UPSTREAM THINKING IN ACTION: THE RIVER EXE

- The whole of the Exe catchment is at risk for pesticides (i.e. MCPA, Mecoprop, Chlorotoluron, Triclopyr)
- Turbidity in the River Exe is driven by rainfall events and increased river flow; high turbidity events occur more frequently in winter, reducing across the study period in line with the overall reductions in flow observed.
- Although no pesticide detection reached the regulatory limit of 100 ng L^{-1} in treated water, the number of detections at both SWW drinking water treatment works was high; consistently high and numerous detections in the River Batherm, the River Burn and the River Lowman make them hotspots for pesticides.
- All compounds of concern for the EA are still detected in the catchment apart from Chlorotoluron, highlighting the need for continued work on the pesticide amnesty.

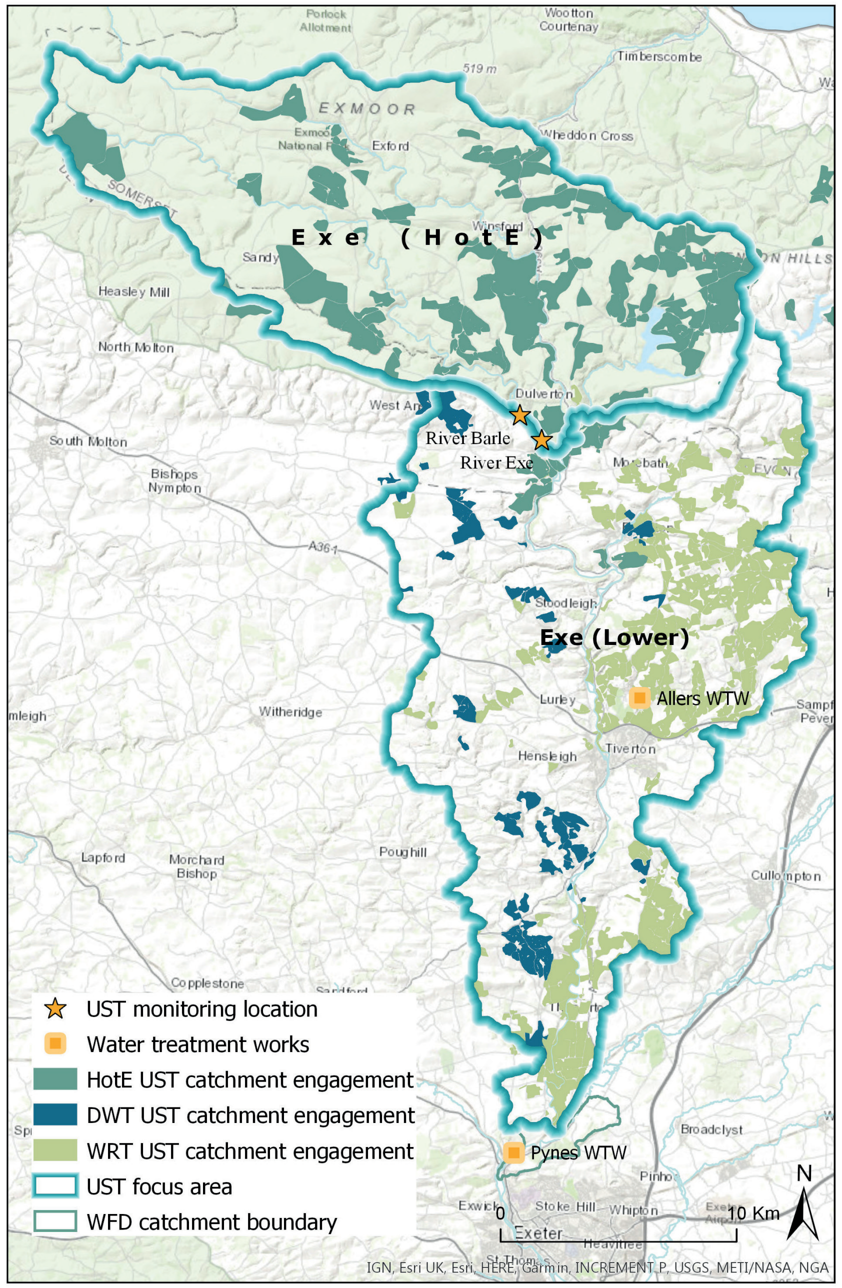

Figure 1 Map of engagement in the Exe by ENPA (through the HotE project), DWT and WRT as part of Upstream Thinking, also showing UoE monitoring locations and water treatment works.

About the catchment

Background site information

The Exe catchment (Figure 1) is within the Wimbleball Strategic Supply Area. The Upper part of the catchment, from the source of the river in the north to Brushford, lies within Exmoor National Park and falls within the **Headwaters of the Exe** (HotE) catchment programme. The catchment covers an area of 27,559 hectares and includes the Rivers Barle, Quarme, Pulham and Haddeo, as well as other smaller tributaries. The area is included in the Devon East Management Catchment and the Exe Main Operational Catchment. The HotE catchment area includes farmland, moorland and some forestry plantations and other woodlands areas. The main land uses in the catchment are upland farming, forestry and game shoots. Recreation and access are also very important in this catchment. Catchment management work for the HotE project was led by Exmoor National Park, with the interventions delivered by **FWAG-SW**.

Further south, Allers and Pynes abstractions and water treatment works provide drinking water for mid-Devon and Exeter, supplying a population of large towns, including Tiverton and Exeter. In both 2015 and 2019, most water bodies in the catchment fell in the Moderate and Good classes of the WFD for their ecological status. For the chemical status, however, there has been a dramatic degradation in the time frame: all water bodies had the "good" chemical status in 2015 but all failed in 2019. The EA states that agriculture and land management is the main reason for this deterioration. Catchment management in the lower part of the Exe was delivered by **Devon Wildlife Trust** (DWT) and **Westcountry Rivers Trust** (WRT)

Catchment Challenges

For the period 2015-2020, the whole of the catchment is at risk for pesticides – particularly MCPA, Mecoprop, Chlorotoluron, Triclopyr, used as a broadleaf weed killer, and metaldehyde (used in slug pellets).

Catchment Activities

Interventions in the HotE project have focused on mitigating sediment loss and reducing pesticides. As of May 2019, almost 30% of the HotE catchment had been engaged in UsT2 with physical activities including establishment of new hedges, farm track management and other works to provide alternative livestock drinking and protect watercourses. Physical interventions completed via UsT, which were quantifiable within the Farmscoper software, amounted to a cumulative total of over 3,500 ha. The most commonly used interventions are shown in Figure 2.

In the lower part of the catchment, activities during UsT2 have focussed on providing advice and guidance to farmers to improve management for pesticides, water quality and water resource issues, and biodiversity. As of May 2019, almost 30% of the Lower Exe had been engaged in UsT2 with physical activities including fencing off rivers from livestock, establishing buffer strips, management of dirty water, farm track management and constructing troughs with concrete bases. Physical interventions completed via UsT, which were quantifiable within the Farmscoper software, amounted to a cumulative area of over 700 ha. The majority of interventions included the building of troughs with a concrete base, which is likely to help reduce sediment loading of waters as well as nutrient loadings. Other commonly used interventions included dirty water and farm track management, in-field grass buffer strips and riverside fencing.

The predicted impact of interventions in the overall Exe catchment on DOC and nitrate is presented (Figure 5 p32).

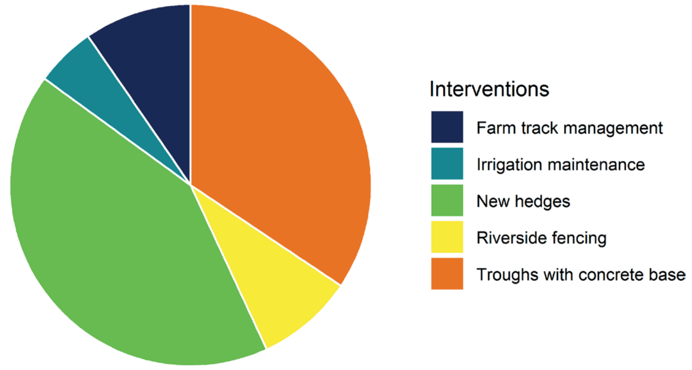

Figure 2 Top 5 interventions (quantified in Farmscoper) used in the Headwaters of the Exe catchment.

The two main rivers in the Exe catchment: The River Barle at Dulverton (top) and the River Exe at Brushford (bottom).

Water quality in the Lower Exe catchment

An understanding of the levels and behaviour of key contaminants in the lower River Exe was built up from spot samples and high-frequency signals at the SWW water treatment works. A summary of the high frequency data for the river water is shown in Table 1. Across all the data collected for this site, the values for the highest colour peaks (occurring alongside peaks in rainfall events) are unavailable, either due to the timings of manual samples or due to the sensor limits for the high frequency data.

Across the study period, the values for the different contaminants generally follow the behaviour seen across the river sites (for more information about these overall patterns see Figure 2 p22.

Parameter	Data completeness*	Min	Max	Mean	Median
Colour (Hazen)	82.5%	0	99.96	10.47	9.19
Conductivity (µS cm^{-1})	91.9%	56.6	366.1	173.12	168.8
Dissolved Oxygen (%)	91.6%	53.08	143.84	94.92	94.92
pH	92.3%	6.002	9.37	7.56	7.52
Turbidity (NTU)	91.5%	0	492.65	9.12	4.45

* Percentage of record with data (after quality control)

Table 1 River water (Northbridge intake) summary statistics for water quality signals covering the period October 2012 to October 2018.

Seasonal change in water quality

Figure 3 shows the seasonal variation in the signal recorded in the river. Colour values were typically at their lowest in the late winter and spring and highest in late summer. Turbidity values were highest during the wetter hydrological winter, with the exception of the dry winter of 2016 to 2017.

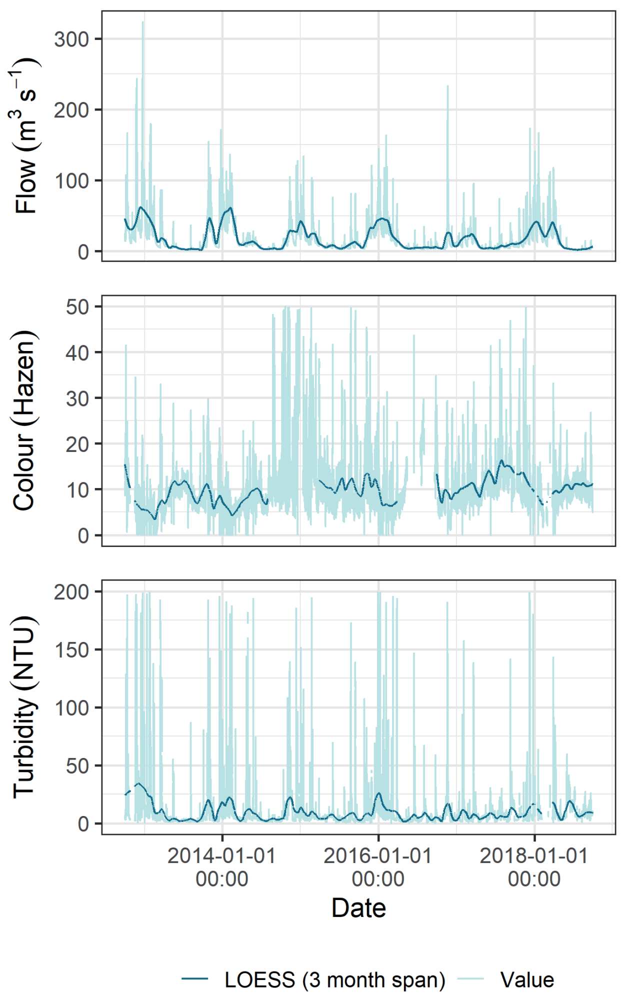

Figure 3 Smoothed and recorded values show annual variation and seasonal cycles for flow, colour and turbidity across the study period. Some of the underlying high-frequency recorded values of colour and turbidity are limited for display purposes.

Field runoff on the road in the Lower Exe (photo by DWT).

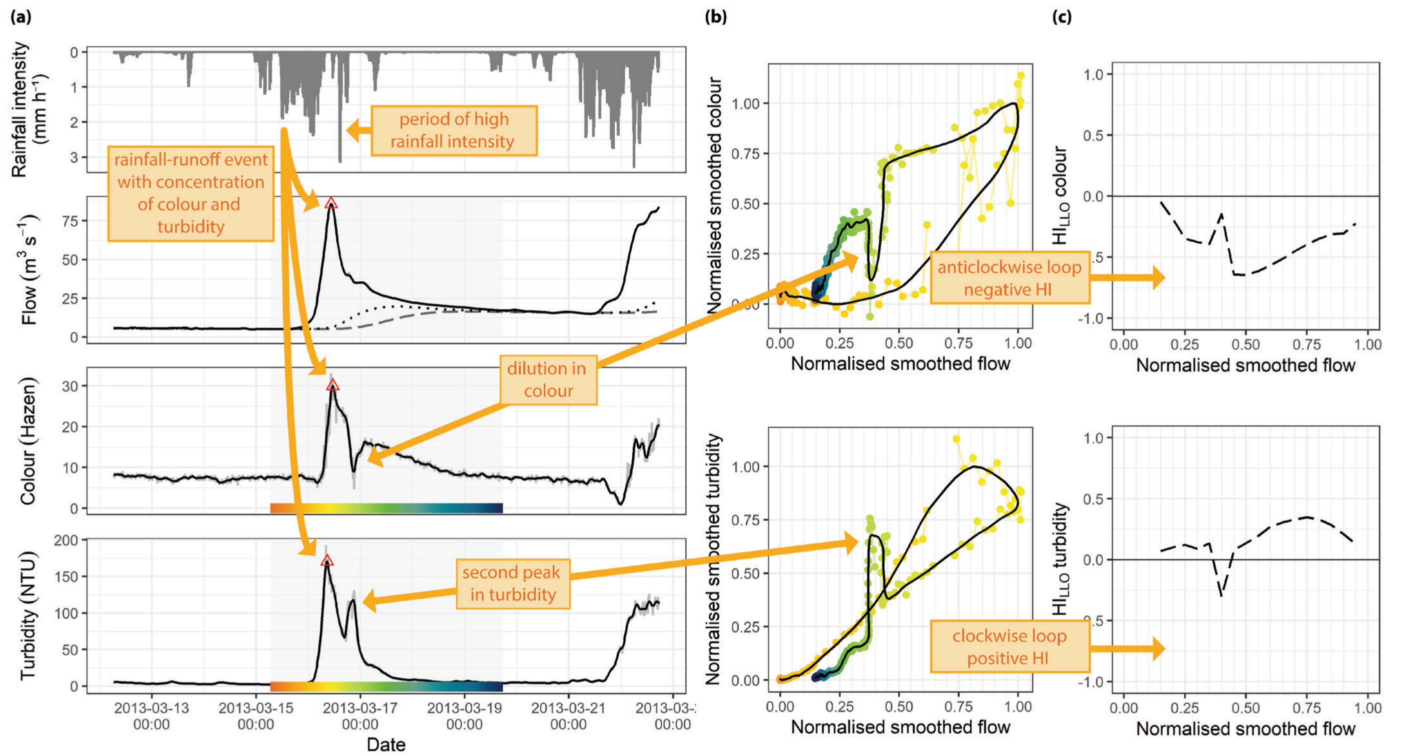

Figure 4 Example of a rainfall event in late winter for the Lower Exe showing (a) time series, (b) hysteresis loops, and (c) the Hysteresis Index calculated across the range of flow conditions for the event.

Water quality during rainfall events

The seasonal patterns for colour and turbidity are influenced by the concentration and dilution effects of the rainfall in the catchment, and the flow conditions in the river. These event scale patterns are related to both contaminant sources and to how they are transported within the catchment.

On the shorter event time scale, the Lower Exe colour displays complex behaviour. Rainfall events are associated with both dilution and concentration, and either behaviour, or both, may be seen during a single flow event. This variability reflects the size of the catchment and the changing dominance of processes affecting overall concentrations in the river. However, even where there are initial dilution effects, generally the highest values for colour still occur after the flow peaks with hysteresis loops formed in an anticlockwise direction. This suggests more distant sources for colour, perhaps from degraded peat in the moorland headwaters of the catchment, or slower pathways for colour enriched waters. Where events show continued concentration effects at the end of the quick flow recession and into the base flow recession, this can also indicate the difference in the transport for colour (throughflow and base flow).

The behaviour of turbidity is more consistent, with all rainfall events analysed showing a concentration effect. For the majority of events analysed the peaks in turbidity occur while the flow in the river is still rising. This 'first-flush' effect is typical for turbidity, and can indicate rapid mobilisation (erosion and transport of sediment) at the start of a rainfall event. The occurrence of the turbidity peak before the flow peak also indicates close proximity to the source (relative to catchment size). However, as there are no notable dilution effects on the falling limb of the events and events often display anticlockwise hysteresis loops, the catchment is not considered to display 'sediment exhaustion'. The continued higher level of turbidity throughout the event, gradually reducing with reduced flows, may represent the transport of sediment from more distant sources[2].

An example of these different behaviours is shown in Figure 5. During this rainfall event there is an initial concentration of colour peaking 45 minutes after the peak in flow. This is then followed by dilution during a period with increased rainfall intensity, but only a small change in flow. There is then a return to higher colour values, gradually decreasing during the remainder of the flow recession. Turbidity also shows elevated concentrations during the rainfall event. However, in contrast, it peaks over an hour before the flow peak, and the increased period of rainfall intensity triggers a sudden increase in turbidity and a second sharp peak. This second peak indicates the occurrence of rapid erosion (such as a bank collapse) or increased transport from nearby sources due to a sudden increase of surface-runoff in a saturated catchment. The behaviour described can also be clearly seen in the hysteresis loops for the event (Figure 4b), and in the Hysteresis Index (HI) values calculated for the event (Figure 4c) with colour response lagging being flow (anticlockwise loop and negative HI), and the turbidity increase occurring more rapidly, but more in-sync with the changes in flow (clockwise loop and overall positive but low HI).

Peaks in turbidity in the River Exe

The annual pattern in the number of turbidity peaks reflects the annual change in peaks of flow. Generally summer peaks in turbidity have a lower magnitude than winter peaks (Figure 5). The overall number of turbidity peaks with a magnitude over the long-term median rose between 2012 and 2018, however there was a fall in the number of peaks in the highest magnitude category (peaks in the top 5% of all turbidity records). Generally, the number of peaks in winter fell, and the reduction in the number of very high magnitude turbidity peaks is pronounced in the early winter months. The number of peaks over the long-term median in summer increased, yet there was no notable increase in very high turbidity peaks during this period.

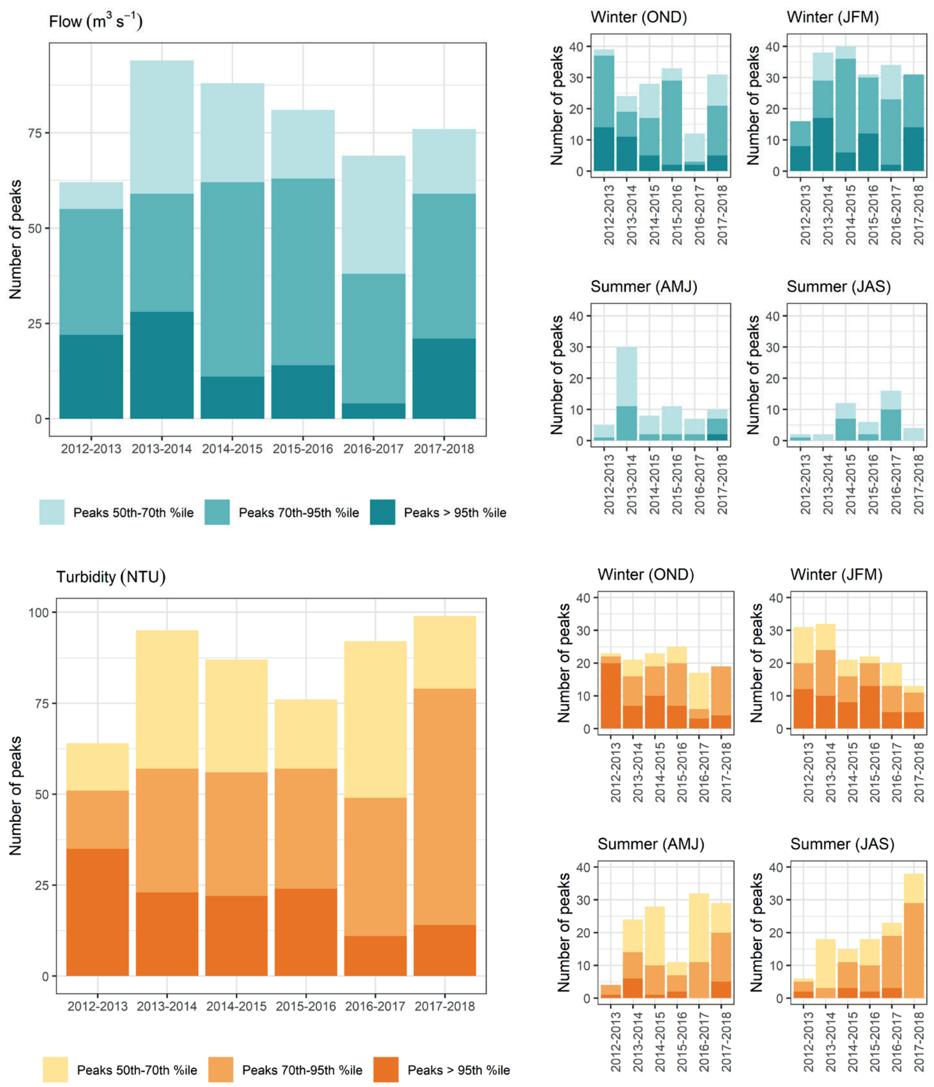

Figure 5 Number of peaks (local maxima) for flow and turbidity exceeding the overall median value; data are presented across the hydrological year (left), and in each of the seasons separately (right).

Grazing in the Exe catchment; photo by Ross Cherrington (WRT).

REFERENCES

1. Lawler, D.M., Petts, G.E., Foster, I.D.L., and Harper, S. (2006). Turbidity dynamics during spring storm events in an urban headwater river system: the Upper Tame, West Midlands, UK. *Science of the Total Environment*, 360 (1–3), 109–26.
2. Vale, S.S., and Dymond, J.R. (2020). Interpreting nested storm event suspended sediment-discharge hysteresis relationships at large catchment scales. *Hydrological Processes*, 34 (2), 420–440.

		Spring 16	Autumn 16	Spring 17	Autumn 17	Spring 18	Autumn 18
Total number of detections	Allers WTW	10	11	16	8	16	14
	Pynes WTW	19	20	21	14	19	19
Nb single exceedances >100 ng L^{-1}	Allers WTW	0	0	0	0	0	0
	Pynes WTW	0	0	0	0	0	0
Max value (ng L^{-1})	Allers WTW	15	5	9	6	23	3
	Pynes WTW	25	13	15	6	12	6
Total number of compounds	Allers WTW	5	6	6	4	6	6
	Pynes WTW	7	8	9	6	7	7

Table 2 Total number of detections, exceedances above 100 ng L^{-1}, maximum concentrations detected and total number of compounds detected in the River Exe at SWW assets between spring 2016 and autumn 18. The blue shading indicates a severity scale separately applied to each parameter, from light blue (low) to dark blue (high).

Pesticide detections in the Lower Exe catchment

The results of passive sampling monitoring in the Lower Exe are presented in Table 2. Overall the total number of detections on either sites were consistently high throughout the monitoring period (i.e. varying between 8 and 21), with higher values measured further down the catchment, highlighting the contribution of streams located between monitoring locations. Similarly, a number of tributaries within the catchment are hotspots: the River Batherm, the River Burn and the River Lowman have experienced high number of detections (i.e. consistently between 16 and 21 per deployment) but also high detections that frequently go above the 100 ng L^{-1} mark (e.g. 309 ng L^{-1} for the River Batherm in Spring 2018). These high detections are not picked up further down the catchment, where the maximum concentrations (as a time weighted average) recorded reached 25 ng L^{-1} at Pynes WTW, and 23 ng L^{-1} at Allers.

The total number chemicals detected at Pynes WTW is significantly larger than that detected at Allers, with values of 12 and 8 respectively (Table 2). This reflects the nature of the catchment, and the importance of agriculture in the lower part of the catchment, whereas the upper part (i.e. above Allers WTW) is more pastoral. Amongst the compound of concern, only Chlorotoluron was not detected in the catchment; other compounds (i.e. MCPA, Mecoprop, Triclopyr) were present at each monitoring period. Metaldehyde was detected during autumn deployment, which coincides with its prime application period.

Overall, both maximum concentrations measured as time weighted average, and the number of compounds detected in each location indicates that pesticides remains a significant problem in the catchment. Such information is invaluable to justify continued efforts of pesticides amnesty in the catchment.

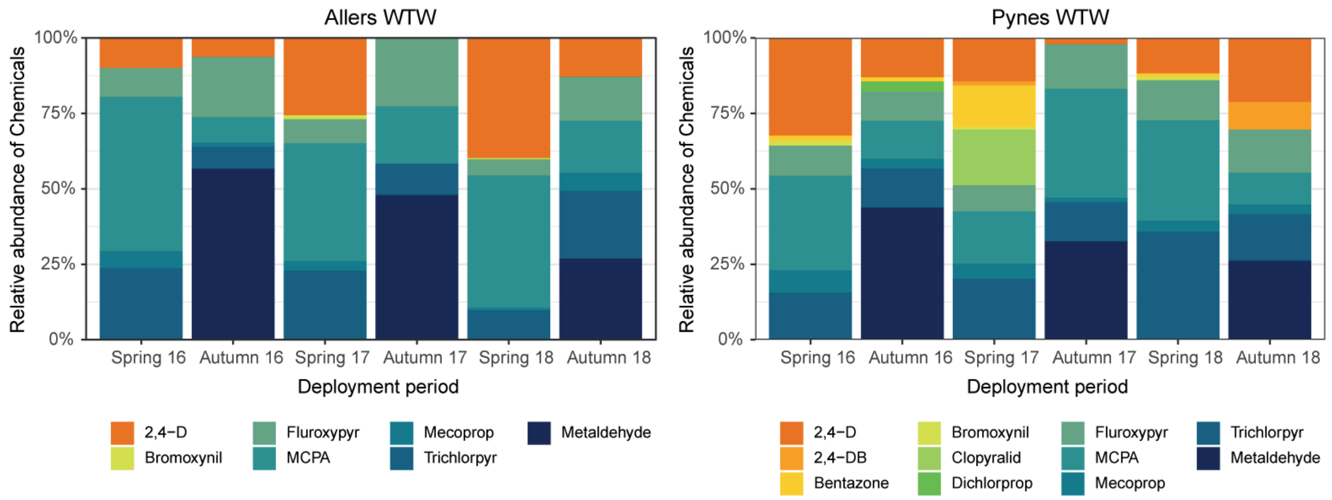

Figure 7 Relative abundance of compounds detected at Allers WTW (left) and Pynes WTW (right).