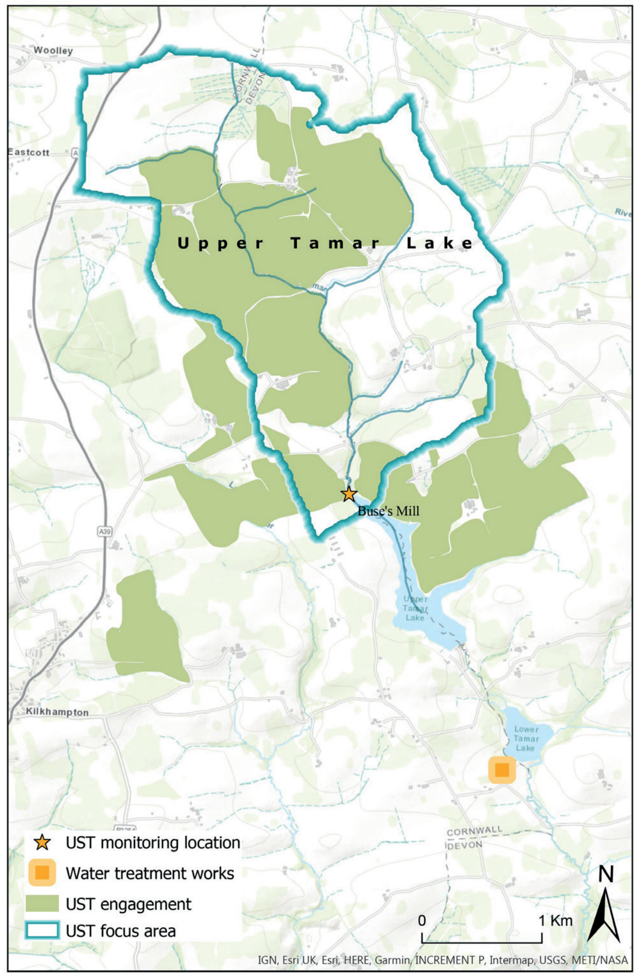


Figure 2 Map of engagement by WRT and DWT as part of UsT in the Upper Tamar Lake catchment.

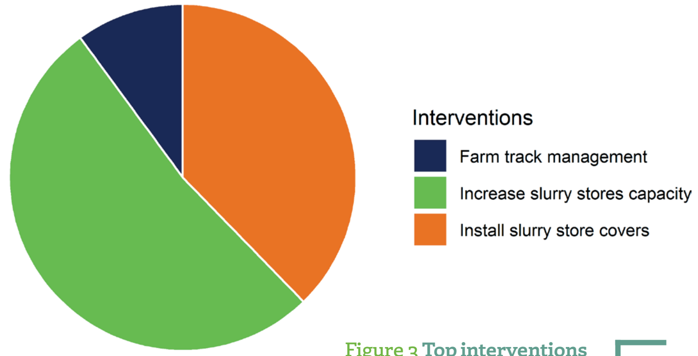
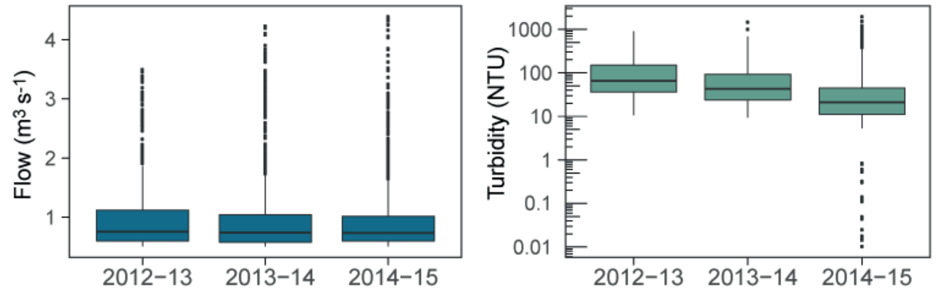


Figure 3 Top interventions (quantified in Farmscoper) used in the Upper Tamar Lake catchment.

Figure 4 High flow (Q5 and above) measured per hydrological year (left) and corresponding turbidity (NTU) measurements in feeder stream to Upper Tamar Lake plotted on a log scale.



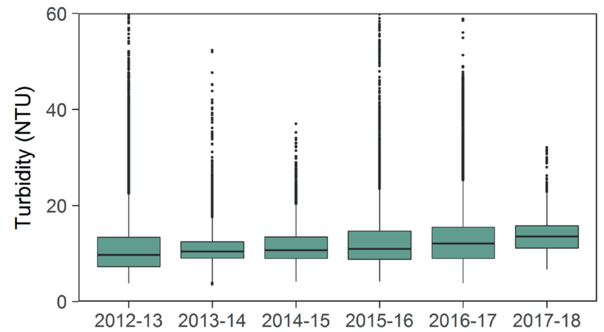
Water quality at Upper Tamar Lake

Turbidity in feeder streams

Continuous measurements of turbidity in the feeder stream to Upper Tamar Lake (Figure 4) performed by the University of Exeter indicate a slight decrease in the turbidity or suspended sediment inputs to the lake at high flow (i.e. Q5 flows and above, with stream flow remaining unchanged between hydrological years) between 2016-2017 and 2018-2019. However, this positive, recent change is not yet detectable in the overall turbidity of the raw water at the Water Treatment Works (WTW), with no significant change being observed in concentrations between the hydrological years of 2012-2013 and 2017-2018 (Figure 5).

These results therefore highlight some positive change in turbidity at a small scale that contributes to the lack of deterioration in the reservoir and, over time, will hopefully lead to a reduction in sediment content in the reservoir.

Figure 5 Overall changes in turbidity between 2012-2013 and 2017-2018 for all flow records at Tamar Lake WTW.



UPSTREAM THINKING IN ACTION: UPPER TAMAR LAKE

Continuous sensors (left) placed in the feeder stream (right) to Upper Tamar Lake; photo by Paul Henderson.

Water quality and diffuse pollution during rainfall events

Samples were also collected in the feeder stream to the lake (Figure 6) during rainfall events and analysed for nutrient inputs to the reservoir. Soluble Reactive Phosphorus (SRP) measurements during two distinct rainfall events in the feeder stream show the occurrence of two clear patterns at different times. In one case, a peak of SRP occurs just before peak flow (Figure 6, top), which results in a clockwise hysteresis loop. During another event (Figure 6, bottom), the SRP response is delayed and occurs after the peak in stream flow, leading to an anticlockwise hysteresis loop. It has been shown that these differences indicate two different rainfall event dynamics, caused by a difference in the delivery of SRP to the stream. In the case of an anticlockwise loop, the SRP source might originate from another, more distant, source or from the contribution of a deeper zone within the soil compared to the clockwise loop. Such changes in behaviour in nutrient delivery is most likely to be driven by differences in rainfall event characteristics, i.e. rain intensity, duration and antecedent conditions.

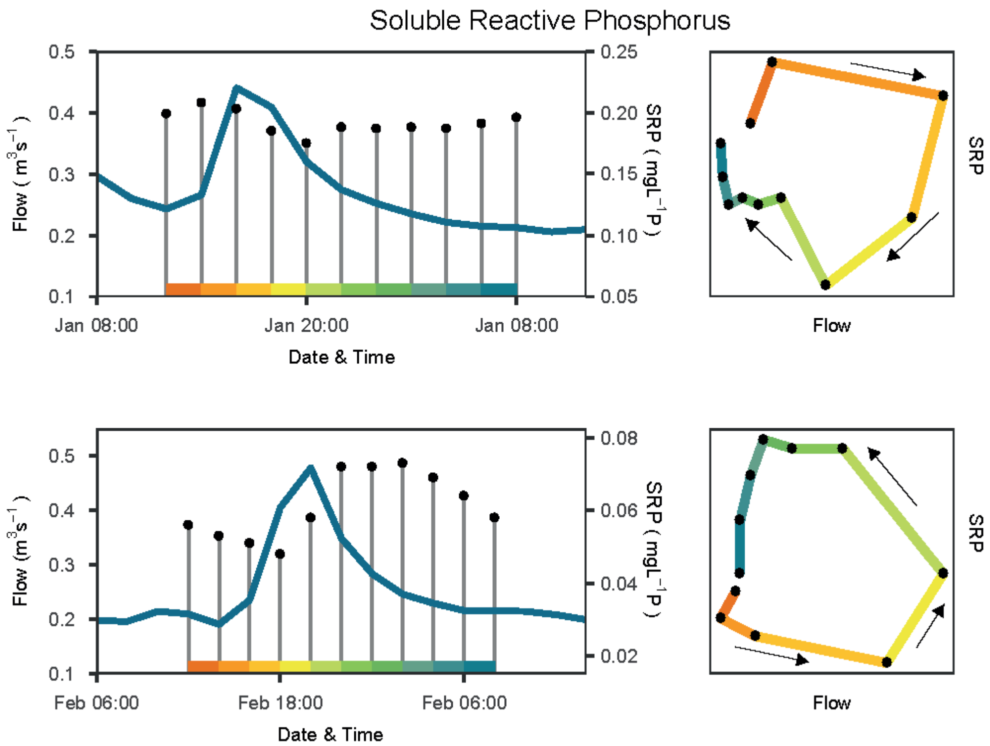


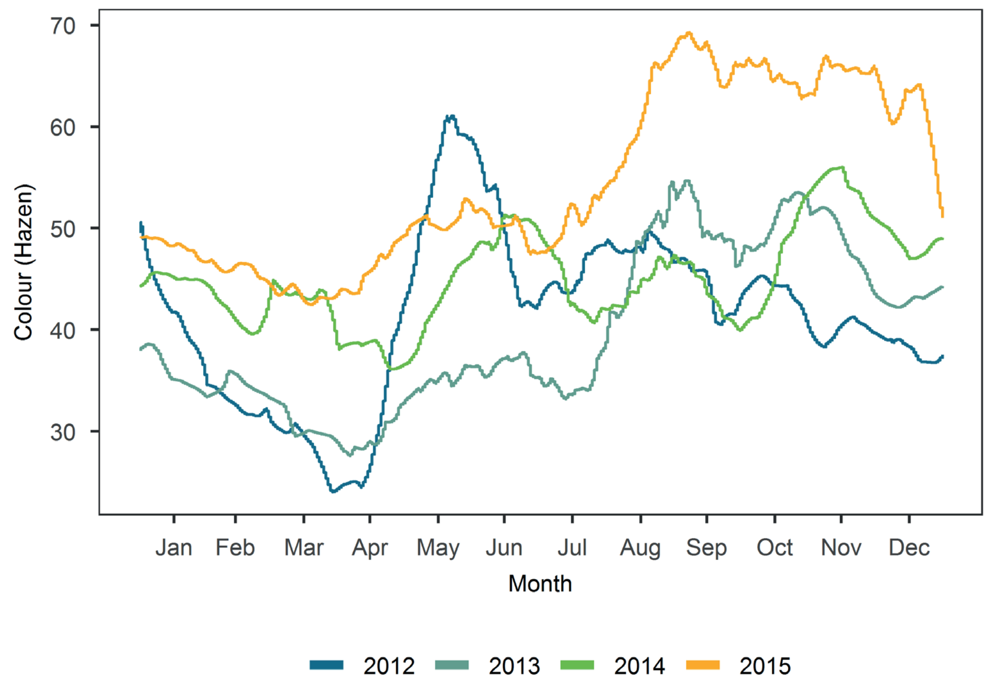
Figure 6 Relationship between flow ($m^3 s^{-1}$) and Soluble Reactive Phosphorus ($mg L^{-1}$) during different rainfall events, with associated hysteresis loop.

Seasonality in the reservoir

Using the continuous data collected by SWW at the WTW can give some information on the seasonal variation and inter-annual variability. In particular, daily colour variations plotted throughout the year for 2012 to 2015 (Figure 7) show an interesting pattern: the general occurrence of two peaks of colour a year, the first one in late spring / early summer (e.g. May – June), and the second one, sometimes more sustained, in late summer (i.e. starting in August – September).

There are marked inter-annual differences highlighting the importance of climatic and general environmental factors on water quality, and on colour especially. For instance, 2012 is now considered one of the wettest on record. The impact of such unusual conditions, marked by high rainfall from April to June can be seen by a peak in colour at ca. 60 Hazen. This is due to high rainfall washing contaminants from farmland down the catchment and into the reservoir.

Figure 7 Daily colour variations throughout the year between 2012 and 2015 at Upper Tamar Lake raw water.



Upper Tamar Lake; photo by Emilie Grand-Clement.

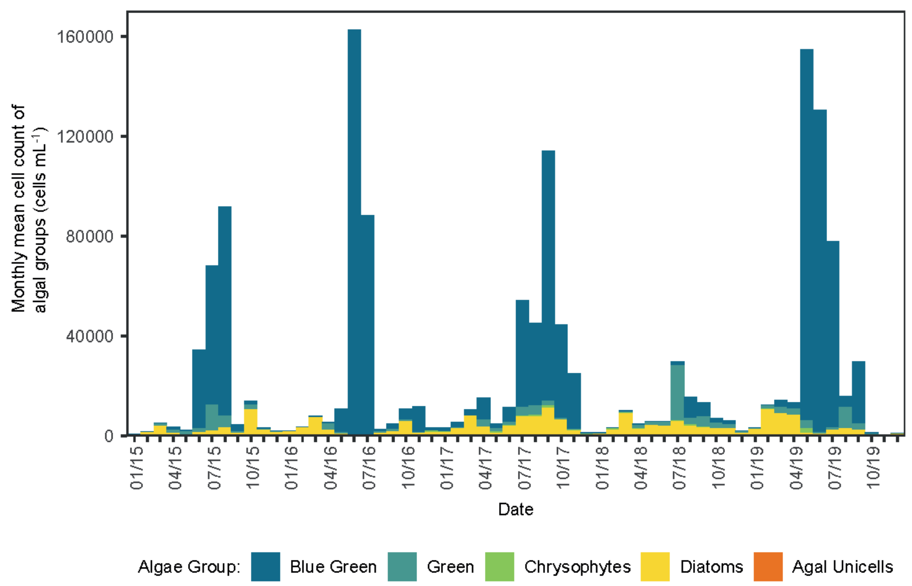


Figure 8 Monthly averages of total algal blooms cell count (cells mL⁻¹) and corresponding abundance of species between 2014 and 2019 at Tamar Lake.

Blue-green algae content in the reservoir

The monthly mean algal counts (Figure 8) as well as measured values across the timeseries (Figure 9) show the occurrence of several algal blooms at Upper Tamar Lake occurring generally in the summer (i.e. June-July). Although a number of outliers were recorded in the dataset (e.g. 300,000 to 500,000 cells mL⁻¹), the peaks in concentrations during blooms tend to be lower, generally reaching up to 200,000 cells mL⁻¹. In later years, algal blooms were also observed to extend into the autumn (i.e. 2017, 2018 and 2019). These blooms are overwhelmingly composed of the toxic blue-green algae species (Figure 9), although diatoms can make a significant part of the total group and are consistently present.

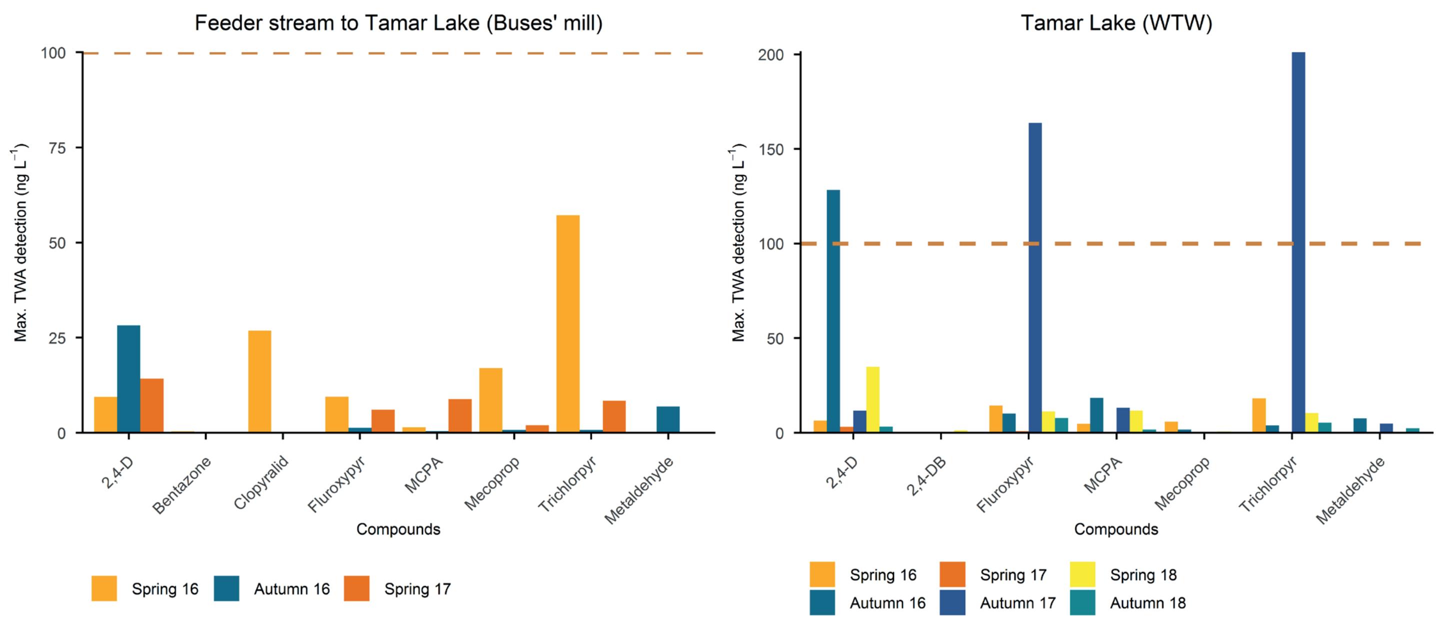
The occurrence of these blooms are often linked to certain environmental characteristics driving algal growth, such as higher temperatures or dry conditions. However, they do not match seasonal peaks in nutrients (Figure 9), as was observed in other locations (see Figure 7 p40): peaks in Total Oxidised Nitrogen (TON) occur in winter, and the seasonal trend in Total Phosphorus (TP) is not clear. It is therefore likely that seasonal variations in algal blooms are largely driven by climate, and the generally high content of nutrient already present in the reservoir. This is a long-term problem that needs to be investigated further by looking at both the nutrient inputs and the overall content already present in the reservoir.

Figure 9 Total Oxidised Nitrogen (top), Total Phosphorus (middle) and blue-green algae cell count (bottom) between 2014 and 2019 in Tamar Lake reservoir; red lines indicate the exceedance limit for each nutrient concentrations.

Pesticide detections within the catchment

Pesticide detections in both feeder stream and reservoir show a high number of compounds being used consistently on intensive farmland in the catchment, with 2,4D, Fluroxypyr and Trichlopyr being detected above the 100 ng L⁻¹ in the lake in autumn deployment (Figure 10). MCPA and Mecoprop are also an issue, but to a lesser extent. The autumns of 2016 and 2017 seem to be the most affected times. Overall, the total number of detections (including all chemicals throughout the 6 week period) ranges between 6 and 18 per deployment period. Although there is no obvious decrease during Upstream Thinking, this data helps project partners to understand pesticide sources (i.e. arable farmland), pattern and address its future use in the catchment.

Figure 10 Maximum concentrations (measured as time weighted average) and compounds detected in feeder stream (left) and in Upper Tamar Lake (right) per deployment period, with the red dotted line indicating the 100 ng L⁻¹ regulatory limit per pesticide; note the difference in the scales between the plots.



Fencing off ditches at Upper Tamar Lake; photo by Emilie Grand-Clement.

REFERENCES

1. Bieroza, M.Z., and Heathwaite, A.L. (2015). Seasonal variation in phosphorus concentration–discharge hysteresis inferred from high-frequency *in-situ* monitoring. *Journal of Hydrology, 524, 333-347.*