4. Water Quality

4.1 Background

The New Forest streams are typically base poor with low nutrient concentrations. Water chemistry varies according to the underlying geology, soils and land use. Waters are particularly acidic in the upper reaches of the catchments which can give rise to the reddy coloured water due to rapid oxidation of iron deposits in the water.

Suspended sediment concentrations during dry weather flows are typically between 5-25mg per litre rising to greater than 200mg per litre during spates (Langford 1996). Pollen and spores from plants form a significant proportion of this load.

Water quality throughout the New Forest is routinely monitored by the Environment Agency. The majority of river and streams are of good quality. Marginal and significant failures are at times due to problems at sewage treatment works, or seepage from septic tanks or urban runoff.

Water temperature is affected by air temperature, storm water runoff, groundwater inflows, turbidity, and exposure to sunlight. In considering the health of organisms, it is necessary to consider their maximum temperature and optimum temperature. The maximum temperature is the highest water temperature at which the organism will live for a few hours. The optimum temperature is the temperature at which it will thrive. Water temperatures are particularly important for fish survival and thermal refugia, such as pools can become important during times of drought. Trout are particularly sensitive to high temperature as shown in Figure 4.1.

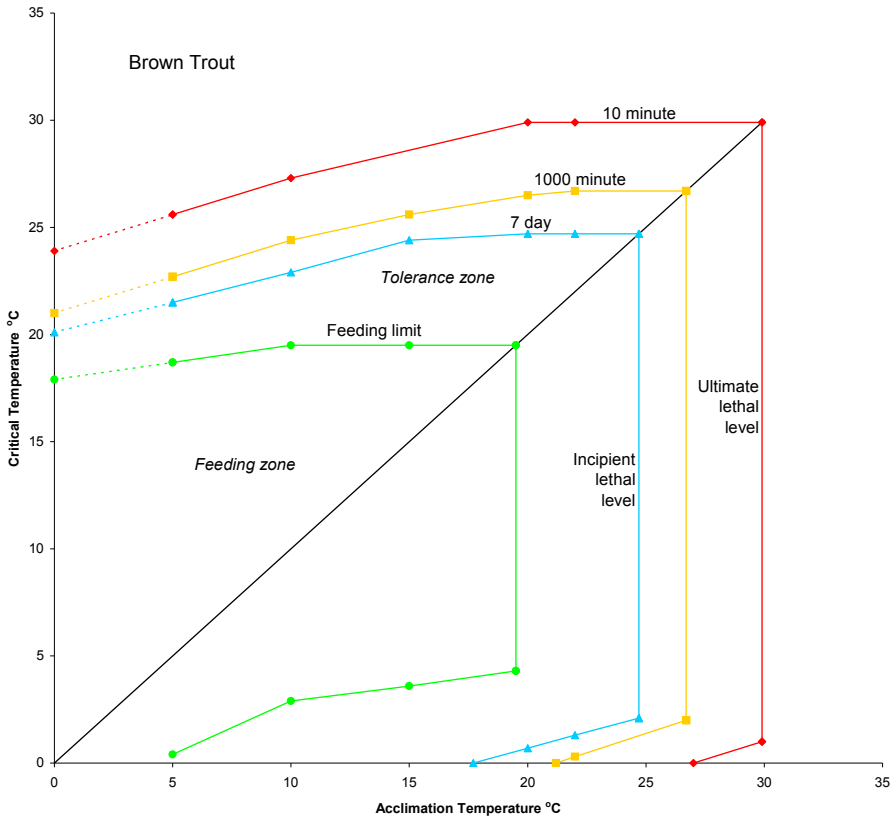
Levels of dissolved oxygen vary depending on factors including water temperature, time of day, season, depth, altitude, and rate of flow. Water at higher temperatures will have less dissolved oxygen. Dissolved oxygen reaches its peak during the day. At night, it decreases as photosynthesis has stopped while oxygen consuming processes such as respiration, oxidation, and respiration continue, until shortly before dawn. Human factors that affect dissolved oxygen in streams include addition of oxygen consuming organic wastes such as sewage, addition of nutrients, changing the flow of water, raising the water temperature, and the addition of chemicals.
Dissolved oxygen is measured in dissolved oxygen percentage or mg/L.

0-2 mg/L: not enough oxygen to support life.
2-4 mg/L: only a few fish and aquatic insects can survive.
4-7 mg/L: good for many aquatic animals, low for cold water fish
7-11 mg/L: very good for most stream fish

Conductivity is a measure of the capability of a solution such as water in a stream to pass an electric current. This is an indicator of the concentration of dissolved electrolyte ions in the water. It does not identify the specific ions in the water. However, significant increases in conductivity may be an indicator that polluting discharges have entered the water. Every stream will have a baseline conductivity depending on the local geology and soils. Higher conductivity will result from the presence of various ions including nitrate, phosphate, and sodium. The basic unit of measurement for conductivity is micromhos per centimeter (µmhos/cm) or microsiemens per centimeter (µS/cm). Either can be used, they are the same. IIt is a measure of the inverse of the amount of resistance an electric charge meets in traveling through the water. Distilled water has a conductivity ranging from 0.5 to 3 µS/cm, while most streams range between 50 to 1500 µS/cm. Freshwater streams ideally should have a conductivity between 150 to 500 µS/cm to support diverse aquatic life.

pH is a measure of a solution's acidity. In water, small numbers of water molecules (H2O) will break apart or disassociate into hydrogen ions (H+) and hydroxide ions (OH-). Other compounds entering the water may react with these, leaving an imbalance in the numbers of hydrogen and hydroxide ions. When more hydrogen ions react, more hydroxide ions are left in solution and the water is basic; when more hydroxide ions react, more hydrogen ions are left and the water is acidic. pH is a measure of the number of hydrogen ions and thus a measure of acidity. pH is measured on a logarithmic scale between 1 and 14 with 1 being extremely acid, 7 neutral, and 14 extremely basic. Because it is a logarithmic scale there is a ten-fold increase in acidity for a change of one unit of pH, e.g. 5 is 100 times more acid than 7 on the pH scale. The largest variety of freshwater aquatic organisms prefer a pH range between 6.5 to 8.0.

Figure 4.1 Thermal polygon for Brown Trout



Source: Environment Agency – Solomon & Lightfoot (2008)

4.2 Restoration Objectives

- To maintain low nutrient status and good water quality in New Forest streams
- To maintain water temperature and ideally lower summer temperatures in streams either through maintaining flow for longer periods or through the development of more thermal refugia

4.3 HLS Monitoring Sites

As part of HLS Monitoring, water quality measurements were taken in conjunction with fish/macro-invertebrate surveys and have been carried out by:

- APEM (2014) and Bournemouth University Global Solutions (BUG) from 2015 to 2019. Water quality measurements have been taken at 30 locations, pre and post restoration. The locations of measurements are shown in Table 4-1 and Figure 5.1 and 6.2 (fish & macro-invertebrate survey locations).

4.4 Methodology

Basic water quality parameters covering temperature, dissolved oxygen, conductivity and pH were measured in association with fish and invertebrate surveys. The methodology for these surveys is described in more detail in Chapters 5 and 6.

4.5 Analysis & Discussion of Results

The results for water quality parameters for each site are shown in Table 4-2 and Figures 4.1 to 4.4. Although the water quality measurements vary between different sites, they appear fairly consistent for individual sites.

Temperatures ranged from 10.5^{o}C to 20.9^{o}C although it should be noted that measurements were taken at different times of the year so are indicative of temperature range rather than variation between sites.

Dissolved oxygen generally ranged from 61.8 % to 98.9% and 6.26 to 10.09 μScm-1but there was one extreme result at Pondhead 2 in 2014 which recorded a dissolved oxygen reading of 22.1% with associated readings of dissolved oxygen 2.26 mg1-1, pH 5.83 and Conductivity 424 μScm-1. This may be indicative of a pollution event as the water quality readings had recovered again to normal levels by the next survey in 2016. Dissolved oxygen across all sites is generally well within the limits that support healthy fish communities

pH varied from 4.49 to 8.4. Higher pH values tend to be found close to mire and heathland areas where soils are generally more acidic.

Conductivity varied from 52.6 to 424 μScm-1. The lowest conductivities were associated with sites in the north of the New Forest such as Millersford 1, Latchmore 1 & 2 and Dockens Water which is likely to be indicative of the underlying geology.

Figures 4.5 and 4.6 show the trends in water quality pre and post restoration at Wootton and Harvestlade whilst Figures 4.7 and 4.8 show the trends from year to year for sites where no restoration has taken place at Millersford 1 and Latchmore 1. Caution needs to be taken when interpreting the results as they only represent one measurement in time and trends vary across all sites. However, it does appear that water quality may have improved at Harvestlade as there is a noticeable decline in conductivity and a rise in dissolved oxygen post restoration. PH also dropped immediately after restoration but had restored to similar background levels comparable to pre-restoration levels by 2018, suggesting the introduced substrate may have had a temporary effect.

With the exception of the one result mentioned above for Pondhead, water quality appears to be good across all sites.

Table 4-2: Water Quality Measurements

Sites	Year	Status	Temperature (oC)	Dissolved Oxygen (%)	Dissolved Oxygen	pH	Conductivity µScm-1
Dames Slough 1	2017	Restored	11.5	90.8	9.9	6.28	104.1
Dames Slough 2	2017	Restored	13.4	101.4	10.57	7.17	109.7
Dockens Water	2019	Unrestored	10.5	86.6	9.86	No data	69.8
Drivers Nursery	2016	Restored	15.9	86.1	8.5	n/a	177
Harvestlade 1	2014	Unrestored	16.1	95.8	9.37	6.64	103
Harvestlade 1	2016	Restored	14.7	92.6	9.32	n/a	74
Harvestlade 1	2018	Restored	15.1	108.7	10.91	8.15	73.2
Harvestlade 2	2014	Unrestored	17.1	83.3	7.96	6.5	110
Harvestlade 2	2016	Restored	15.6	92.2	9.18	n/a	73
Harvestlade 2	2018	Restored	10.6	101.7	11.3	8.12	66.8
Highland Water	2019	Unrestored	15.5	92.9	9.23	No data	132.5
Latchmore 1	2017	Unrestored	14.4	102.5	10.44	7.2	86.9
Latchmore 1	2018	Unrestored	17.9	100.3	9.54	7.8	65.6
Latchmore 1	2019	Unrestored	13.3	95.7	10.2		61.9
Latchmore 2	2017	Unrestored	12.9	98.4	10.39	7.61	80.1
Latchmore 2	2018	Unrestored	16	75	7.39	6.83	63.9
Latchmore 2	2019	Unrestored	14.6	95.9	9.69		64.5
Linford 1	2016	Unrestored	14.9	102.3	10.32	n/a	148
Linford 2	2016	Unrestored	15.2	101.2	10.16	n/a	154
Longwater 1	2016	Restored	17.3	104.3	10	n/a	240
Longwater 2	2016	Restored	20	118.2	10.74	n/a	242
Mill Lawn Brook	2018	Unrestored	12	89.7	9.62	8.14	212.7
Mill Stream	2019	Unrestored	11.5	87.8	9.52		205.6
Millerford 3	2019	Unrestored	14.4	92.7	9.44		293
Millersford 1	2016	Unrestored	15.5	91.5	9.13	n/a	52
Millersford 1	2017	Unrestored	13	101.2	10.69	4.69	59.6
Millersford 1	2018	Unrestored	16.3	99.2	9.73	5.2	64.9
Millersford 1	2019	Unrestored	12.7	100	10.3		54
Millersford 2	2016	Unrestored	14.9	99.4	10.01	n/a	128
Millersford 2	2017	Unrestored	13	89.5	9.43	7.26	127.6
Millersford 2	2018	Unrestored	16	94	9.25	7.92	253.5
Millersford 2	2019	Unrestored	14.4	92.7	9.44		293
Millersford 3	2016	Unrestored	15.8	96.7	9.57	n/a	206
Millersford 3	2017	Unrestored	11.6	93.8	10.18	7.8	172.9
Millersford 3	2018	Unrestored	16.7	99	9.62	8.11	299.1
Ober Water	2019	Unrestored	15.3	101.6	10.12		149.6
Pondhead 1	2014	Unrestored	14.1	61.8	6.26	6.57	318
Pondhead 1	2016	Unrestored	13.8	68	7.03	n/a	222
Pondhead 1	2019	Unrestored	10.9	87.4	9.62		227.8
Pondhead 2	2014	Unrestored	14.1	22.1	2.26	5.83	424
Pondhead 2	2016	Unrestored	13.8	68	7.03	n/a	222
Pondhead 2	2019	Restored	10.9	87.4	9.62		227.8
Rhinefield	2017	Restored	12	92	9.92	7.13	105.6
Slufters	2017	Restored	16.3	95.8	9.39	7.16	103.8
Soldiers Bog	2016	Restored	20.9	92.8	8.28	n/a	142
Soldiers Bog	2018	Restored	14.5	110.7	11.29	8.05	131.6
South Oakley 2	2016	Unrestored	15.9	68.2	6.74	n/a	126
South Oakley 3	2016	Unrestored	16	80.4	7.94	n/a	138
Wootton P1 - 1	2014	Unrestored	14.8	98.7	9.94	6.62	154
Wootton P1 - 1	2017	Restored	12.9	92.7	9.79	7.03	128
Wootton P1 - 1	2018	Restored	14.5	102.5	10.4	8.14	123.1
Wootton P1 - 1	2019	Restored	14.4	98.2	10.4		127.1
Wootton P1 - 2	2014	Unrestored	13.6	86.8	8.98	6.56	142
Wootton P1 - 2	2017	Restored	12.8	87.7	9.27	6.45	111.8
Wootton P1 - 2	2018	Restored	14.5	102.5	10.4	8.14	123.1
Wootton P1 - 2	2019	Restored	14.4	92.6	9.47		114
Wootton P2	2014	Unrestored	15.3	91.4	9.09	6.4	153
Wootton P2	2017	Unrestored	12.8	93.9	9.94	6.84	123.6
Wootton P2	2018	Unrestored	14.4	98.7	10.05	7.66	121.9
Wootton P2	2019	Unrestored	13.9	98.9	10.09		121.5
Wootton P2 - 2	2018	Restored	14.4	98	9.97	8.4	120.2
Wootton P2 - 2	2019	Restored	13.9	98.9	10.09		121.5

Figure 4.1

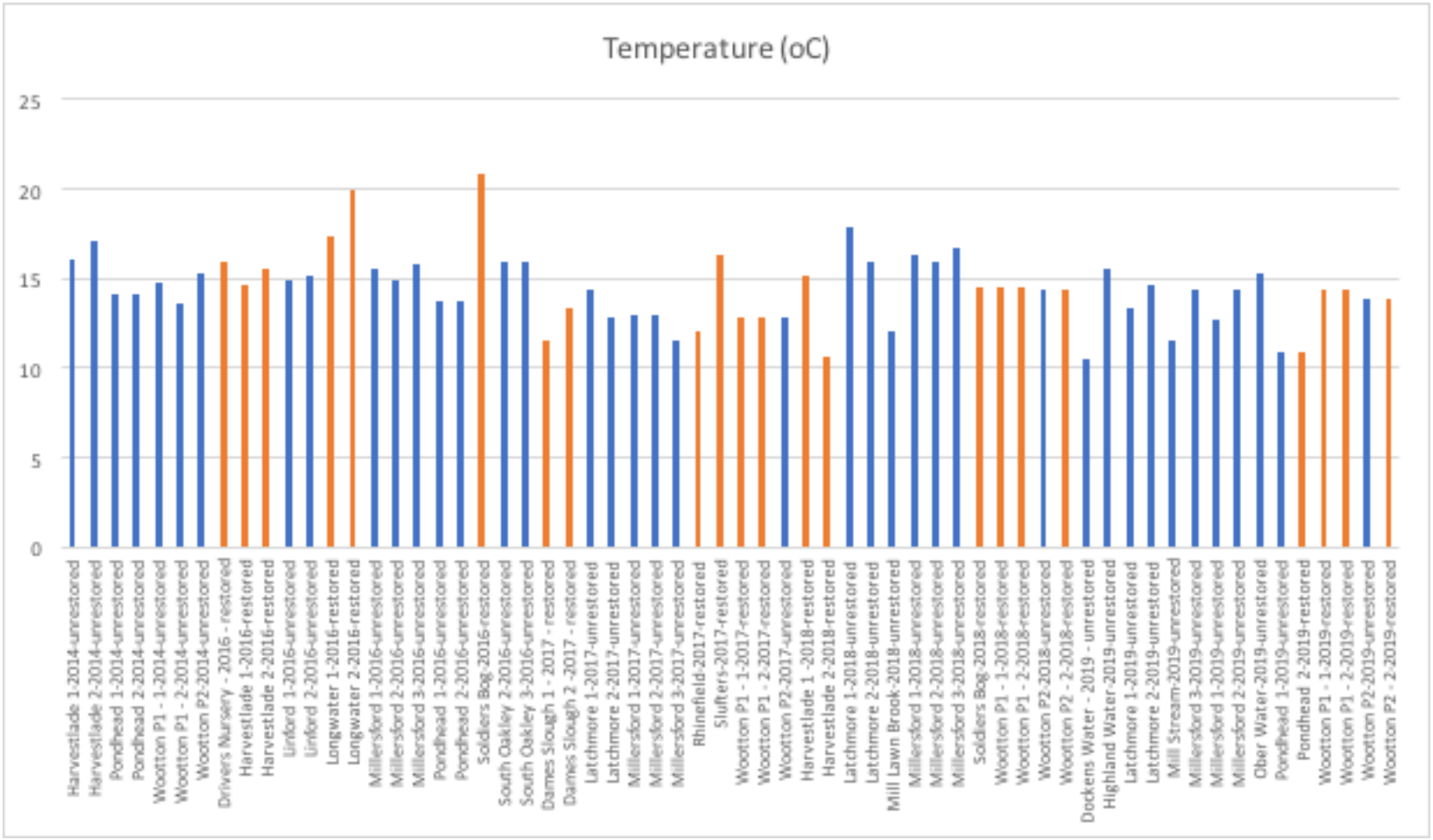

Temperature (oC)
25
20
15
10
5
0
Harvestlade 1-2014-unrestored
Harvestlade 2-2014-unrestored
Pondhead 1-2014-unrestored
Pondhead 2-2014-unrestored
Wootton P1 - 1-2014-unrestored
Wootton P1 - 2-2014-unrestored
Wootton P2-2014-unrestored
Drivers Nursery - 2016 - restored
Harvestlade 1-2016-restored
Harvestlade 2-2016-restored
Linford 1-2016-unrestored
Linford 2-2016-unrestored
Longwater 1-2016-restored
Longwater 2-2016-restored
Millersford 1-2016-unrestored
Millersford 2-2016-unrestored
Millersford 3-2016-unrestored
Pondhead 1-2016-unrestored
Pondhead 2-2016-unrestored
Soldiers Bog 2016-restored
South Oakley 2-2016-unrestored
South Oakley 3-2016-unrestored
Dames Slough 1 - 2017 - restored
Dames Slough 2 -2017 - restored
Latchmore 1-2017-unrestored
Latchmore 2-2017-unrestored
Millersford 1-2017-unrestored
Millersford 2-2017-unrestored
Millersford 3-2017-unrestored
Rhinefield-2017-restored
Slufters-2017-restored
Wootton P1 - 1-2017-restored
Wootton P1 - 2-2017-restored
Wootton P2-2017-unrestored
Harvestlade 1 -2018-restored
Harvestlade 2-2018-restored
Latchmore 1-2018-unrestored
Latchmore 2-2018-unrestored
Mill Lawn Brook-2018-unrestored
Millersford 1-2018-unrestored
Millersford 2-2018-unrestored
Millersford 3-2018-unrestored
Soldiers Bog 2018-restored
Wootton P1 - 1-2018-restored
Wootton P1 - 2-2018-restored
Wootton P2-2018-unrestored
Wootton P2 - 2-2018-restored
Dockens Water - 2019 - unrestored
Highland Water-2019-unrestored
Latchmore 1-2019-unrestored
Latchmore 2-2019-unrestored
Mill Stream-2019-unrestored
Millersford 3-2019-unrestored
Millersford 1-2019-unrestored
Millersford 2-2019-unrestored
Ober Water-2019-unrestored
Pondhead 1-2019-unrestored
Pondhead 2-2019-restored
Wootton P1 - 1-2019-restored
Wootton P1 - 2-2019-restored
Wootton P2-2019-unrestored
Wootton P2 - 2-2019-restored

Figure 4.2

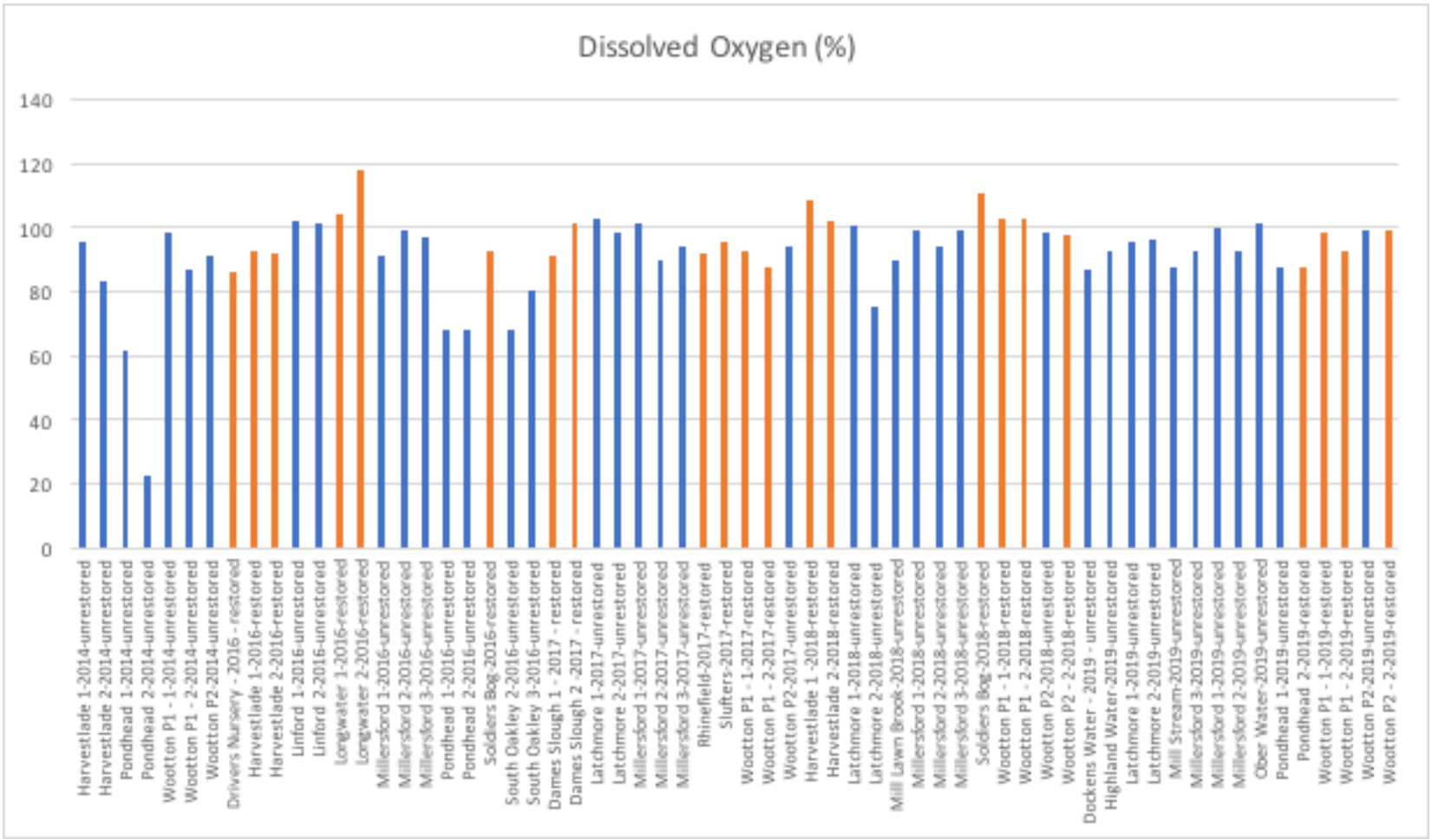
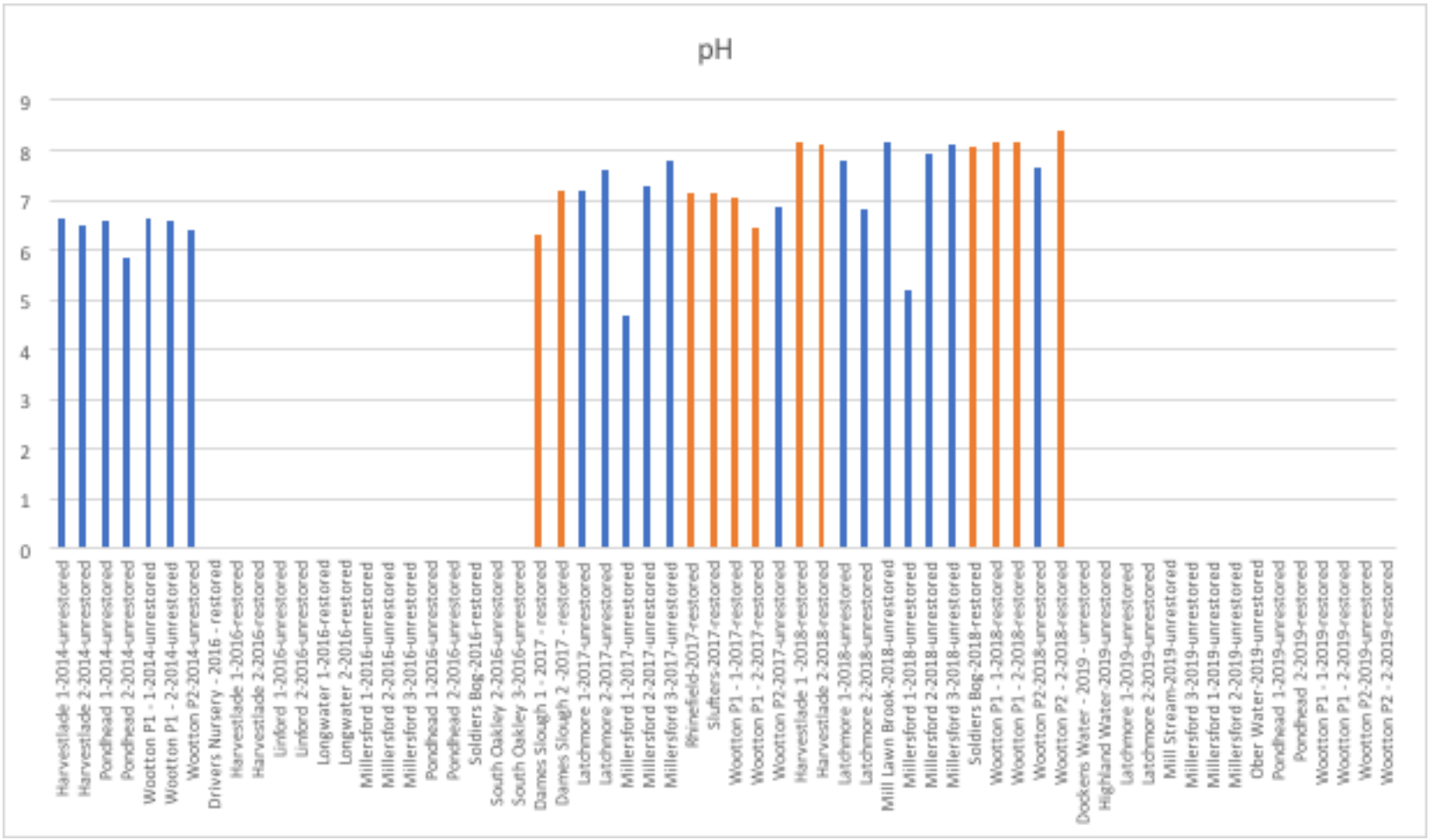

Dissolved Oxygen (%)
140
120
100
80
60
40
20
0
Harvestlade 1-2014-unrestored
Harvestlade 2-2014-unrestored
Pondhead 1-2014-unrestored
Pondhead 2-2014-unrestored
Wootton P1 - 1-2014-unrestored
Wootton P1 - 2-2014-unrestored
Wootton P2-2014-unrestored
Drivers Nursery - 2016 - restored
Harvestlade 1-2016-restored
Harvestlade 2-2016-restored
Linford 1-2016-unrestored
Linford 2-2016-unrestored
Longwater 1-2016-restored
Longwater 2-2016-restored
Millersford 1-2016-unrestored
Millersford 2-2016-unrestored
Millersford 3-2016-unrestored
Pondhead 1-2016-unrestored
Pondhead 2-2016-unrestored
Soldiers Bag-2016-restored
South Oakley 2-2016-unrestored
South Oakley 3-2016-unrestored
Dames Slough 1 - 2017 - restored
Dames Slough 2 -2017 - restored
Latchmore 1-2017-unrestored
Latchmore 2-2017-unrestored
Millersford 1-2017-unrestored
Millersford 2-2017-unrestored
Millersford 3-2017-unrestored
Rhinefield-2017-restored
Slufters-2017-restored
Wootton P1 - 1-2017-restored
Wootton P1 - 2-2017-restored
Wootton P2-2017-unrestored
Harvestlade 1 -2018-restored
Harvestlade 2-2018-restored
Latchmore 1-2018-unrestored
Latchmore 2-2018-unrestored
Mill Lawn Brook-2018-unrestored
Millersford 1-2018-unrestored
Millersford 2-2018-unrestored
Millersford 3-2018-unrestored
Soldiers Bag-2018-restored
Wootton P1 - 1-2018-restored
Wootton P1 - 2-2018-restored
Wootton P2-2018-unrestored
Wootton P2 - 2-2018-restored
Dockens Water - 2019 - unrestored
Highland Water-2019-unrestored
Latchmore 1-2019-unrestored
Latchmore 2-2019-unrestored
Mill Stream-2019-unrestored
Millersford 3-2019-unrestored
Millersford 1-2019-unrestored
Millersford 2-2019-unrestored
Ober Water-2019-unrestored
Pondhead 1-2019-unrestored
Pondhead 2-2019-restored
Wootton P1 - 1-2019-restored
Wootton P1 - 2-2019-restored
Wootton P2-2019-unrestored
Wootton P2 - 2-2019-restored

Figure 4.3


pH
9
8
7
6
5
4
3
2
1
0
Harvestlade 1-2014-unrestored
Harvestlade 2-2014-unrestored
Pondhead 1-2014-unrestored
Pondhead 2-2014-unrestored
Wootton P1 - 1-2014-unrestored
Wootton P1 - 2-2014-unrestored
Wootton P2-2014-unrestored
Drivers Nursery - 2016 - restored
Harvestlade 1-2016-restored
Harvestlade 2-2016-restored
Linford 1-2016-unrestored
Linford 2-2016-unrestored
Longwater 1-2016-restored
Longwater 2-2016-restored
Millersford 1-2016-unrestored
Millersford 2-2016-unrestored
Millersford 3-2016-unrestored
Pondhead 1-2016-unrestored
Pondhead 2-2016-unrestored
Soldiers Bag-2016-restored
South Oakley 2-2016-unrestored
South Oakley 3-2016-unrestored
Dames Slough 1 - 2017 - restored
Dames Slough 2 -2017 - restored
Latchmore 1-2017-unrestored
Latchmore 2-2017-unrestored
Millersford 1-2017-unrestored
Millersford 2-2017-unrestored
Millersford 3-2017-unrestored
Rhinefield-2017-restored
Sluffers-2017-restored
Wootton P1 - 1-2017-restored
Wootton P1 - 2-2017-restored
Wootton P2-2017-unrestored
Harvestlade 1 -2018-restored
Harvestlade 2-2018-restored
Latchmore 1-2018-unrestored
Latchmore 2-2018-unrestored
Mill Lawn Brook-2018-unrestored
Millersford 1-2018-unrestored
Millersford 2-2018-unrestored
Millersford 3-2018-unrestored
Soldiers Bag-2018-restored
Wootton P1 - 1-2018-restored
Wootton P1 - 2-2018-restored
Wootton P2-2018-unrestored
Wootton P2 - 2-2018-restored
Dookens Water - 2019 - unrestored
Highland Water-2019-unrestored
Latchmore 1-2019-unrestored
Latchmore 2-2019-unrestored
Mill Stream-2019-unrestored
Millersford 3-2019-unrestored
Millersford 1-2019-unrestored
Millersford 2-2019-unrestored
Ober Water-2019-unrestored
Pondhead 1-2019-unrestored
Pondhead 2-2019-restored
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Wootton P1 - 2-2019-restored
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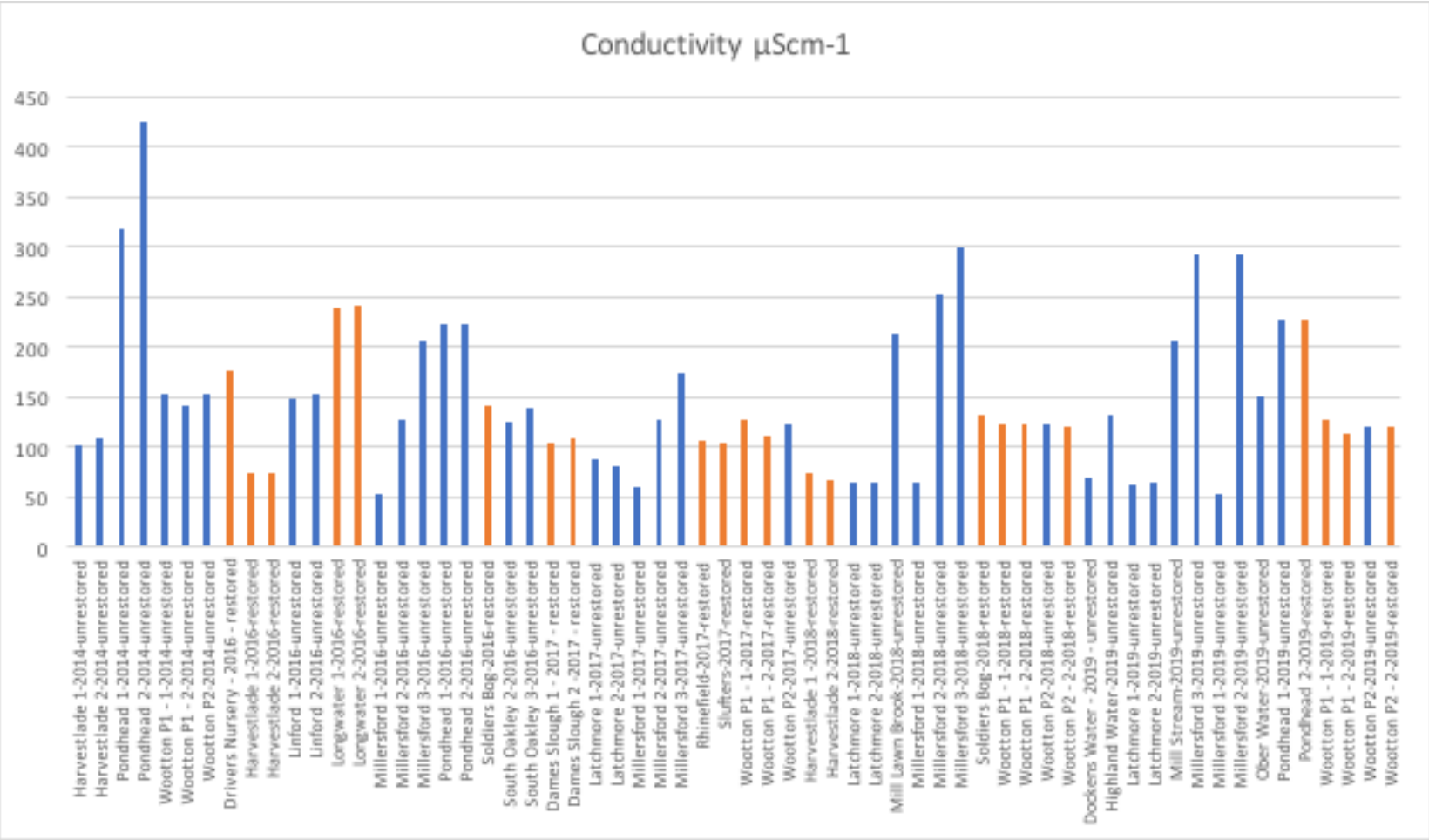
Wootton P2 - 2-2019-restored

Figure 4.4


Conductivity µScm-1
450
400
350
300
250
200
150
100
50
0
Harvestlade 1-2014-unrestored
Harvestlade 2-2014-unrestored
Pondhead 1-2014-unrestored
Pondhead 2-2014-unrestored
Wootton P1 - 1-2014-unrestored
Wootton P1 - 2-2014-unrestored
Wootton P2-2014-unrestored
Drivers Nursery - 2016 - restored
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Longwater 2-2016-restored
Millersford 1-2016-unrestored
Millersford 2-2016-unrestored
Millersford 3-2016-unrestored
Pondhead 1-2016-unrestored
Pondhead 2-2016-unrestored
Soldiers Bog-2016-restored
South Oakley 2-2016-unrestored
South Oakley 3-2016-unrestored
Dames Slough 1 - 2017 - restored
Dames Slough 2 -2017 - restored
Latchmore 1-2017-unrestored
Latchmore 2-2017-unrestored
Millersford 1-2017-unrestored
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Rhinefield-2017-restored
Sluffiers-2017-restored
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Harvestlade 2-2018-restored
Latchmore 1-2018-unrestored
Latchmore 2-2018-unrestored
Mill Lawn Brook-2018-unrestored
Millersford 1-2018-unrestored
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Millersford 3-2018-unrestored
Soldiers Bog-2018-restored
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Wootton P1 - 2-2018-restored
Wootton P2-2018-unrestored
Wootton P2 - 2-2018-restored
Dockens Water - 2019 - unrestored
Highland Water-2019-unrestored
Latchmore 1-2019-unrestored
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Mill Stream-2019-unrestored
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Millersford 1-2019-unrestored
Millersford 2-2019-unrestored
Ober Water-2019-unrestored
Pondhead 1-2019-unrestored
Pondhead 2-2019-restored
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Wootton P2 - 2-2019-restored

Figure 4.5

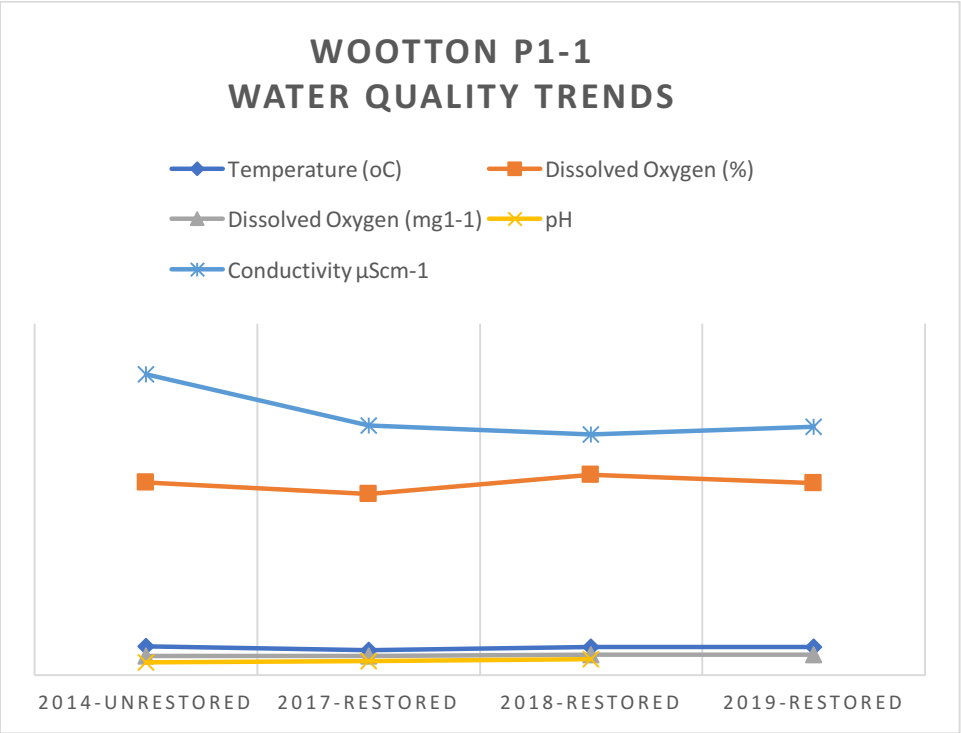
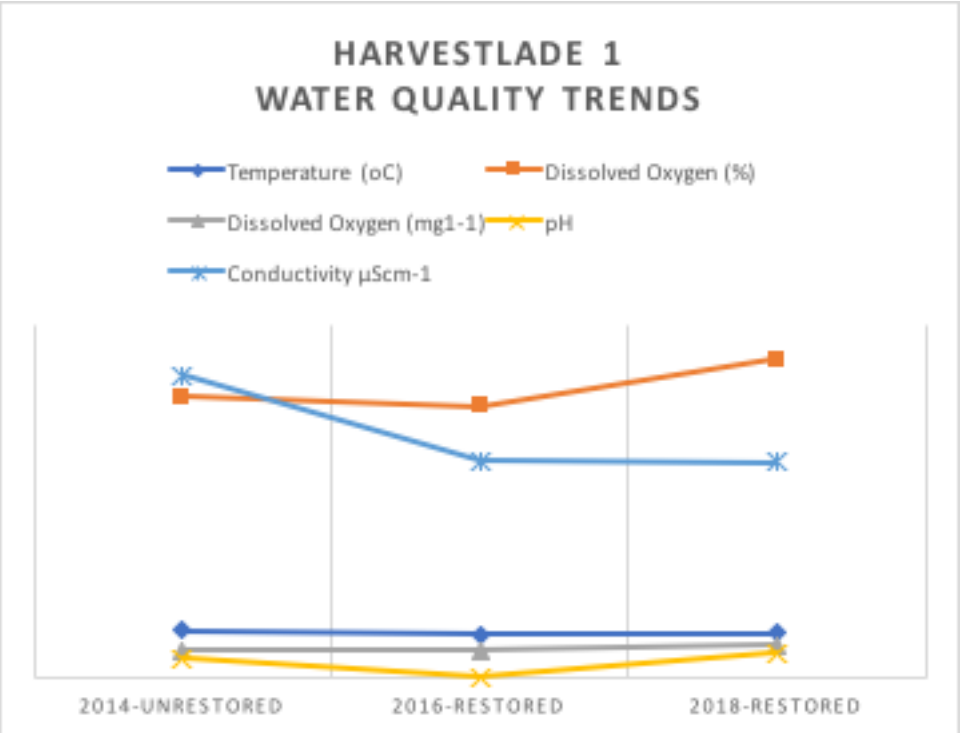


Figure 4.6



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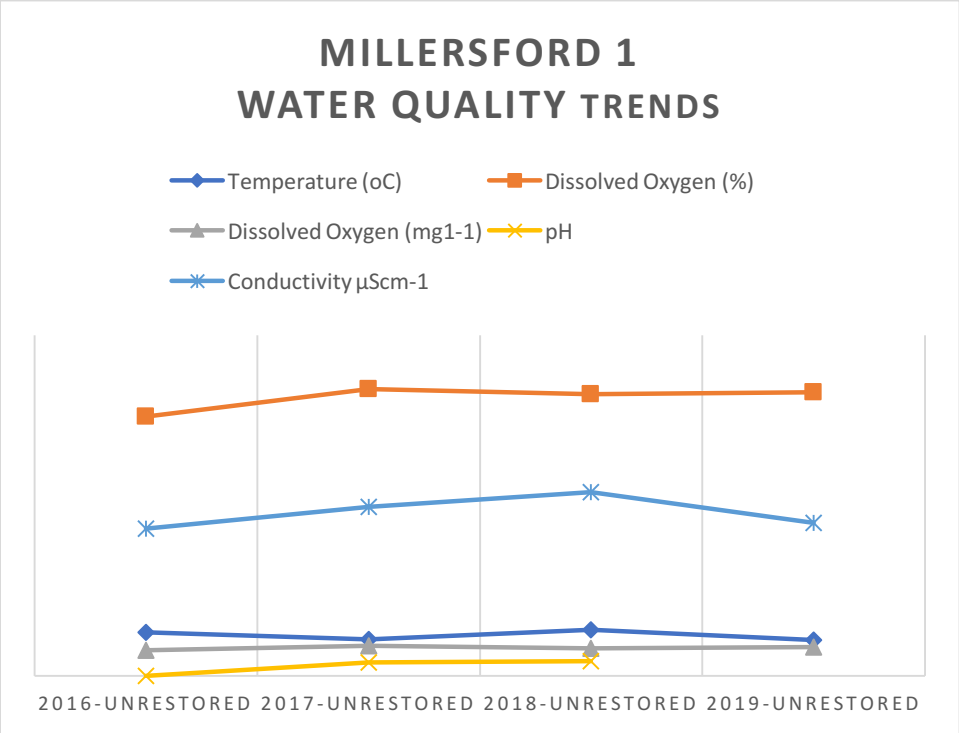
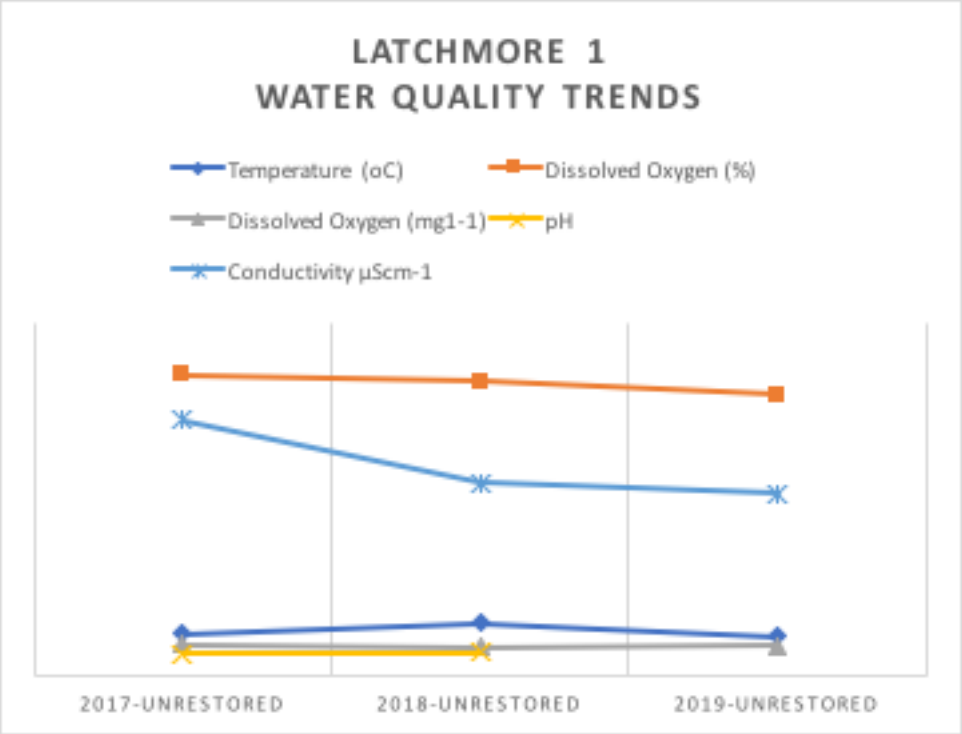


Figure 4.8



4.6 Conclusions

The water quality measurements collected as part of the fish and macro-invertebrate surveys are useful indicators about the water quality across the New Forest streams and show that there is no long-term effect on background water quality from restoration works. Water quality fluctuates, especially in response to temperature changes so unless water quality data loggers were installed at specific locations prior to restoration it is not really possible to gather enough data to determine whether the stream restoration work is having any effect in lowering summer water temperatures. Even this would be complicated to determine as water temperature varies according to levels of vegetation cover, water levels and air temperature and data loggers would need to have been in place for several years to derive meaningful results.

It can be concluded that the HLS Restoration Objective Traffic Light Status is **Green** with monitoring results suggesting that river restoration does appear to meeting its aims and objectives in terms of:

- Maintaining good water quality and general water temperature

However, the HLS Restoration Objective Traffic Light is **Red** in regard to:

- Ideally lower summer temperatures in stream either through maintaining flow for longer periods or through the development of more thermal refugia

This is because there is insufficient data to be able draw any valid conclusions.