5. Macro-Invertebrate Monitoring

5.1 Background

The New Forest streams support a diverse population of macroinvertebrates including several rare species. The abundance and diversity of the macro-invertebrate community is closely linked to the quality of the aquatic environment so provides an extremely useful indicator to the health of the river environment. Many macro-invertebrate species are very sensitive to changes in their surrounding environment including substrate and water quality so changes in the invertebrate population provides a useful indicator of changes in the river environment including impacts from river restoration and signs of recovery.

As part of the wetland restoration process, new meandering, sinuous channel sections are restored by scraping out the original, historic channel course and the straightened channel infilled. The new channel will often be dressed with new material of a suitable size sourced from a nearby quarry providing substrate from the same geological strata. Where possible bed material is reclaimed and moved from the old straightened channel to the new restored channel to try and preserve some of the original macro-invertebrate population. However, it is assumed that the macro-invertebrate population will be very low to start with in the restored channel and will take time to recolonise and recover. It is anticipated that over time the restored channel will become more diverse in terms of substrate, in-channel features and habitat diversity and therefore support a richer, more diverse macro-invertebrate community.

Past studies undertaken by the Environment Agency as part of Life 3 [1] found that community structure varies according to whether the channels are sinuous or channelized although it was found that the conservation value of the macroinvertebrate fauna did not generally differ between sinuous and channelised reaches. Of particular note was that some areas of marginal aquatic habitat were found to support extremely valuable invertebrate communities. The richest marginal habitats were found to be those that flood on a regular basis including palaeomeanders and ephemeral leaf litter pools.

5.2 Restoration Objective

To restore sites to achieve a more rich and diverse macro-invertebrate community

5.3 HLS Monitoring Sites

Macro-invertebrate monitoring has taken place through two monitoring programmes:

- Formal macroinverebrate surveys carried out by BUG at 21 sites
- Riverfly monitoring which is a citizen science volunteer monitoring scheme carried out through the Riverfly Partnership at 9 sites

[1] Michael Thomas (July 2002) A Study of Habitat Structure and Macroinvertebrate Communities of the Highland Water and Black Water.

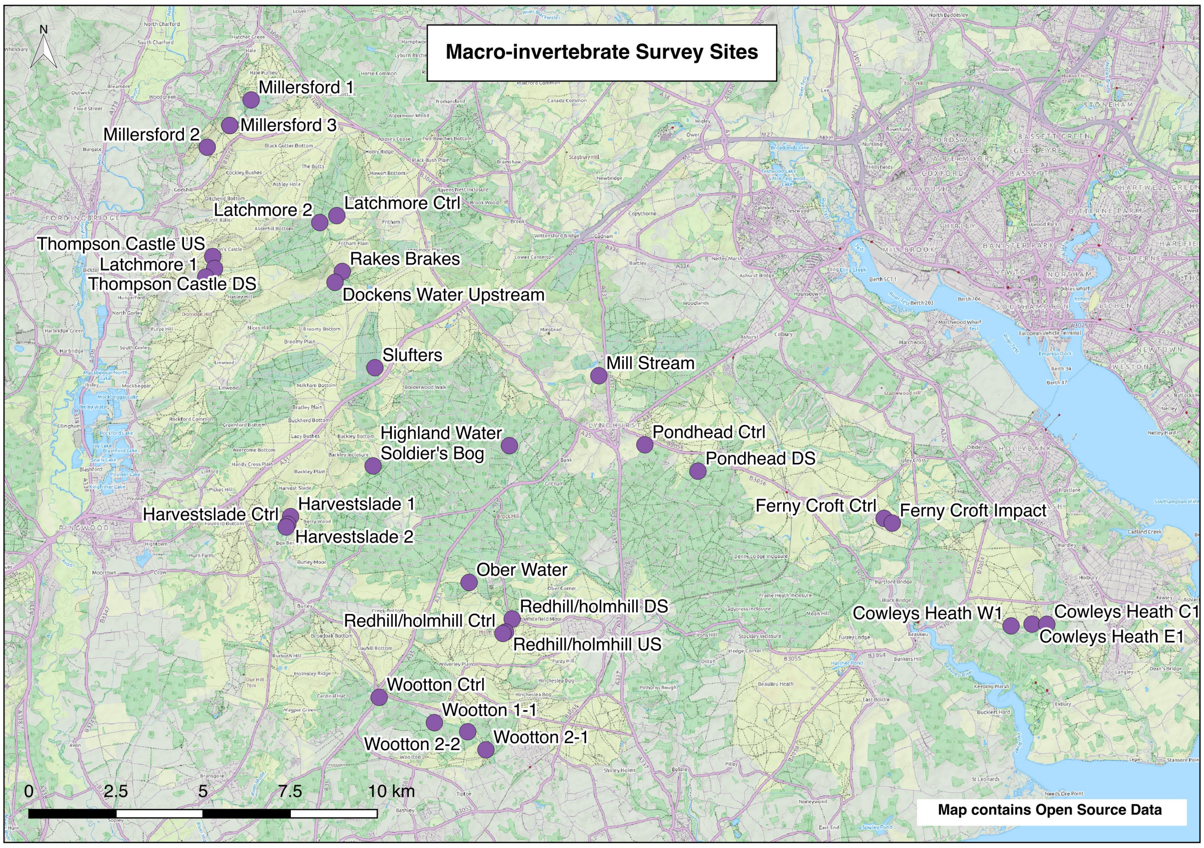
Figure 5.1 and Table 5-1. show the locations of the monitoring sites. For some restored sites there is no pre-restoration survey data but upstream or downstream control sites have subsequently been surveyed to try and allow comparison.

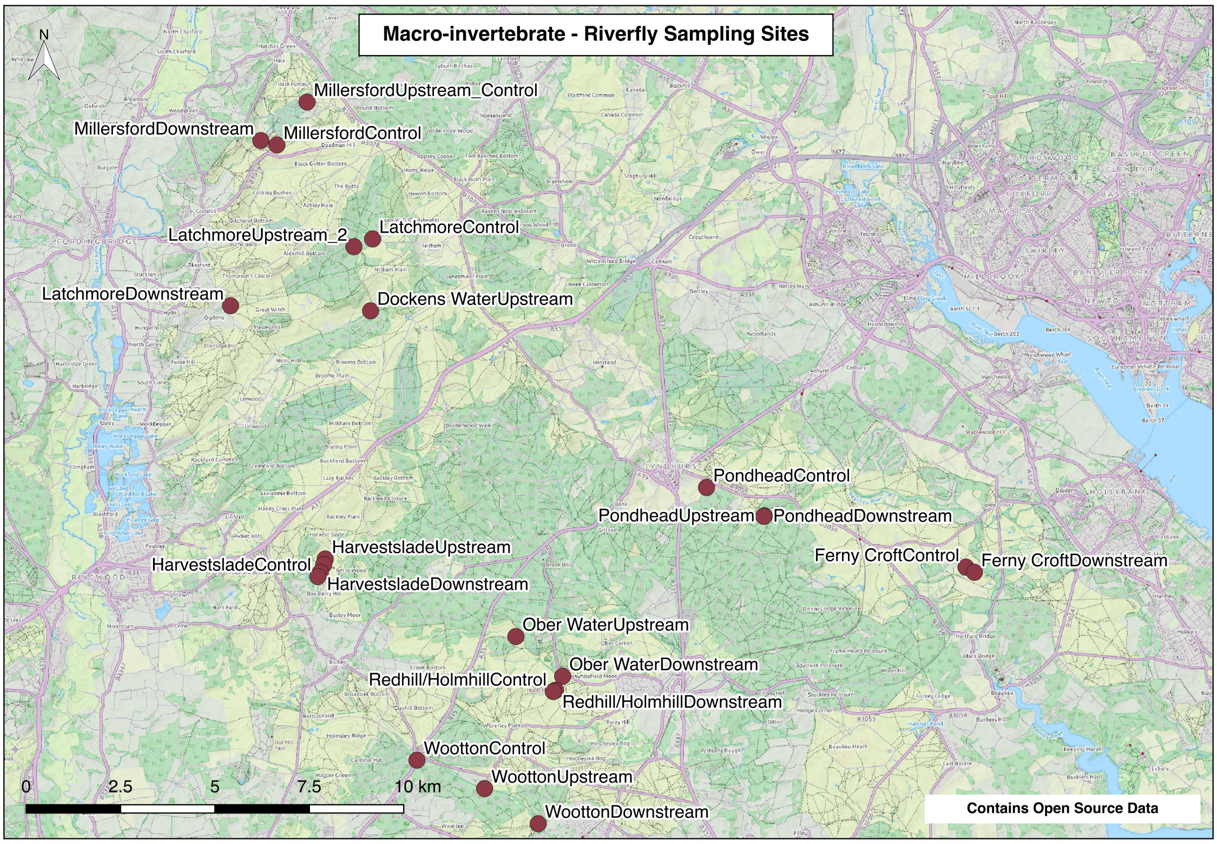
Table 5-1: Macro-invertebrate Sample Sites

Site	Type	Pre-Restoration Surveys	Post Restoration Surveys	Restoration Status
Cowleys Heath	Formal (BUG)	2015	2016	Restored
Dames Slough	Formal (BUG)	No data	2017	Restored
Dockens Water	Formal (BUG)	2019	N/A	Unrestored
Dockens Water	Volunteer Riverfly	2019	N/A	Unrestored
Ferny Croft	Formal (BUG)	No data	2019	Restored
Ferny Croft	Volunteer Riverfly	No data	2019	Restored
Harvestlade	Formal (BUG)	2015	2016,2018,2019	Restored
Harvestlade	Volunteer Riverfly	2015	2016,2017,2018, 2019	Restored
Highland Water	Formal (BUG)	2019	N/A	Unrestored
Latchmore	Formal (BUG)	2017,2018,2019	N/A	Unrestored
Latchmore	Volunteer Riverfly	2016,2017,2019 *2018 too dry to survey	N/A	Unrestored
Linford	Formal (BUG)	2016	N/A	Unrestored
Longwater	Formal (BUG)	No data	2016	Restored
Millersford	Formal (BUG)	2016,2017,2018,2019	N/A	Unrestored
Millersford	Volunteer Riverfly	2019	N/A	Unrestored
Mill Lawn Brook	Formal (BUG)	2018	N/A	Unrestored
Mill Stream	Formal (BUG)	2019	N/A	Unrestored
Ober Water	Formal (BUG)	2019	N/A	Unrestored
Ober Water	Volunteer Riverfly	2019	N/A	Unrestored
Pondhead	Formal (BUG)	2015,2016	No data	Restored
Pondhead	Volunteer Riverfly	2015,2016,	2018,2019	Restored

Site	Type	Pre-Restoration Surveys	Post Restoration Surveys	Restoration Status
Rakes Brakes	Formal (BUG)	2019	N/A	Unrestored
Redhill/Holmhill	Formal (BUG)	2019	N/A	Unrestored
Redhill/Holmhill	Volunteer Riverfly	2019	N/A	Unrestored
Slufters	Formal (BUG)	No data	2017	Restored
Soldiers Bog	Formal (BUG)	No data	2018	Restored
Thompsons Castle	Formal (BUG)	2019	N/A	Unrestored
Wootton – Phase 1	Formal (BUG)	2014,2015,2016	2017,2018,2019	Restored
Wootton – Phase 2	Formal (BUG)	2015,2016,2017,2018	2019	Restored
Wootton	Volunteer Riverfly	**2016 (partial), 2017-2018.**	2017,2018	Restored

Figure 5.1: Macro-Invertebrate Monitoring Sites





5.4 Methodology

5.4.1 Formal Surveys (BUG)

Macroinvertebrate monitoring has been carried out annually by Bournemouth University Global Solutions (BUG) since 2014/2015.

Macroinvertebrate samples were collected in accordance with the standard Environment Agency (EA) three-minute kick sampling procedure using a 1 mm mesh pond net (set out in 'Procedures For Collecting and Analysing Macroinvertebrate Samples". BT001 3.0, Third Issue; 1991) and by the procedure for collecting and analysing macroinvertebrate samples for RIVPACS (Murray-Bligh et al. 1992).

At each sampling site, a basic suite of physio-chemical parameters (pH, temperature, conductivity, dissolved oxygen) and general habitat characteristics (water velocity category, width, depth and substratum composition) were recorded on standard RIVPACS/RICT 'Sample Area' forms. These variables are useful both for describing the general sampling site characteristics, and also as predictor variables for running the RIVPACS (River Invertebrate and Prediction and Classification System) model. All samples were accompanied by a GPS reading, and sampling site sketch map to facilitate subsequent return to the same location for re-survey work. In addition, the presence of aquatic macrophytes and other species observed incidentally during the macroinvertebrate sampling (e.g. fish) were also recorded.

In the laboratory, macroinvertebrate samples were sorted, identified and enumerated following the procedures set out in 'Procedures For Collecting and Analysing Macroinvertebrate Samples". BT001 3.0, Third Issue; 1991) and by the procedure for collecting and analysing macroinvertebrate samples for RIVPACS (Murray-Bligh et al. 1992). Samples were processed to species-level, specifically RIVPACS Taxonomic Level 'TL5' (Davy-Bowker et al. 2010), and numerical abundances of all taxa were estimated and recorded on laboratory sample data sheets. Macroinvertebrate data from sample analysis laboratory datasheets were validated and entered into a Microsoft® Access data then exported for the calculation of biotic indices and RIVPACS/RICT Observed/Expected ratios.

Data were imported into a Microsoft® Access database containing queries for the automatic calculation of a wide range of freshwater macroinvertebrate biotic indices at family and/or species levels. Table 5-2 summarises the biotic indices that were calculated.

Table 5-2: Macro-invertebrate Biotic Indices

Biotic Indices	Stressor Test	Notes
BMWP Biological Monitoring Working Party	General degradation	The biological monitoring working party (BMWP) is a procedure for measuring water quality using families of macroinvertebrates as biological indicators.[1] The method is based on the principle that different aquatic invertebrates have different tolerances to pollutants. In the case of

Biotic Indices	Stressor Test	Notes
		BMWP, this is based on the sensitivity/tolerance to organic pollution (i.e. nutrient enrichment that can affect the availability of dissolved oxygen). It is important to recognise that the ranking of sensitivity/tolerance will vary for different kinds of pollution. In the case of BMWP/Organic pollution rankings, the presence of mayflies or stoneflies for instance indicate the cleanest waterways and are given a tolerance score of 10.[2] The lowest scoring invertebrates are worms (*Oligochaeta*) which score 1. The number of different macroinvertebrates is also an important factor, because a better quality water is assumed to contain fewer pollutants that would exclude "sensitive" species - resulting in a higher diversity.
NTAXA Number Taxa	General degradation	Number of groups or families of invertebrates
ASPT Average Score per Taxon	General degradation	The ASPT equals the average of the tolerance scores of all macroinvertebrate families found, and ranges from 0 to 10. The main difference between both indices is that ASPT does not depend on the family richness.
WHPT Score	General degradation	This classification method enables the assessment of invertebrates in rivers (in relation to general degradation, including organic pollution) according to the requirements of the Water Framework Directive (WFD).
WHPT NTAXA		The classification comprises two metrics that are assessed separately and then combined in a “worst of” approach to provide the overall invertebrate classification; Number of taxa contributing to the assessment
WHPT ASPT		The classification comprises two metrics that are assessed separately and then combined in a “worst of” approach to provide the overall invertebrate classification; WHPT ASPT (Average Score Per Taxon)
AWIC Acid Water Indicator	Acidity/acidification stress	Macroinvertebrate biotic index for assessing the impact of acidity on streams and rivers in England and Wales.

Biotic Indices	Stressor Test	Notes
Community		
WFD Water Framework Directive Acid Water Indicator Community	Acidity/acidification stress	The Water Framework Directive (WFD) requires the assessment of acidification in sensitive water bodies. Detecting and quantifying acidification is important for conservation, in the context of appropriate restoration, for example, by ensuring that naturally acid waters are not treated as anthropogenically acidified.
LIFE Lotic-invertebrate index for Flow Evaluation	Flow Stress	The Lotic-invertebrate Index for Flow Evaluation (LIFE) method is primarily based on recognized flow associations of different macroinvertebrate species and families. The index encapsulates ecological response to changing flow patterns in a range of river types.
PSI Proportion of Sediment-sensitive invertebrates	Sedimentation Stress	The Proportion of Sediment-sensitive Invertebrates (PSI) index is a biomonitoring tool that is designed to identify the degree of sedimentation in rivers and streams.
Spear Species at Risk	Pesticide Stress	Chemical pollution is one of the main causes of degradation and biodiversity loss in aquatic ecosystems. The Spear Biotic index is used to detect effects of pesticides on non-target freshwater organisms. The Species at risk (SPEAR(pesticides)) bioindicator based on biological traits was previously developed and successfully validated over different biogeographical regions of Europe using species-level data on stream invertebrates.
CCI Conservation value	Conservation Value	The CCI biotic index aims to summarize aquatic macroinvertebrate data obtained from inland flowing- and still-water sites in Great Britain. Unlike other summary expressions of conservation value, the Community Conservation Index (CCI) accounts for community richness in the final analysis, as well as the relative rarity of species present. CCI is capable of local adjustment, to accommodate nationally common species occurring outside their normal range

In addition to the calculation of observed biotic indices for the macroinvertebrate samples (described above) RIVPACS/RICT classification was undertaken using the RIVPACS IV predictive model (Davy-Bowker et al. 2008), run through the web-based RICT (River Invertebrate Classification Tool) software:

www.sepa.org.uk/environment/water/classification/river-invertebrates-classification-tool/

RIVPACS IV is the current RIVPACS model used by the Environment Agency and others to perform WFD quality assessments and is the industry standard for assessing the biological condition of running waters. RIVPACS (River Invertebrate Prediction and Classification System) is a predictive model that uses environmental variables such as stream width and depth, distance from source, altitude, etc. to predict the reference (undisturbed) values of a range of biotic indices (Wright et al. 1997; Clarke et al. 2003). RIVPACS is based on a dataset of 685 GB reference sites that are grouped into similar 'end groups' whose biological communities are similar to each other. Predicted biotic indices for test samples were obtained by gathering the same environmental variables (environmental predictor variables) and running these through the model. Each test sample is assigned a probability of RIVPACS end group membership based on its environmental variables. The biotic index values of the reference sites in the various end groups then contribute to the predicted index values for the test sample. Rather than drawing the prediction solely from one end group of reference sites, the predictions of reference condition biotic indices are derived by the model as a weighted average depending upon probability of end group membership (Clarke et al. 2011).

The observed values of a wide range of commonly used biotic indices from the test samples were then compared to the RIVPACS expected values of the indices by the calculation of observed/expected ratios. For example, an observed biotic index value of 75 would be divided by an expected value of the same index, of say 85, to give an observed/expected (O/E) ratio of 0.882. An O/E ratio of greater than 1.0 indicates that a test sample has exceeded its predicted biotic index value (it is better than similar reference condition sites in the model); an O/E ratio of slightly below 1.0 (e.g. 0.882) indicates that a test sample is close to its predicted index value and is, therefore, only minimally impacted; an O/E ratio close to zero indicates that a test sample falls a long way short of its predicted biotic index value and it is, therefore, heavily stressed or degraded.
The O/E ratios of the Observed/Expected biotic indices were fitted into five bands, indicating the degree of disparity between the observed values and those expected by RIVPACS/RICT in the unstressed state. The five bands of O/E ratios used were as follows:

> 1.3 Better than expected

1.3 – 0.7 Within expected range

0.7 – 0.5 Slightly degraded

0.5 – 0.3 Moderately degraded

< 0.3 Very degraded

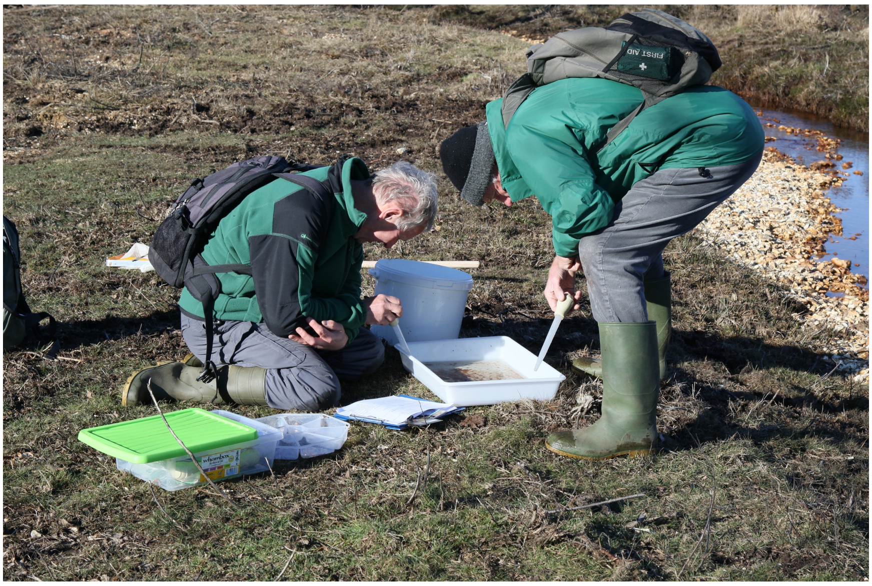
It is important to note that the bands above are not WFD ecological status classes (which exist only for the WHPT biotic indices). They do, however, give a consistent framework to examine deviations of observed and expected biotic index values across all biotic indices used and, therefore, provide a framework to quantify the effects of a wider range of environmental stressors than WFD classification alone.

5.4.2 Riverfly

The Anglers' Riverfly Monitoring Initiative (ARMI), launched in 2007 and established UK-wide, is a citizen science initiative in which volunteers are trained to carry out standardised biomonitoring of rivers on a monthly basis and to derive a score which summarises water quality. The key focus of ARMI is to provide an early warning system against acute river pollution incidents but in the case of the New Forest streams it is extremely valuable for helping to monitor invertebrate response to river restoration. The Riverfly Partnership Angler's Riverfly Monitoring Initiative (ARMI) uses 8 groups of commonly occurring freshwater invertebrates to monitor the biological condition of rivers across the UK. Population changes in these 8 key species groups can rapidly detect changes in the river environment:

1. Cased Caddisfly
2. Caseless Cadisfly
3. Mayfly
4. Blue Winged Olive
5. Flat Bodied Hepta
6. Olives
7. Stoneflies
8. Freshwater Shrimp

The methodology involves 3-minute kick sampling moving along the section working upstream, capturing different location features within the river section. Samples are analysed and counted on the bankside. Ideally monitoring is carried out monthly. Analysis of ARMI data shows that ARMI scores correlate closely with Biological Monitoring Working Party (BMWP) scores and that variation between volunteer sampling effort does not significantly affect the ARMI score. ARMI data are submitted by the volunteers into an online open access database and once records have been verified they are available under the terms of the Open Government Licence



Riverfly volunteers in action

In the New Forest, 8 Group Riverfly monitoring was started in 2015 although not all sites have been monitored monthly either due to volunteer availability, because restoration work was in progress or at some sites, for example in 2018, rivers ran dry which prevented surveys being carried out.

In 2019, Riverfly surveys were extended to capture 33 species groups.

5.5 Analysis & Discussion of Results

BUG surveys have recorded over 200 macro-invertebrate species (Appendix A)from New Forest macro-invertebrate sample sites including 8 species of conservation interest (Table 5-3).

Table 5-3: Macro-invertebrate Species of Conservation Interest

Species	Type/Family/Species	Conservation Status	Sample Site Recorded
Aquarius najas	River Skater	Nationally scarce (occurring in 16-100 hectads in Great Britain)	Millstream Upstream Wootton 2-1
Hydatophylax infumatus	Caddisfly	Nationally scarce (occurring in 16-100 hectads in Great Britain)	Wootton Control 1-2
Hydrochus nitidicollis	Brass Necked Beetle	BAP-2007 England_NERC_S.41 GB Red List (post 2001) – Vulnerable	Wootton Control 1-2
Enallagma cyathigerum	Common Blue Damselfly, Common Bluet	IUCN 2010 Red List Lower risk - least concern	Millersford1 Millersford 3
Calopteryx splendens	Banded Demoiselle Damselfly	IUCN 2010 Red List Lower risk - least concern	Latchmore 1 Latchmore 2 Wootton 1-2
Anax imperator	Blue Emperor, Emperor Dragonfly	IUCN 2010 Red List Lower risk - least concern	Latchmore 1
Helophorus (Trichohelophorus) alternans	Water beetle	Nationally scarce (occurring in 16-100 hectads in Great Britain)	Cowleys Heath East 1
Hydrochus angustatus	Water beetle	Nationally scarce (occurring in 16-100 hectads in Great Britain	Wootton 1-2

Source: BUG reports

Table 5-4 summarises the actual observed values for all the BUG macro-invertebrate monitoring sites. The colours represent the Observed/Expected (O/E) biotic index band that the results fell into when BUG calculated the O/E ratio using RIVPACS end group membership to determine the expected baseline for the monitoring sites.

Certain results suggest that some caution may need to be applied to the interpretation of O/E biotic index band results for mire sites as their unique communities may not fit as well with the reference sites used in the RIVPACS model. For example, the mire sites tended to show a severely degraded AWIC score which is related to the impact of acidity on macro-invertebrate communities and these sites also had lower BMWP and TAXA scores. However, mire habitats are naturally more acidic than habitats further downstream and are also fairly unique habitats in their own right so may well not be well represented in the national classifications that feed into the RIVPACS model.

Figure 5.2 shows the average macro-invertebrate response calculated from all BUG sample site biotic indices and compares unrestored sites with restored sites. Overall the number of macro-invertebrate species is currently lower in most restored sites than un-restored sites. This is not entirely surprising considering that most restored reaches will have started from a very low baseline given the creation of a new channel and raw substrate and most of the monitoring sites have only been restored for between 1 to 3 years. Substrate is one of the key drivers in determining macro-invertebrate composition and in the first few years post restoration is probably one of the most significant factors driving community composition and recovery. Further observations and analysis on sediment changes is given in Section 2

However, the Riverfly data presents a slightly different picture. Figure 5.3 and Table 5-5 shows average abundance logs for all the 2019 Group 33 Riverfly sites. The riverfly data includes samples taken over a number of months so picks up seasonal variations and considers groups of invertebrates rather than individual species. Although the Riverfly data is not as in-depth as the BUG data its simplicity may well be effective at picking up general recovery trends. What is apparent is that each site is unique with every site experiencing seasonal variations with the variations and seasonality in peak abundance differing between individual sample sites. It should be noted that the group 33 data only started to be collected in 2019 and not every site has been sampled monthly so some caution is required in interpreting these early results.

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Table 5-4: Summary of biotic index values

Site	Date	Status	No Species	TL1 BMWP	TL1NTAXA	TL1 ASPT	TL2 WHPT Score	TL2 WHPT NTAXA	TL2 WHPT ASPT	TL5 AWIC	TL5 WFD	TL5 LIFE	TL5 PSI	TL5 Spear %	CCI
Cowleys Heath C1	Apr-15	Unrestored	35	154	25	6.16	186.8	29	6.44	7.25	10.08	8.3	75.56	41	10.59
Cowleys Heath C1	May-16	Unrestored	38	163	26	6.27	189.8	29	6.55	7	9.8	8.05	75	43.36	15.84
Cowleys Heath E1	Apr-15	Unrestored	27	112	20	5.6	141.4	23	6.15	5.5	7	7.12	30.77	36.58	17.5
Cowleys Heath E1	May-16	Restored (2015)	28	101	19	5.32	112.2	22	5.1	6.67	9.33	6.64	10.53	19.6	6.6
Cowleys Heath W1	Apr-15	Unrestored	30	152	24	6.33	168	26	6.46	6.46	8.55	8	68.75	49.51	9.33
Cowleys Heath W1	May-16	Restored (2015)	30	62	13	4.77	63.1	14	4.51	9	13	8.33	50	15.36	1
Dockens Water (upstream)	Sep-19	Unrestored	28	124	22	5.636	126	22	5.727	6.833	9.5	7.417	42.308	29.461	5
Ferney Croft Impact	Sep-19	Restored (2018)	10	21	6	3.5	27.6	7	3.943	6	8	8	33.333	0	2
FernyCroft Control	Sep-19	Unrestored	7	25	6	4.167	25.8	7	3.686	0	0	6	0	0	1
Harvestlade 2	Sep-19	Restored (2015)	21	94	15	6.267	124.9	19	6.574	6.5	8.25	7.714	43.75	37.107	4.714
Harvestlade H1	Apr-15	Unrestored	20	108	16	6.75	128.3	18	7.13	5.33	6.67	7.89	57.14	43.66	11.25
Harvestlade H1	Sep-18	Restored (2015)	10	36	8	4.5	32.3	8	4.037	7	9.5	6	25	12.333	11.667
Harvestlade NC	May-16	Unrestored	7	31	7	4.43	32.4	7	4.63	4	4	8.33	42.86	23.8	1
Harvestlade NC	Sep-18	Unrestored	19	81	15	5.4	95.7	16	5.981	5.5	7.5	7.444	50	26.48	6
Harvestslade 1	Sep-19	Restored (2015)	14	75	13	5.769	65.9	13	5.069	3	5	6.667	25	24.861	1
HarvestSlade Control	Sep-19	Unrestored	23	104	18	5.778	131.9	21	6.281	6	7.8	7.273	55	36.99	4.8
Highland Water	Sep-19	Unrestored	18	103	17	6.059	107.9	17	6.347	7.5	10.167	8	78.947	26.191	4.333
Latchmore 1	Sep-17	Unrestored	40	145	26	5.577	153.4	28	5.479	5	7	6.529	27.907	36.736	9.375
Latchmore 1	Sep-18	Unrestored	17	67	13	5.154	75.4	15	5.027	7	10	6.143	23.529	17.53	5.143
Latchmore 1	Sep-19	Unrestored	20	79	16	4.938	77.1	17	4.535	9	12	6.556	35.294	35.062	14.444
Latchmore 2	Sep-17	Unrestored	20	111	18	6.167	111.2	18	6.178	6	8.2	7.667	70	30.341	9.091
Latchmore 2	Sep-18	Unrestored	12	57	10	5.7	62.3	11	5.664	7.5	10	7.714	81.818	21.72	1.143
Latchmore 2	Sep-19	Unrestored	21	97	17	5.706	105.9	18	5.883	7	9.5	7.385	56	21.87	9.231
Mill Brook Lawn	Sep-18	Unrestored	15	78	14	5.571	83.7	14	5.979	7.667	11	7.857	50	21.426	5.5
Millerford 1	Sep-17	Unrestored	15	69	12	5.75	78.1	14	5.579	4.5	5	7.571	62.5	40.395	15.833
Millerford 1	Sep-18	Unrestored	15	58	11	5.273	61.7	12	5.142	5	7	7.143	25	17.01	15.833
Millerford 3	Sep-17	Unrestored	37	157	26	6.038	171.6	28	6.129	6.667	8.75	7.583	64.103	35.631	14.333
Millerford 3	Sep-18	Unrestored	46	164	26	6.308	208.9	31	6.739	6.538	9	8.043	71.739	38.018	8.333
Millerford 3	Sep-19	Unrestored	30	143	22	6.5	149	23	6.478	6.444	8.556	7.867	65.517	32.753	5.143
Millersford 2	Sep-17	Unrestored	27	120	19	6.316	132.3	21	6.3	6.625	8.75	7.467	62.5	36.855	10
Millersford 2	Sep-18	Unrestored	36	165	26	6.346	188.2	28	6.721	6.909	9.091	8.105	66.667	39.334	9.412
Millersford 2	Sep-19	Unrestored	26	108	17	6.3534	114.2	18	6.344	7	9	7.364	57.143	39.426	10.455
Millersford 1	Sep-19	Unrestored	16	66	12	5.5	76.2	13	5.862	4.5	5.5	8.2	71.429	38.853	18
Millersford Upstream	Sep-19	Unrestored	11	34	8	4.25	48.8	11	4.436	0	0	7	25	11.226	2
Millstream Upstream	Sep-19	Unrestored	37	158	26	6.077	179.4	29	6.186	7.286	9.857	7.857	59.259	40.608	10.357
Ober Water Upstream	Sep-19	Unrestored	35	157	25	6.28	161.5	27	5.981	7.286	9.571	7.053	33.333	36.775	8.947
Pondhead C1	Apr-15	Unrestored	39	170	29	5.86	187.6	31	6.05	7	9.75	7.92	62.71	37.04	8.96
Pondhead C1	May-16	Unrestored	39	151	26	5.81	153.8	28	5.49	7.4	10	7.57	52.17	32.05	8.42
Pondhead Downstream	Sep-19	Restored (2018)	23	124	20	6.2	132	21	6.286	8	10.75	7.75	59.091	43.353	8.636
Pondhead DS2	Apr-15	Unrestored	52	213	33	6.46	237.5	36	6.6	6	8.4	7.78	65.22	57	11.52
Pondhead DS2	May-16	Unrestored	48	204	32	6.38	234.5	36	6.51	6.5	8.86	7.84	58.46	47.73	9.31
Pondhead US1	Apr-15	Unrestored	38	166	26	6.39	179.5	28	6.41	6.91	9.46	7.71	60	48.95	11.54
Pondhead US1	May-16	Unrestored	45	179	29	6.17	185.3	31	5.98	6.58	9.08	7.55	51.56	55.86	9.44
Rakes Brakes Downstream	Sep-19	Unrestored	8	31	7	4.429	28.7	8	3.587	9	12	6.33	10	0	1
Redhill/Holmhill Control	Sep-19	Unrestored	14	66	11	6	65.4	11	5.945	0.5	7.5	7.8	30	0	5.25
Redhill/Holmhill Downstream	Sep-19	Unrestored	6	23	6	3.833	22.5	6	3.75	3	5	6	0	19.729	1
Redhill/Holmhill Upstream	Sep-19	Unrestored	10	58	10	5.8	48	10	4.8	0	0	8	0	14.542	0
Slufters	Sep-17	Restored (2015)	36	144	24	6	165.8	28	5.921	6.727	9.182	7.5	51.724	29.295	9.375
Soldiers Bog	Sep-18	Unrestored	17	62	12	5.167	69.6	13	5.354	9	13	8	55.556	21.855	1
Thompson Castle Downstream	Sep-19	Unrestored	17	67	13	5.154	60.5	13	4.654	5.5	7.5	7.5	23.077	20.832	15.714
Thompson Castle Upstream	Sep-19	Unrestored	4	16	4	4	17.5	4	4.375	0	0	0	0	42.28	0
Wootton Control	Sep-19	Unrestored	45	179	29	6.172	213.6	33	6.473	6.9	9.8	7.952	69.048	36.854	9.25
Wootton P1 S1	Oct-15	Unrestored	43	187	29	6.45	214.9	32	6.72	6.56	8.94	8.11	78.57	35.4	10.2
Wootton P1 S1	Mar-16	Unrestored	38	199	31	6.42	223	33	6.76	6.53	8.82	7.96	73.91	43.46	10.42
Wootton P1 S1	Sep-17	Restored (2016)	30	106	22	4.818	126	25	5.04	7	9.714	7	34.375	30.041	3.643
Wootton P1 S1	Sep-18	Restored (2016)	39	143	25	5.72	171.4	28	6.121	7.462	10.077	7.652	65.116	30.524	4.143
Wootton P1 S1	Sep-19	Restored (2016)	29	128	22	5.818	157	26	6.038	7.444	10.222	7.625	56.25	23.385	3.75
Wootton P1 S2	Oct-15	Unrestored	37	158	26	6.08	186.9	29	6.45	6.18	8.64	7.76	63.89	37.39	10.53
Wootton P1 S2	Mar-16	Unrestored	40	167	28	5.96	192.4	31	6.21	6	8.33	7.46	56.82	36.28	17.08
Wootton P1 S2	Sep-17	Unrestored	38	157	27	5.815	185.2	31	5.974	6.909	9.818	7.72	60.87	41.103	12.478
Wootton P1 S2	Sep-18	Unrestored	53	184	31	5.935	211.5	35	6.043	6.333	9	7.593	61.111	36.371	10.8
Wootton P2 S1	Oct-15	Unrestored	30	142	22	6.46	167.5	24	6.98	6.5	8.92	8.11	70.59	36.74	5.81
Wootton P2 S1	Mar-16	Unrestored	40	197	33	5.97	224.8	36	6.24	6.73	9.4	7.93	61.54	37.22	10
Wootton P2 S1	Sep-17	Unrestored	25	121	20	6.05	124.2	20	6.21	7.273	10	8.176	78.378	34.741	4.312
Wootton P2 S1	Sep-18	Unrestored	36	148	25	5.92	163.8	27	6.067	7.125	9.625	7.778	77.143	29.194	14.778
Wootton P2 S1	Sep-19	Unrestored	39	149	25	5.96	175	28	6.25	6.727	9.273	7.737	59.459	31.578	9.25
Wootton P2 S2	Sep-18	Unrestored	13	73	13	5.615	72.9	13	5.608	7	9.5	8.25	87.5	25.537	14.778
Wootton P2 S2	Sep-19	Restored (2018)	28	120	21	5.714	134.6	22	6.118	7.125	9.625	7.214	54.167	30.28	3.857

Observed/Expected RIVPAC Ratio Classification
Very degraded
Moderately degraded
Slightly degraded
Within expected range
Better than expected

. ***Figure 5.2: Macro-invertebrate Response***

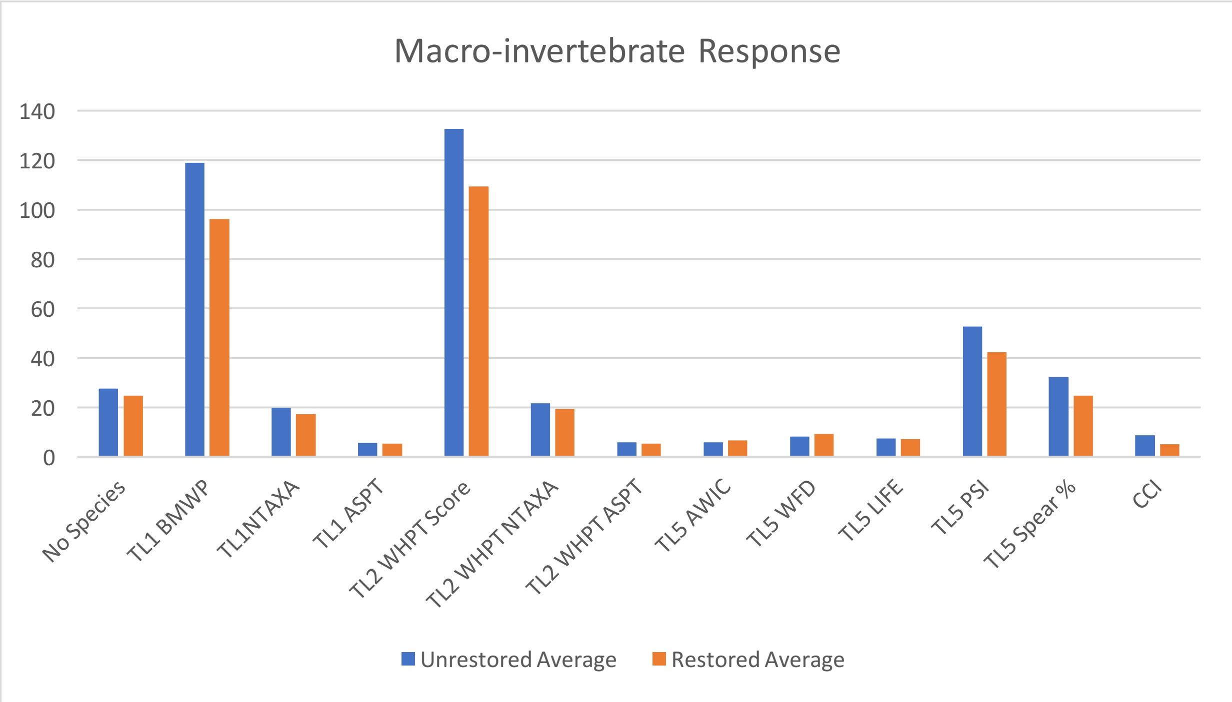


Figure 5.3: Riverfly Average Abundance for 201933 Group Sites

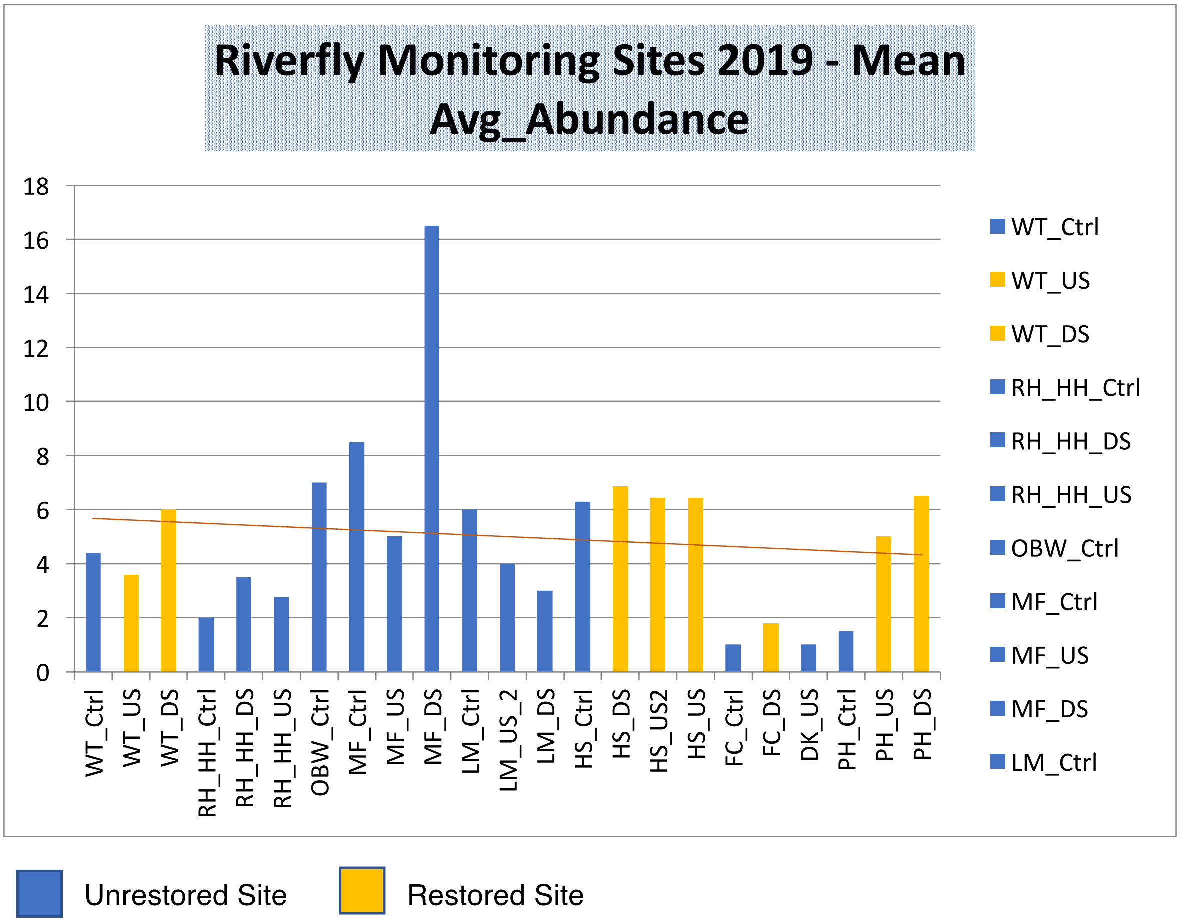


Table 5-5: Summary of Riverfly Logs (All Sites)

Sample Site	Survey Date	Flatworms	Freshwater Snails	Limpets	Bivalves	Aquatic Worms	Leeches	Crayfish	Water Hoglouse	Freshwater Shrimp	Invasive Non-Native Shrimps	Mayflies- Angler's curse	Mayflies - Olives	Mayflies - Prong Gilled	Mayflies - Flatbodied	Mayflies - Green Drake	Mayflies - Blue-Winged Olive	Stoneflies	Dragonflies and Damselflies	Water Boatman	Other Water Bugs	Water Beetles (Adults and Larvae)	Alderflies	Caseless Caddisflies - Green Sedge	Caseless Caddisflies - Net Spinners	Caseless Caddisflies - Non- Gilled	Cased Caddisflies - Hood Case-Maker	Cased Caddisflies - Weight Case-Maker	Cased Caddisflies- Bush tailed Caddisfly	Cased Caddisflies - Other	Craneflies	Blackflies	Non-biting Midges	Water Snipe Flies	Total Count	Score	Mean_Avg
WT_Ctrl	16/05/2019									8			3				3												2						16	4	
WT_Ctrl	06/06/2019						2			8			2				4												1						17	5	
WT_Ctrl	04/07/2019						1			35			2					5																	43	5	
WT_Ctrl	01/08/2019						1			5							2	1															1		10	5	
WT_Ctrl	05/09/2019						1			7								3																	11	3	
		0	0	0	0	0	5	0	0	63	0	0	7	0	0	0	9	9	0	0	0	0	0	0	0	0	0	0	3	0	0	0	1	0			4.40
WT_US	16/05/2019									12			2		1										1								1		17	6	
WT_US	06/06/2019						1			3					1														1						6	4	
WT_US	04/07/2019					1				6			1		1			1																	10	5	
WT_US	01/08/2019									1																									1	1	
WT_US	05/09/2019								1	2																									3	2	
		0	0	0	0	1	1	0	1	24	0	0	3	0	3	0	0	1	0	0	0	0	0	0	1	0	0	0	1	0	0	0	1	0			3.60
WT_DS	16/05/2019									14			5		3			1	1														3		27	7	
WT_DS	06/06/2019									12			3		3		3	6	1						1				1						30	9	
WT_DS	04/07/2019					1				8			1		1			2											2						15	6	
WT_DS	01/08/2019						1			8								12											4		1				26	6	
WT_DS	05/09/2019									6								2																	8	2	
		0	0	0	0	1	1	0	0	48	0	0	9	0	7	0	3	23	2	0	0	0	0	0	1	0	0	0	7	0	1	0	3	0			6.00
RH_HH_Ct	03/07/2019						2														1	2													5	3	
RH_HH_Ct	07/08/2019																		1													10			11	3	
RH_HH_Ct	04/09/2019																																		0	0	
RH_HH_Ct	02/10/2019					1													1																2	2	
		0	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	2	0	1	2	0	0	0	0	0	0	0	0	0	10	0	0			2.00
RH_HH_DS	03/07/2019					2												2	2		1	3								1					11	6	
RH_HH_DS	07/08/2019					2												1	2											5					10	4	
RH_HH_DS	04/09/2019																																		0	0	
RH_HH_DS	02/10/2019		1			3													1											1					6	4	
		0	1	0	0	7	0	0	0	0	0	0	0	0	0	0	0	3	5	0	1	3	0	0	0	0	0	0	0	7	0	0	0	0			3.50
Rh_HH_US	03/07/2019					2																										1			3	2	
Rh_HH_US	07/08/2019																				1									1					2	2	
Rh_HH_US	04/09/2019																				1									1					2	2	
Rh_HH_US	02/10/2019					1												1	1			1										1			5	5	
		0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	1	1	0	2	1	0	0	0	0	0	0	0	2	0	2	0	0			2.75
OBW_Ctrl	03/07/2019					8							2															2		1		1			14	5	
OBW_Ctrl	07/08/2019					6							1				1	1			2									2					13	6	
OBW_Ctrl	04/09/2019					2							5						4			2	2					2		6					23	7	
OBW_Ctrl	02/10/2019		1			4				3			1		1	2							3					1		7			1		24	10	
		0	1	0	0	20	0	0	0	3	0	0	9	0	1	2	1	1	4	0	2	2	5	0	0	0	0	5	0	16	0	1	1	0			7.00
MF_Ctrl	18/07/2019												3				1		1	11	60	2													78	8	
MF_Ctrl	21/08/2019		1										7		2		1		1	8	60	4													84	9	
MF_Ctrl	23/09/2019																10		4	20	60	6											5		105	9	
MF_Ctrl	10/10/2019						1						3				1	5	2	6	60														78	8	
		0	1	0	0	0	1	0	0	0	0	0	13	0	2	0	13	5	8	45	240	12	0	0	0	0	0	0	0	0	0	0	5	0			8.50
MF_US	18/07/2019																		1		3	2													6	3	
MF_US	21/08/2019																		2	3	3	2											1		11	5	
MF_US	23/09/2019																	1	2	5	5	2											5		20	6	
MF_US	10/10/2019					2													1	10	3												2		18	6	
		0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	1	6	18	14	6	0	0	0	0	0	0	0	0	0	0	8	0			5.00
MF_DS	18/07/2019									4			20				1	25	6		5			1					2	8			120		192	14	
MF_DS	21/08/2019		2							6			12				2	10	4	4	1			1		2			3				20		67	15	
MF_DS	23/09/2019						10			6			13				5	20	2		10							1	2	2			200		271	17	
MF_DS	10/10/2019		1			2	10			18			70					20	12		1				6	1			2	1	2		50		196	20	
		0	3	0	0	2	20	0	0	34	0	0	115	0	0	0	8	75	24	4	17	0	0	2	6	3	0	1	9	11	2	0	390	0			16.50
LM_Ctrl	29/07/2019					4	1		25	20																							1		51	7	
LM_Ctrl	29/08/2019	1							26	30										1		1													59	7	
LM_Ctrl	30/09/2019					4			29	8																									41	4	
LM_Ctrl	30/10/2019					7			18	13																							1		39	6	
		1	0	0	0	15	1	0	98	71	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	2	0			6.00
LM_US_2	29/07/2019					2				3									1																6	3	
LM_US_2	29/08/2019								2	4								7																	13	3	
LM_US_2	30/09/2019					3			3	12								7																	25	5	
LM_US_2	30/10/2019						1		7	8								4															3		23	5	
		0	0	0	0	5	1	0	12	27	0	0	0	0	0	0	0	18	1	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0			4.00
LM_DS	29/07/2019									15																									15	2	
LM_DS	29/08/2019									10																									10	2	
LM_DS	30/09/2019									30														2											32	3	
LM_DS	30/10/2019					1	2			40								1																	44	5	
		0	0	0	0	1	2	0	0	95	0	0	0	0	0	0	0	1	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0			3.00
HS_Ctrl	29/04/2019					4	6						1					25	1											10		1			48	9	
HS_Ctrl	20/05/2019					6	5						1					35												10	1				58	8	
HS_Ctrl	24/06/2019					5	1											20											1			1	3		31	7	
HS_Ctrl	22/07/2019					15												3				4									1				23	5	
HS_Ctrl	19/08/2019					5																									1		2		8	3	
HS_Ctrl	23/09/2018					6																							1		1				8	3	
HS_Ctrl	21/10/2019					8	4			1			1					5							1				1	4	1				26	9	
		0	0	0	0	49	16	0	0	1	0	0	3	0	0	0	0	88	1	0	0	4	0	0	1	0	0	0	3	24	5	2	5	0			6.29
HS_DS	29/04/2019					3	3											10	1											1		1			19	7	
HS_DS	20/05/2019					4	3						1					7	1		2									1					19	7	
HS_DS	24/06/2019		1				4											20	1														1		27	6	
HS_DS	22/07/2019																	30															1		31	3	
HS_DS	19/08/2019					1	2											50	1		3					2				2			2		63	9	
HS_DS	23/09/2018					3	1						4					8	1	1					1				2	1					22	9	
HS_DS	21/10/2019		1			4	2						20						1											3					31	7	
		0	2	0	0	15	15	0	0	0	0	0	25	0	0	0	0	125	6	1	5	0	0	0	1	2	0	0	2	8	0	1	4	0			6.86
HS_US2	29/04/2019		1				3											3	2							2				2	1				14	7	
HS_US2	20/05/2019		1			2	2											12	2											3					22	7	
HS_US2	24/06/2019		1			3	3											50	2																59	6	
HS_US2	22/07/2019					1	2											40	2			2													47	6	
HS_US2	19/08/2019						3											40		1	2										1		5		52	7	
HS_US2	23/09/2018						2						3					6																	11	3	
HS_US2	21/10/2019		2			2	10						3					10												5	1				33	9	
		0	5	0	0	8	25	0	0	0	0	0	6	0	0	0	0	161	8	1	2	2	0	0	0	2	0	0	0	10	3	0	5	0			6.43
HS_US	29/04/2019					3	6						3					3												1					16	5	
HS_US	20/05/2019					6	3										1	10																	20	5	
HS_US	24/06/2019					4	1											40	1														9		55	6	
HS_US	22/07/2019		2			3	1											14	4	1													1		26	8	
HS_US	19/08/2019					3	2						2					10	1														2		20	7	
HS_US	23/09/2018					1	1						3					4	1																10	5	
HS_US	21/10/2019		3			4	2						10					10	2												1				32	9	
		0	5	0	0	24	16	0	0	0	0	0	18	0	0	0	1	91	9	1	0	0	0	0	0	0	0	0	0	1	1	0	12	0			6.43
FC_Ctrl	20/06/2019					3																													3	1	
FC_Ctrl	11/07/2019		1			1															2														4	3	
FC_Ctrl	08/08/2019																																		0	0	
FC_Ctrl	13/09/2019																																		0	0	
FC_Ctrl	10/10/2019																			1															1	1	
		0	1	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0			1.00
FC_DS	20/06/2019		2			3												1	1		1	4													12	6	
FC_DS	11/07/2019																				2	30													32	3	
FC_DS	08/08/2019																																		0	0	
FC_DS	13/09/2019																																		0	0	
FC_DS	10/10/2019																																		0	0	
		0	2	0	0	3	0	0	0	0	0	0	0	0	0	0	0	1	1	0	3	34	0	0	0	0	0	0	0	0	0	0	0	0			1.80
DK_US	16/08/2019																																		0	0	
DK_US	21/09/2019									58								2																	60	3	
DK_US	04/10/2019																																		0	0	
		0	0	0	0	0	0	0	0	58	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			1.00
PH_Ctrl	14/06/2019	0	0	0	0	0	0	0	9	325	0	0	1	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	6	0	2	5	0	350	10	1.50
PH_US	14/06/2019	0	0	0	0	0	0	0	1	23	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	27	3	5.00
PH_DS	14/06/2019	0	0	0	0	0	0	0	6	19	0	0	0	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	4	0	1	0	0	33	7	6.50
		0	0	0	0	0	0	0	16	367	0	0	1	0	0	0	2	2	0	0	0	1	0	1	0	0	0	0	0	10	0	3	7	0			

Figures 5.4 a-h graph the Biotic Indices for a range of sites. For certain sites, notably Cowleys Heath, Ferny Croft, Harvestlade, Pondhead and Wootton Phase 2 where there are records for pre and post restoration it is possible to observe and compare short-term changes in the biotic indices pre and post restoration. Records for Harvestlade and Wootton Phase 1 allow observation over 3 to 4 years. However, the records for Latchmore and Millersford show how non-restored, undisturbed sites naturally vary from year to year therefore a degree of caution is required in trying to interpret the results too precisely.

Research has shown that a number of environmental factors can affect trends in diversity and density of macro-invertebrate communities. Substrate and water quality significantly influence species diversity and abundance but other factors such as the presence of marginal and in-channel macrophytes or un-grazed banksides and tree cover and biotic influences such as trout predation can all influence the macro-invertebrate community.

Results are conclusive in showing that the macro-invertebrate population does show a significant decline within the first year or two following restoration with marked declines in species diversity and abundance. This is to be expected, especially where new, sterile channel sections are created and require re-population. Where possible the substrate from the old channel is translocated to the new channel to try and help re-population of the new channel but much of the former population is likely to be lost. BUG analysis from shortly before and after restoration in 2015/2016 shows the immediate impact on taxa at Cowleys and Harvestlade (refer to Figure5.4a & c and Figure 5.5).

Ferny Croft, which is surrounded by good quality mire habitat is one site which does not show such marked declines and indeed the restored site shows better diversity than the unrestored control site within the first year. This is evident in both the BUG and Riverfly data (refer to Figures 5.4b and 5.6) However, it can also be noted that Ferny Croft was not a particularly diverse site to start with BUG species data listing 7 species recorded in the control site and 10 species recorded in the restored section with snails and water beetles adding to the diversity of the latter. The PSI index suggests that the control site is highly degraded due to sedimentation and the restored site moderately degraded due to sedimentation which may be a key factor in explaining why the restored site is slightly more diverse.

BUG & RIverfly records for Harvestlade,(Figures 5.4c Table 5-6, 5-7 & 5-8) and Wootton Phase 1 (Figures 5.4g, Table 5-7, Table 5-8) allow observation over a period of 3 to 4 years and these sites do seem to be showing trends toward recovery in terms of population recovery. However, the 2019 BUG Survey still considered the Observed/Expected ratio indices when analyses against RIVPACS to be:

- Harvestlade Control – Slightly degraded
- Harvestlade Site 1 –Very degraded
- Harvestlade Site 2 – Slightly degraded

- Wootton Phase 1 – Site 1 – Most indices within expected range but still some slight degradation in relation to sediment stressors (PSI) and moderate degradation with regard to conservation value (CCI)
- Wooton Phase 1 – Site 2 (Wootton Control 2019) – Within expected range

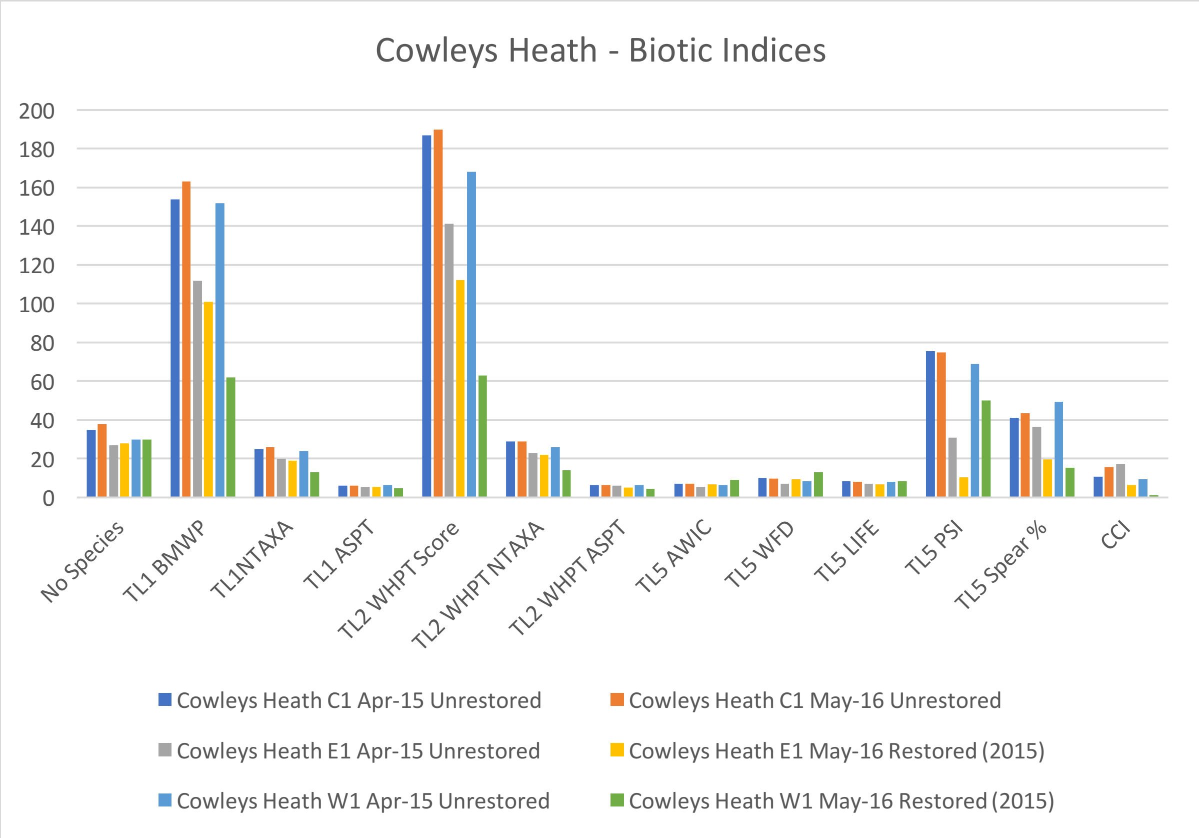
Nevertheless, at Harvestlade both the Riverfly and BUG species survey data seems to be showing signs of recovery with the former showing particular trends in species group recovery (Figure 5.7, Table 5-6, Table 5-7). Stoneflies, Mayflies (Olives) and Dragonflies &

Damselfly populations are all outperforming the control site and the Leech group has also recovered. However, Cased Caddisflies have not yet recovered with numbers at restored sites less than half that of the control site. Stoneflies appear to have particularly benefited from the restoration. The substrate is likely in part to account for these trends as Stoneflies require highly oxygenated water and a stony substrate. Table 5-9 records site environmental parameters and it is noticeable that smaller substrate sizes (e.g. sand & silt) and detritus is lacking at Harvestlade which caddisfly like to use to form their cases.

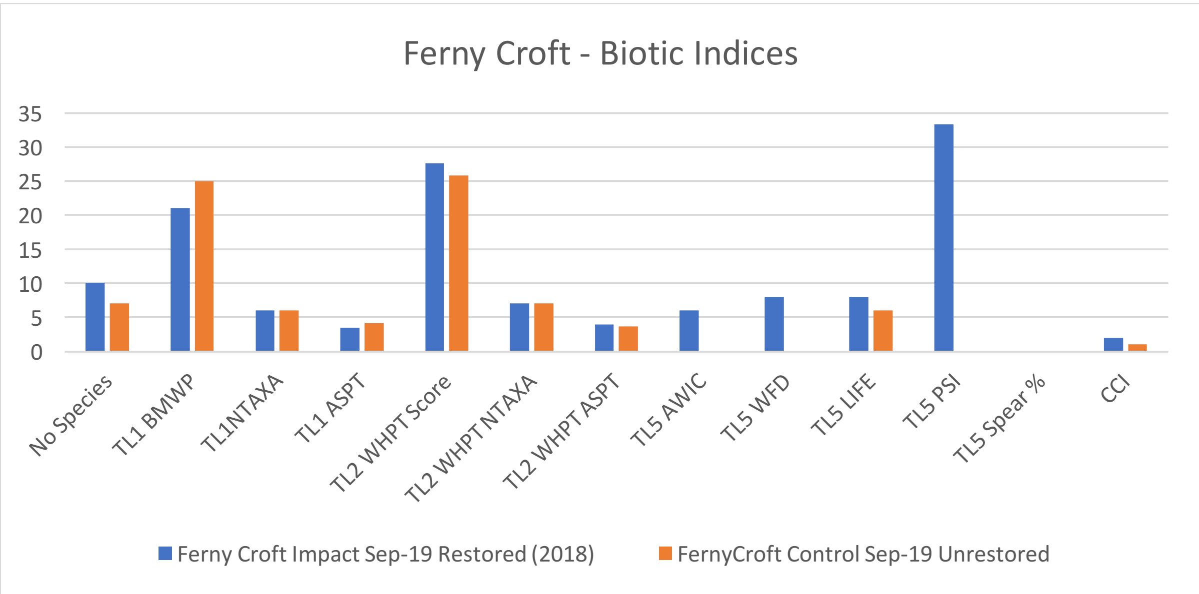
Further observation of the 33 Group monthly results (Figures 5.11a-h) also seems to show marked seasonal variations across all sites. At unrestored sites abundance values are generally lower during the summer months with lowest values occurring around July when water levels are lower and temperatures higher. Control sites that are generally in better condition than the reaches due to be restored tend to show higher comparative values. At restored sites, for example Harvestlade and Wootton, differences are not as marked and certain species groups show higher abundance trends during the late summer and early autumn at restored sample sites compared to their control sites and or unrestored sites. This tentatively suggests that restored sites could be more robust during times of low flow and higher summer temperatures but further monitoring and analysis will be required to evaluate this theory further.

Figure 5.4: Biotic Indices for Individual Sites

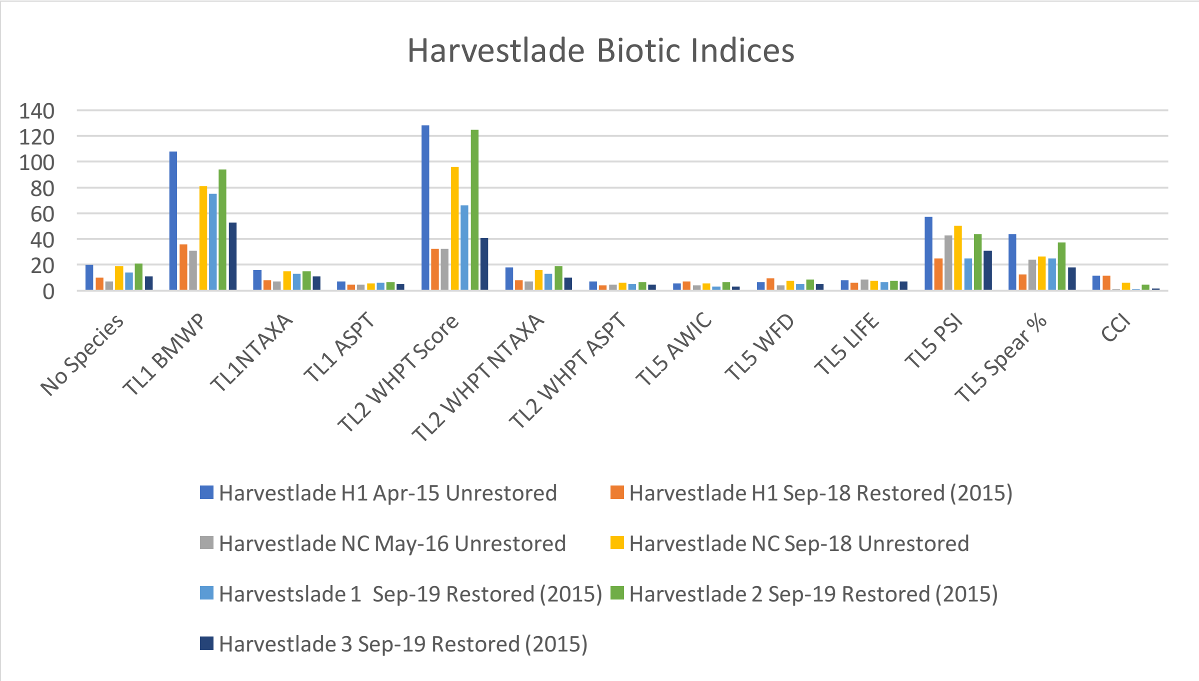
a)



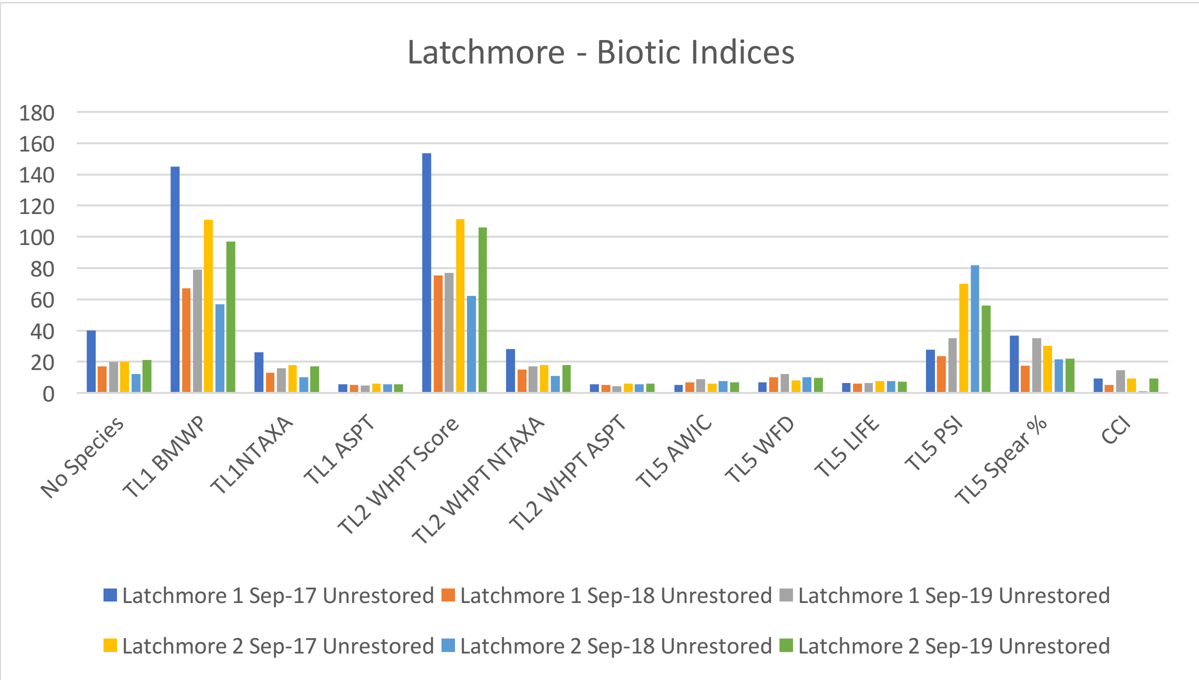
b)



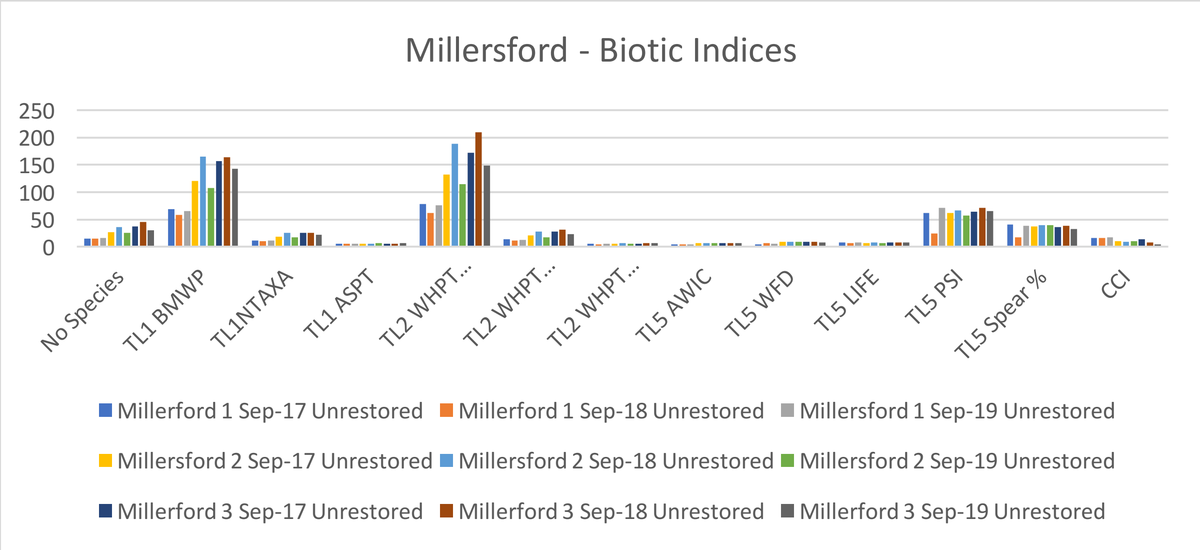
c)


Harvestlade Biotic Indices
140
120
100
80
60
40
20
0
No Species
TL1 BMWP
TL1NTAXA
TL1 ASPT
TL2 WHPT Score
TL2 WHPT NTAXA
TL2 WHPT ASPT
TL5 AWIC
TL5 WFD
TL5 LIFE
TL5 PSI
TL5 Spear %
CCI
Harvestlade H1 Apr-15 Unrestored
Harvestlade H1 Sep-18 Restored (2015)
Harvestlade NC May-16 Unrestored
Harvestlade NC Sep-18 Unrestored
Harvestslade 1 Sep-19 Restored (2015)
Harvestlade 2 Sep-19 Restored (2015)
Harvestlade 3 Sep-19 Restored (2015)

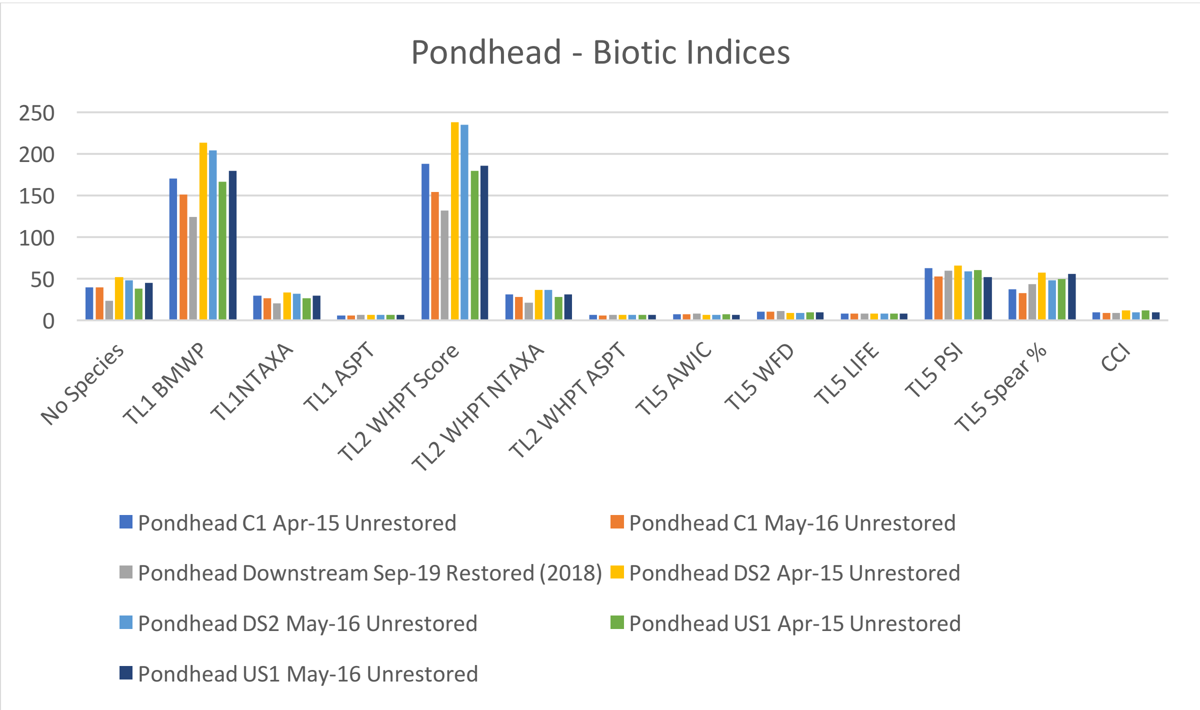
d)


Latchmore - Biotic Indices
180
160
140
120
100
80
60
40
20
0
No Species
TL1 BMWP
TL1NTAXA
TL1 ASPT
TL2 WHPT Score
TL2 WHPT NTAXA
TL2 WHPT ASPT
TL5 AWIC
TL5 WFD
TL5 LIFE
TL5 PSI
TL5 Spear %
CCI
Latchmore 1 Sep-17 Unrestored
Latchmore 1 Sep-18 Unrestored
Latchmore 1 Sep-19 Unrestored
Latchmore 2 Sep-17 Unrestored
Latchmore 2 Sep-18 Unrestored
Latchmore 2 Sep-19 Unrestored

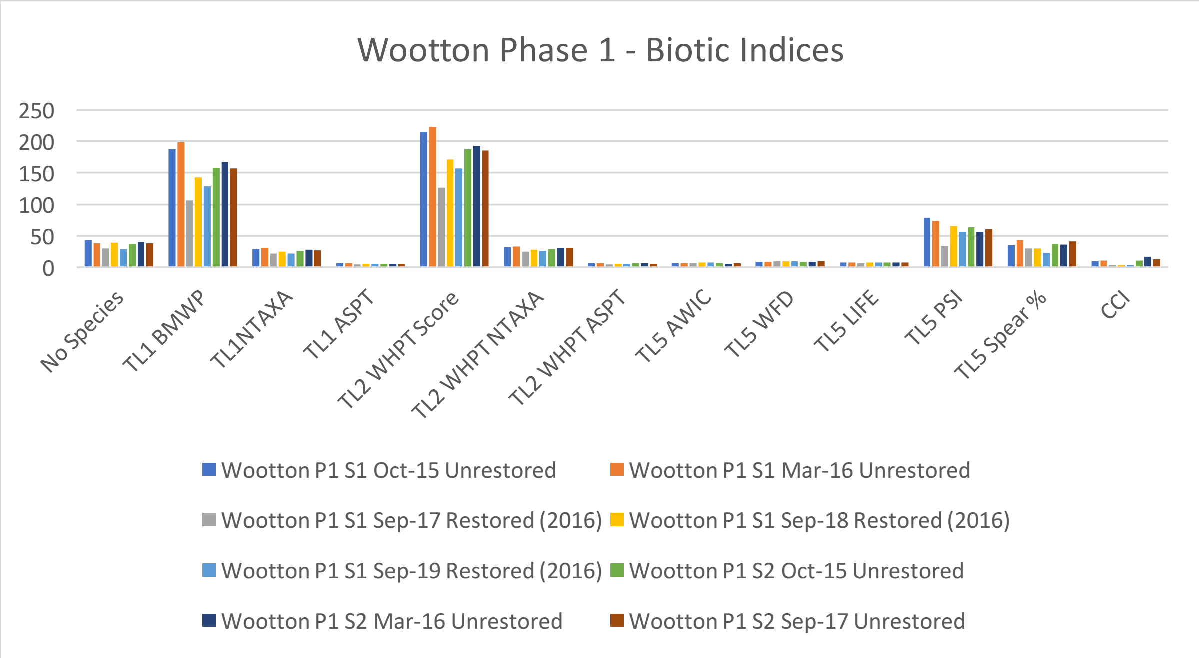
e)


Millersford - Biotic Indices
250
200
150
100
50
0
No Species
TL1 BMWP
TL1NTAXA
TL1 ASPT
TL2 WHPT...
TL2 WHPT...
TL2 WHPT...
TL5 AWIC
TL5 WFD
TL5 LIFE
TL5 PSI
TL5 Spear %
CCI
Millerford 1 Sep-17 Unrestored
Millerford 1 Sep-18 Unrestored
Millersford 1 Sep-19 Unrestored
Millersford 2 Sep-17 Unrestored
Millersford 2 Sep-18 Unrestored
Millersford 2 Sep-19 Unrestored
Millerford 3 Sep-17 Unrestored
Millerford 3 Sep-18 Unrestored
Millerford 3 Sep-19 Unrestored

f)

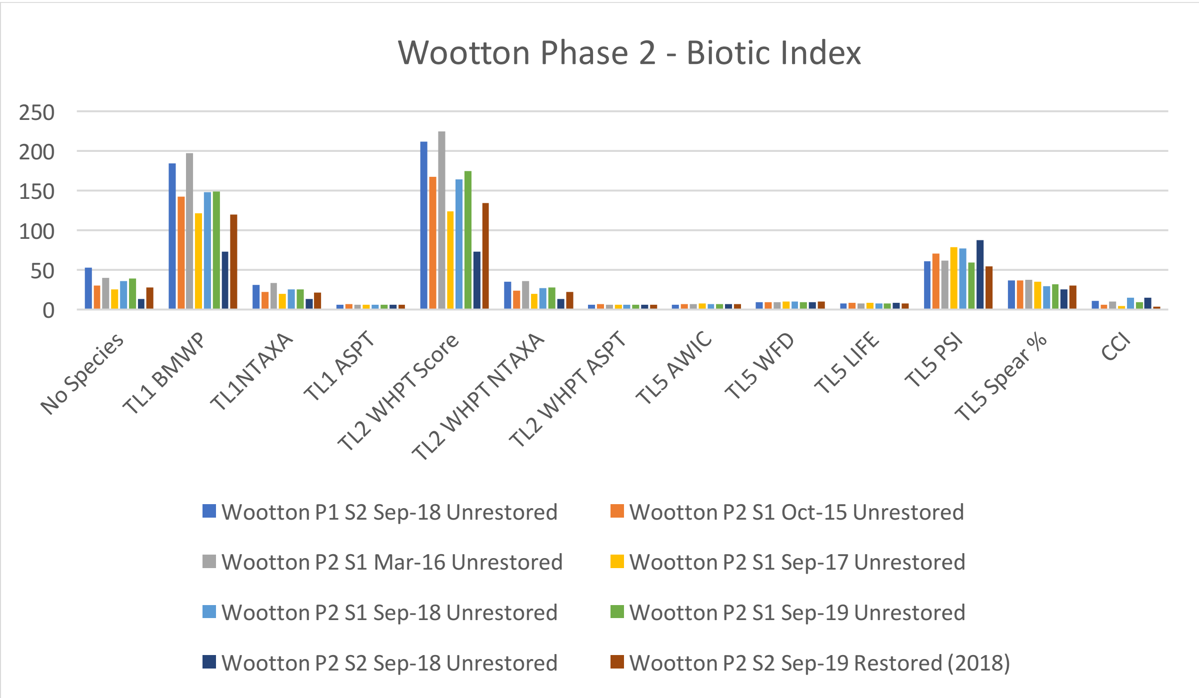

Pondhead - Biotic Indices
250
200
150
100
50
0
No Species
TL1 BMWP
TL1NTAXA
TL1 ASPT
TL2 WHPT Score
TL2 WHPT NTAXA
TL2 WHPT ASPT
TL5 AWIC
TL5 WFD
TL5 LIFE
TL5 PSI
TL5 Spear %
CCI
Pondhead C1 Apr-15 Unrestored
Pondhead C1 May-16 Unrestored
Pondhead Downstream Sep-19 Restored (2018)
Pondhead DS2 Apr-15 Unrestored
Pondhead DS2 May-16 Unrestored
Pondhead US1 Apr-15 Unrestored
Pondhead US1 May-16 Unrestored

g)



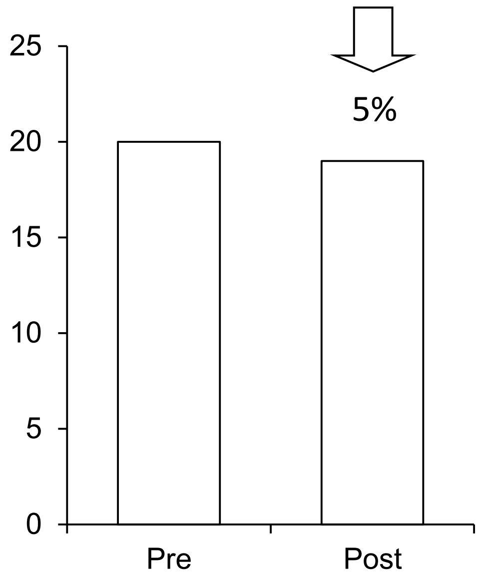
Wootton Phase 1 - Biotic Indices
250
200
150
100
50
0
No Species
TL1 BMWP
TL1NTAXA
TL1 ASPT
TL2 WHPT Score
TL2 WHPT NTAXA
TL2 WHPT ASPT
TL5 AWIC
TL5 WFD
TL5 LIFE
TL5 PSI
TL5 Spear %
CCI
Wootton P1 S1 Oct-15 Unrestored
Wootton P1 S1 Mar-16 Unrestored
Wootton P1 S1 Sep-17 Restored (2016)
Wootton P1 S1 Sep-18 Restored (2016)
Wootton P1 S1 Sep-19 Restored (2016)
Wootton P1 S2 Oct-15 Unrestored
Wootton P1 S2 Mar-16 Unrestored
Wootton P1 S2 Sep-17 Unrestored

h)

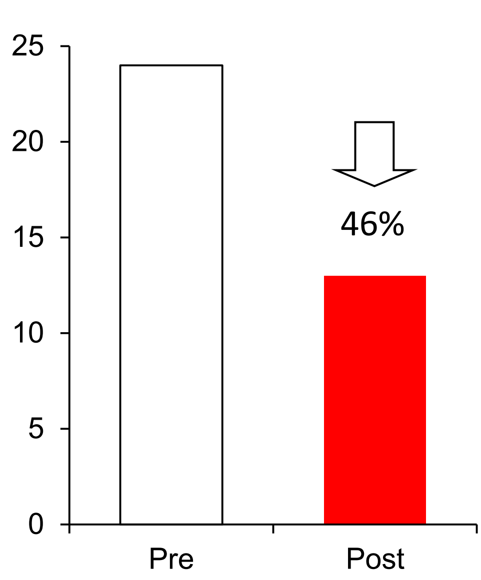


Wootton Phase 2 - Biotic Index
250
200
150
100
50
0
No Species
TL1 BMWP
TL1NTAXA
TL1 ASPT
TL2 WHPT Score
TL2 WHPT NTAXA
TL2 WHPT ASPT
TL5 AWIC
TL5 WFD
TL5 LIFE
TL5 PSI
TL5 Spear %
CCI
Wootton P1 S2 Sep-18 Unrestored
Wootton P2 S1 Oct-15 Unrestored
Wootton P2 S1 Mar-16 Unrestored
Wootton P2 S1 Sep-17 Unrestored
Wootton P2 S1 Sep-18 Unrestored
Wootton P2 S1 Sep-19 Unrestored
Wootton P2 S2 Sep-18 Unrestored
Wootton P2 S2 Sep-19 Restored (2018)

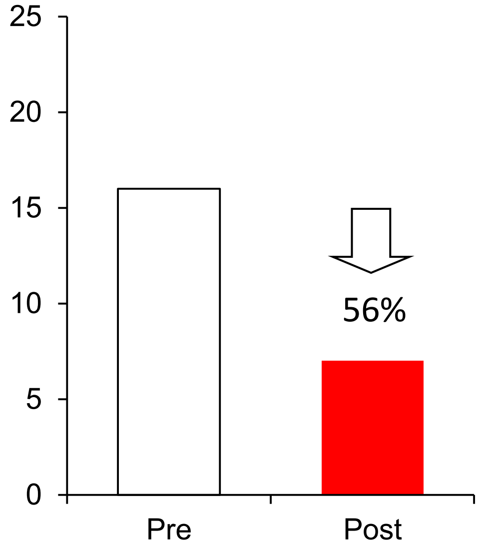
Figure 5.5: BUG Comparison of pre and post restoration changes in the number of invertebrate families (NTAXA) at A) Cowleys Heath East; B) and Cowleys Heath West; and C) Harvestslade old channel vs. new channel. Pre and Post samples taken 27 April 2015 and 17 May 2016 respectively.



A) Cowleys Heath East

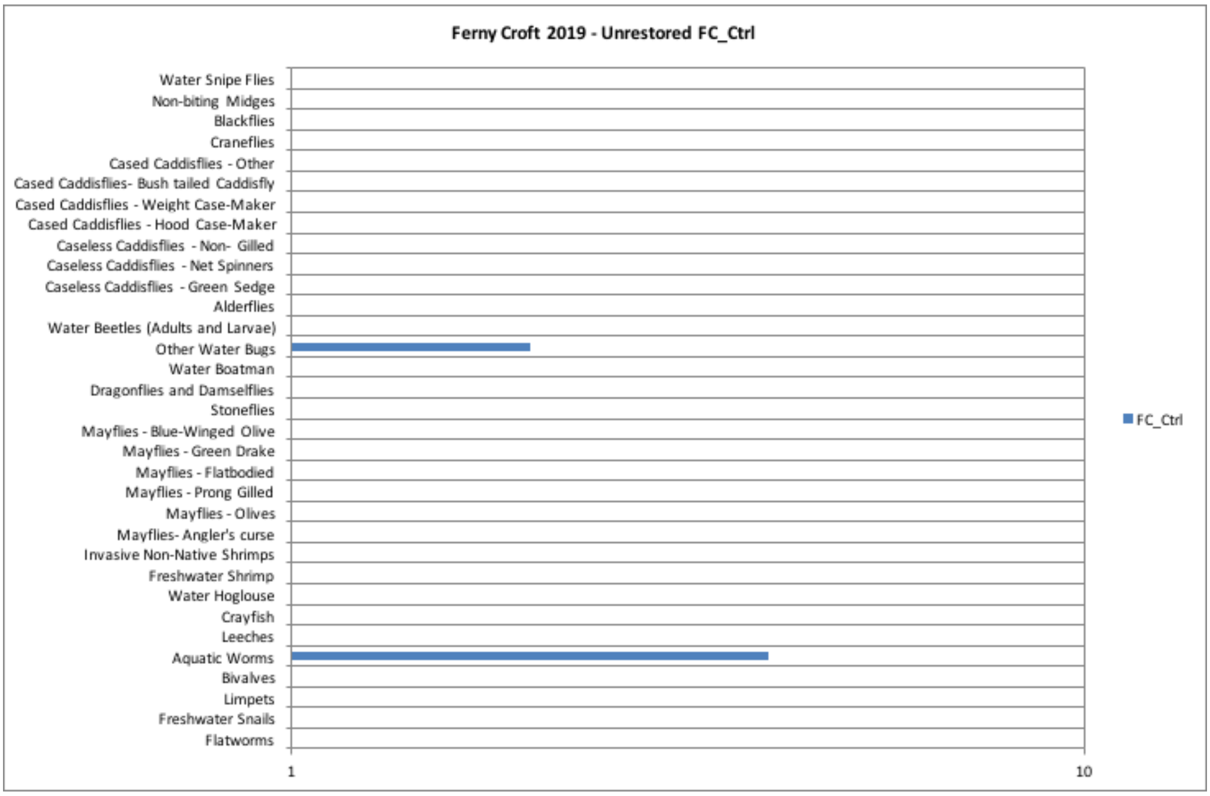


B) Cowleys Heath West



C) Harvestslade old vs. new channel

Figure 5.6: Ferny Croft 2019 Riverfly Group 33 Results



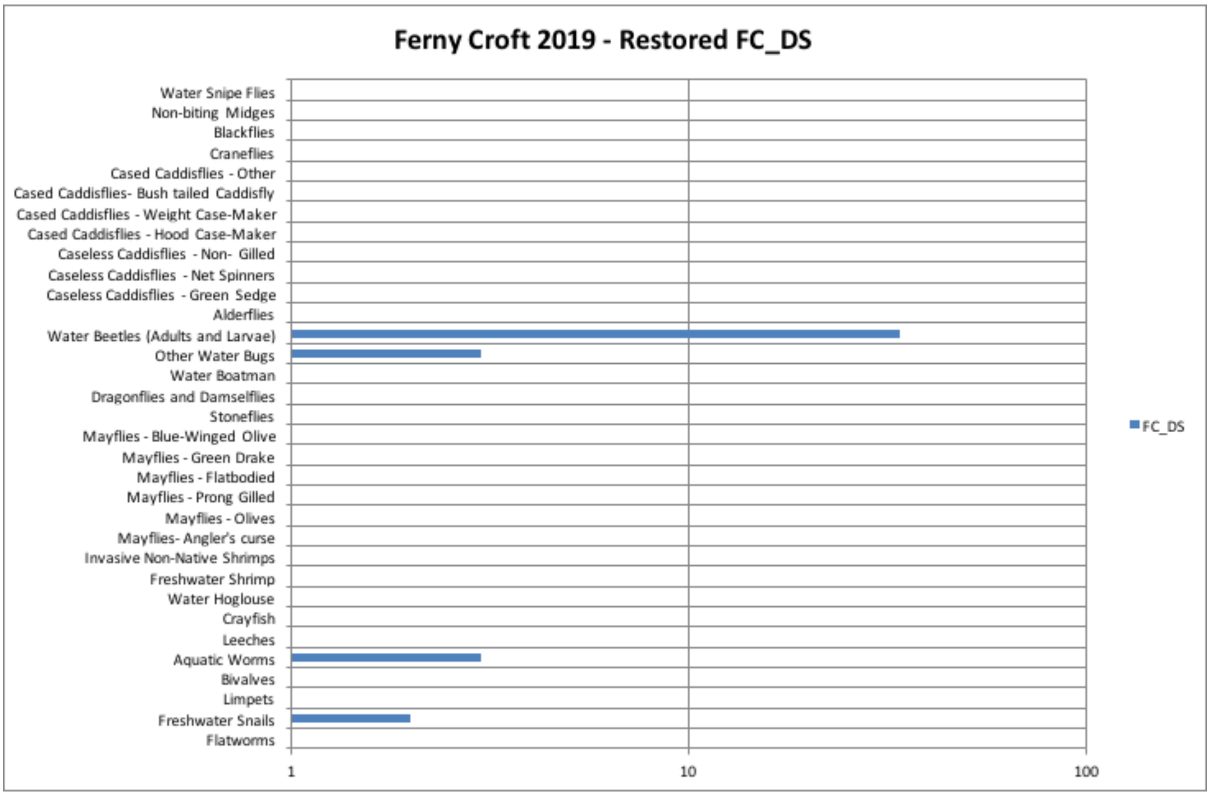


Table 5-6: Harvestlade 2019 - 33 Group Scores

TAXA		HS_Ctrl	HS_DS	HS_US_1	HS_US_2
1	Flatworms	0	0	0	0
2	Freshwater Snails	0	2	5	5
3	Limpets	0	0	0	0
4	Bivalves	0	0	0	0
5	Aquatic Worms	49	15	8	24
6	Leeches	16	15	25	16
7	Crayfish	0	0	0	0
8	Water Hoglouse	0	0	0	0
9	Freshwater Shrimp	1	0	0	0
10	Invasive Non-Native Shrimps	0	0	0	0
11	Mayflies- Angler's curse	0	0	0	0
12	Mayflies - Olives	3	25	6	18
13	Mayflies - Prong Gilled	0	0	0	0
14	Mayflies - Flatbodied	0	0	0	0
15	Mayflies - Green Drake	0	0	0	0
16	Mayflies - Blue-Winged Olive	0	0	0	1
17	Stoneflies	88	125	161	91
18	Dragonflies and Damselflies	1	6	8	9
19	Water Boatman	0	1	1	1
20	Other Water Bugs	0	5	2	0
21	Water Beetles (Adults and Larvae)	4	0	2	0
22	Alderflies	0	0	0	0
23	Caseless Caddisflies - Green Sedge	0	0	0	0
24	Caseless Caddisflies - Net Spinners	1	1	0	0
25	Caseless Caddisflies - Non- Gilled	0	2	2	0
26	Cased Caddisflies - Hood Case-Maker	0	0	0	0
27	Cased Caddisflies - Weight Case-Maker	0	0	0	0
28	Cased Caddisflies- Bush tailed Caddisfly	3	2	0	0
29	Cased Caddisflies - Other	24	8	10	1
30	Craneflies	5	0	3	1
31	Blackflies	2	1	0	0
32	Non-biting Midges	5	4	5	12
33	Water Snipe Flies	0	0	0	0
	TOTAL TAXA	13	14	13	11

Figure 5.7: Riverfly 33 Group Survey Results for Harvestlade 2019

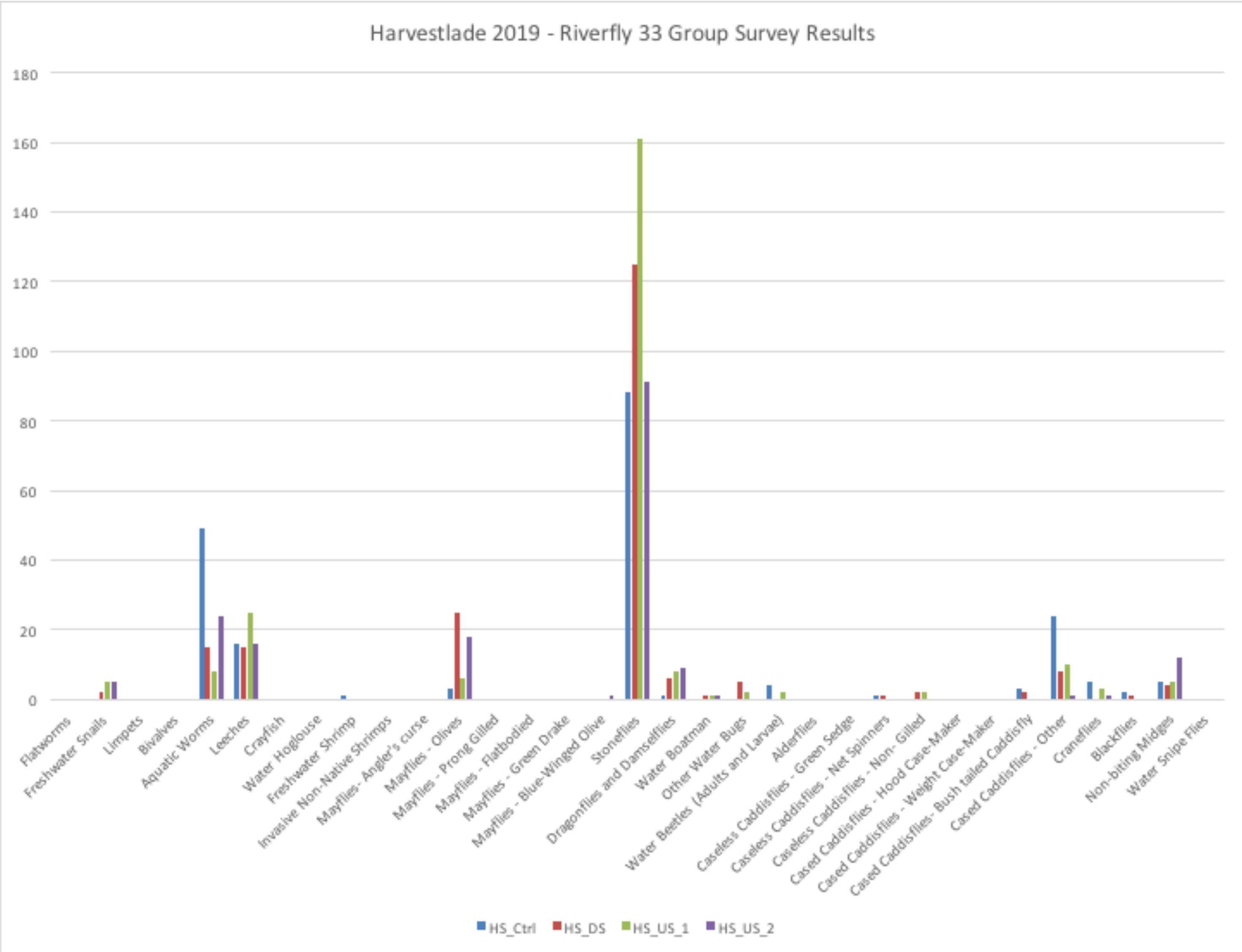


Table 5-7: Wootton 2019 - 33 Group Scores

TAXA	WT_Ctrl	WT_US	WT_DS
Flatworms	0	0	0
Freshwater Snails	0	0	0
Limpets	0	0	0
Bivalves	0	0	0
Aquatic Worms	0	1	1
Leeches	5	1	1
Crayfish	0	0	0
Water Hoglouse	0	1	0
Freshwater Shrimp	63	24	48
Invasive Non-Native Shrimps	0	0	0
Mayflies- Angler's curse	0	0	0
Mayflies - Olives	7	3	9
Mayflies - Prong Gilled	0	0	0
Mayflies - Flatbodied	0	3	7
Mayflies - Green Drake	0	0	0
Mayflies - Blue-Winged Olive	9	0	3
Stoneflies	9	1	23
Dragonflies and Damselflies	0	0	2
Water Boatman	0	0	0
Other Water Bugs	0	0	0
Water Beetles (Adults and Larvae)	0	0	0
Alderflies	0	0	0
Caseless Caddisflies - Green Sedge	0	0	0
Caseless Caddisflies - Net Spinners	0	1	1
Caseless Caddisflies - Non- Gilled	0	0	0
Cased Caddisflies - Hood Case-Maker	0	0	0
Cased Caddisflies - Weight Case-Maker	0	0	0
Cased Caddisflies- Bush tailed Caddisfly	3	1	7
Cased Caddisflies - Other	0	0	0
Craneflies	0	0	1
Blackflies	0	0	0
Non-biting Midges	1	1	3
Water Snipe Flies	0	0	0
TOTAL TAXA	97	37	106

Figure 5.8: Wootton 2019 - 33 Group Scores

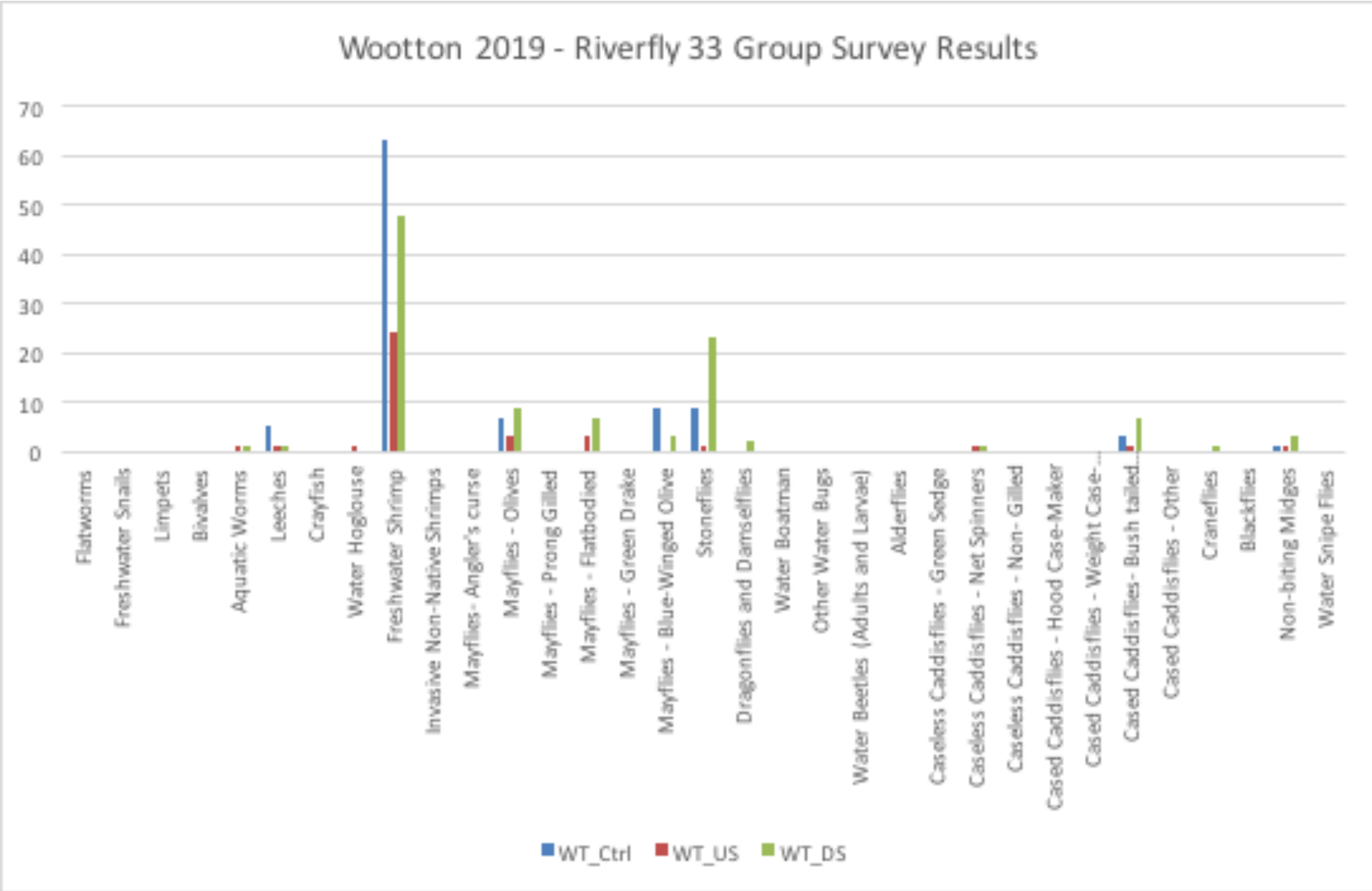


Table 5-8: Harvestlade Group 8 Average Species Scores

Survey Year 2015	HS_DS Restored?	HS_US2 Restored?	HS_US1 Restored?
Stonefly	37	65	0
Olive	0		0
Blue Winged Olive	1		0
Mayfly	0		1
Gammarus	0		8
Cased Caddis	3		0
Caseless caddis	2	3	3
Flat Bodied hepta	0		0
Survey Year 2016	**HS_DS Restored**	**HS_US2 Restored**	**HS_US1 Restored**
Stonefly	112	6	0
Olive	1	7	15
Blue Winged Olive	0	0	0
Mayfly	0	2	0
Gammarus	0	0	0
Cased Caddis	0	0	0
Caseless caddis	1	0	6
Flat Bodied hepta	0	0	0
Survey Year 2017	**HS_DS Restored**	**HS_US2 Restored**	**HS_US1 Restored**
Stonefly	115	242	36
Olive	21	33	130
Blue Winged Olive	2	0	0
Mayfly	1	1	5
Gammarus	0	0	1
Cased Caddis	3	1	1
Caseless caddis	6	1	0
Flat Bodied hepta	1	1	7
Survey Year 2018	**HS_DS Restored**	**HS_US2 Restored**	**HS_US1 Restored**
Stonefly	128	96	58
Olive	169	152	86
Blue Winged Olive	2	10	3
Mayfly	4	0	5
Gammarus	0	0	0
Cased Caddis	7	0	0
Caseless caddis	3	3	3
Flat Bodied hepta	0	0	0

Figure 5.9: Harvestlade Riverfly Group 8 Annual Survey Results

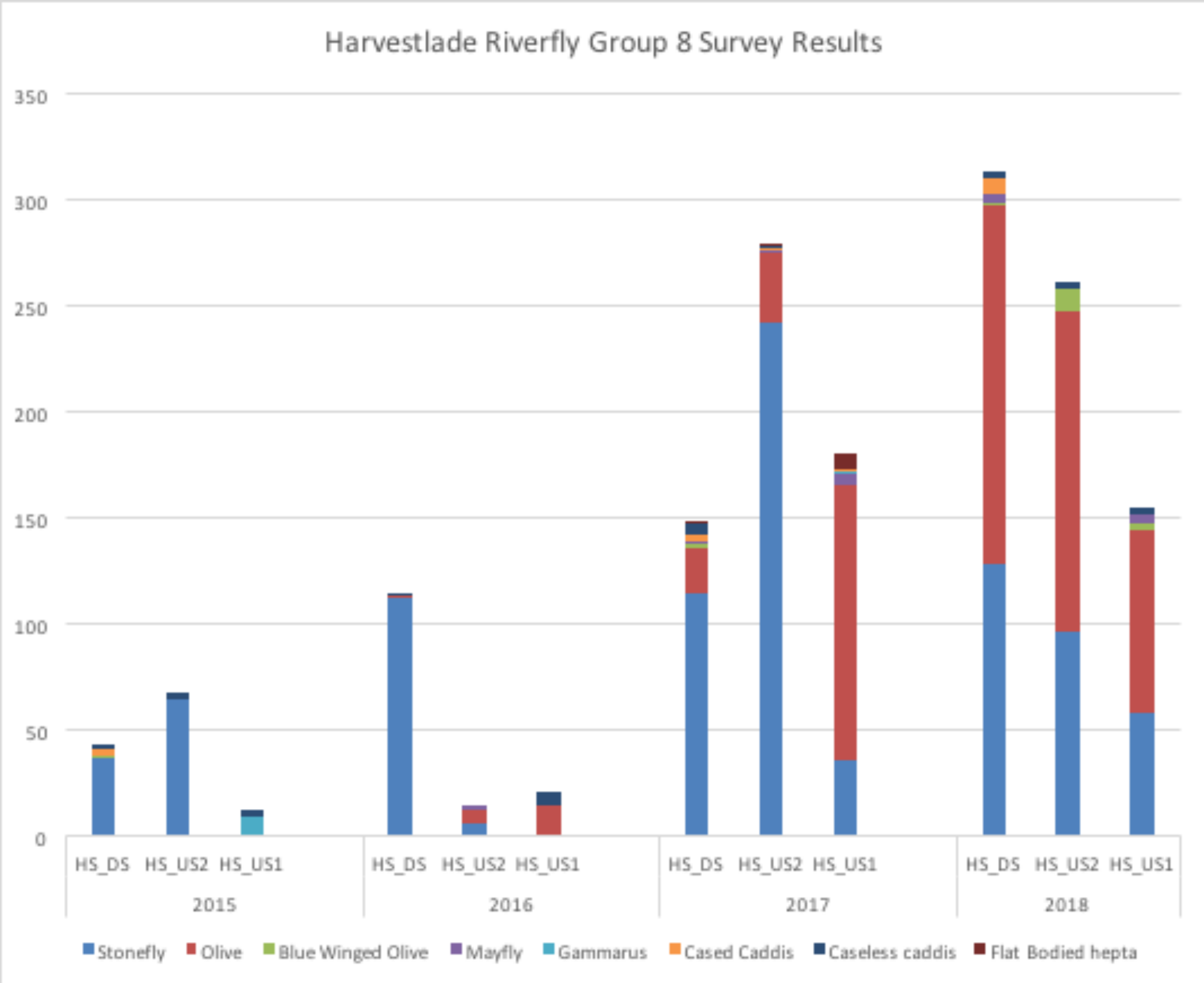


Table 5-8: Wootton – Riverfly Group 8 Survey Results

	WT_US1	US2	WT_US3	DS1	DS2	DS3	WT_DS4
Survey Year - 2016	**Control**	**Partial Restoration**	**Partial Restoration**	**Control**	**Unrestored**	**Unrestored**	**Unrestored**
Cased Caddisfly	3	0	0	1	6	8	0
Caseless Cadisfly	2	3	0	0	0	0	0
Mayfly	0	0	1	0	0	0	0
Blue Winged Olive	0	0	0	0	0	0	0
Flat Bodied Hepta	0	0	0	0	0	1	0
Olives	1	15	3	1	10	6	1
Stoneflies	3	1	0	0	2	0	1
Freshwater Shrimp	120	26	42	59	63	149	30
	WT_US1	**US2**	**WT_US3**	**DS1**	**DS2**	**DS3**	**WT_DS4**
Survey Year - 2017	**Control**	**Restored**	**Restored**	**Control**	**Unrestored**	**Unrestored**	**Unrestored**
Cased Caddisfly	7	29	3	2	12	9	30
Caseless Cadisfly	0	3	0	2	3	1	0
Mayfly	0	2	0	0	0	0	0
Blue Winged Olive	3	20	54	13	96	7	7
Flat Bodied Hepta	0	1	2	11	2	1	8
Olives	13	34	68	9	233	47	27
Stoneflies	4	18	4	5	11	15	11
Freshwater Shrimp	140	84	84	138	380	259	115
	WT_US1	**US2**	**WT_US3**	**DS1**	**DS2**	**DS3**	**WT_DS4**
Survey Year - 2018	**Control**	**Restored**	**Restored**	**Control**	**Restored**	**Restored**	**Unrestored**
Cased Caddisfly	12	46	5	1	4	11	19
Caseless Cadisfly	1	0	0	0	0	1	0
Mayfly	0	1	2	0	0	0	1
Blue Winged Olive	17	27	38	18	78	33	16
Flat Bodied Hepta	1	2	0	1	0	1	6
Olives	59	59	10	14	98	38	13
Stoneflies	11	20	6	4	4	16	16
Freshwater Shrimp	261	159	49	66	113	149	155

Figure 5.10: Wootton Riverfly Group 8 Annual Survey Results

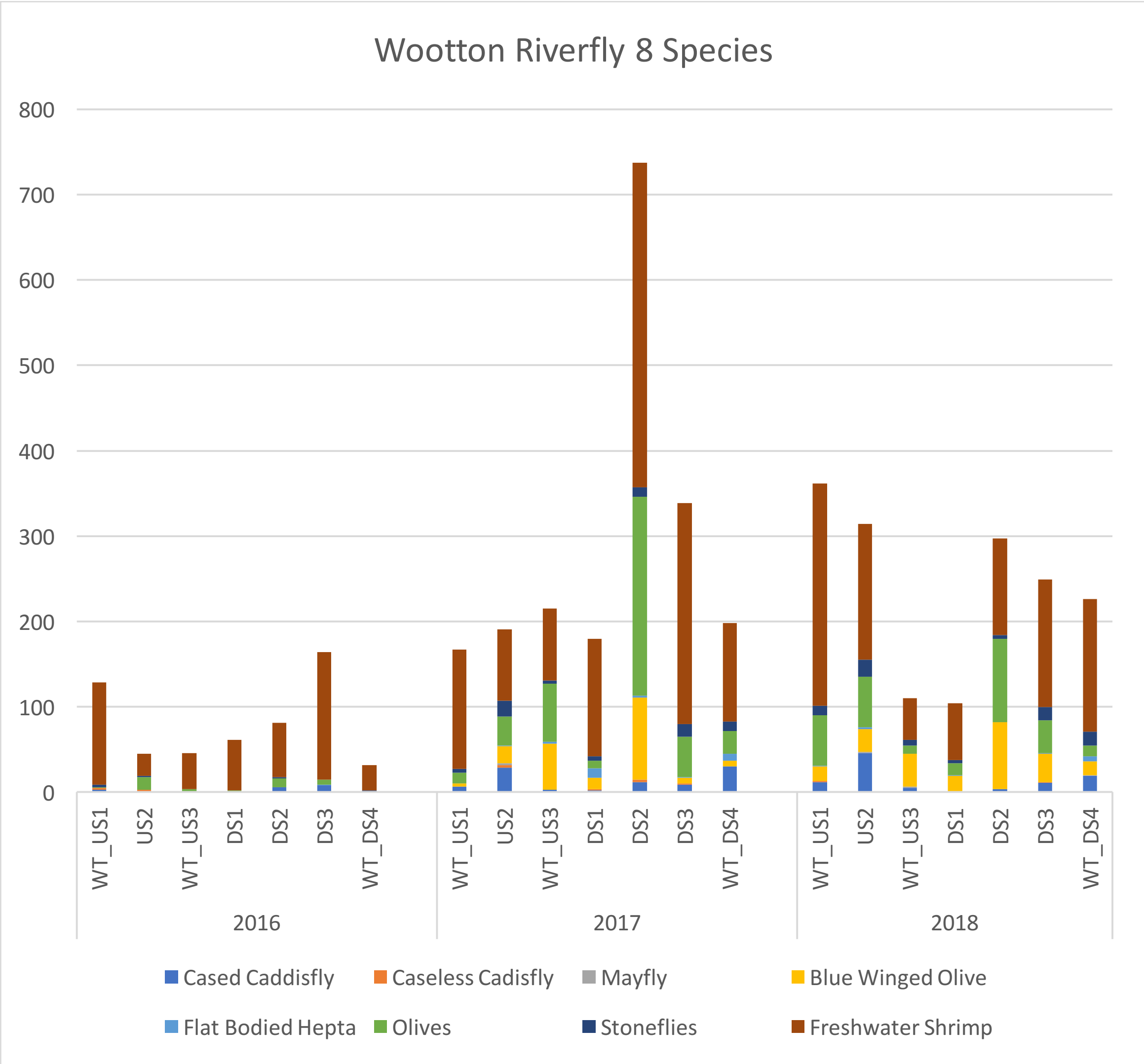
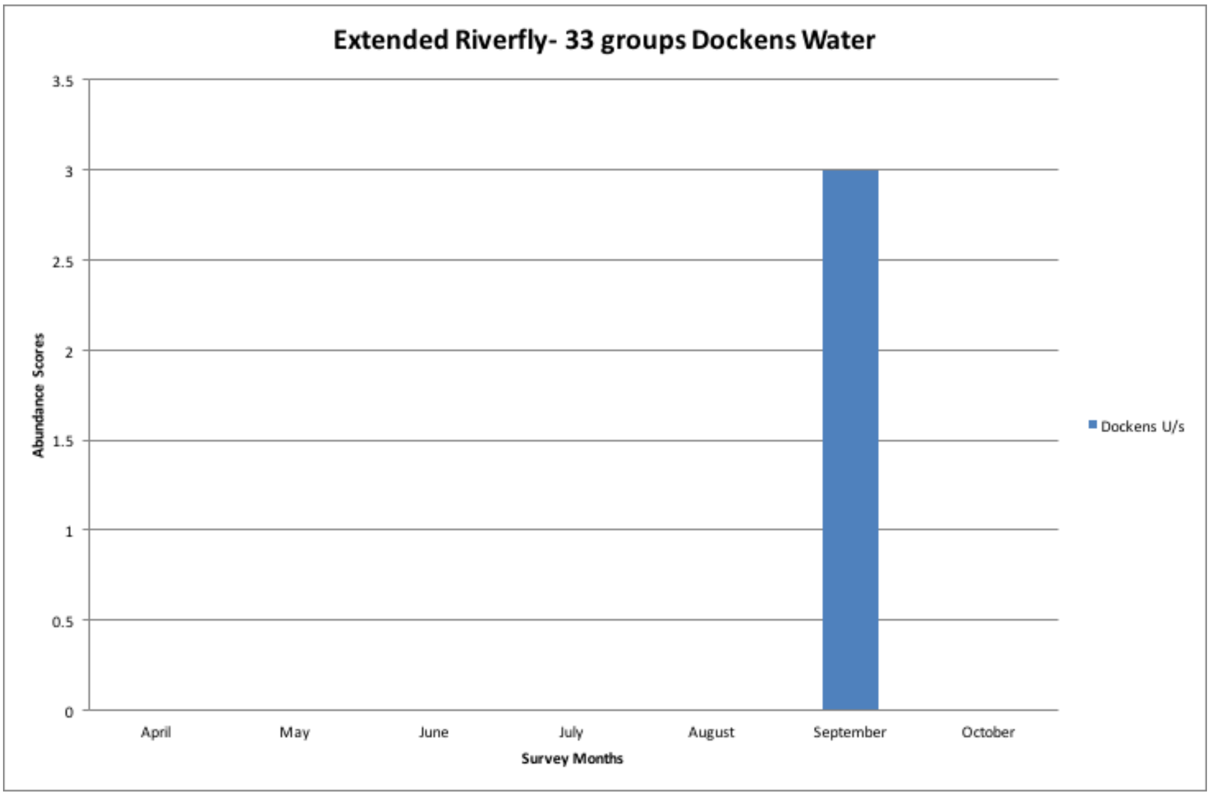
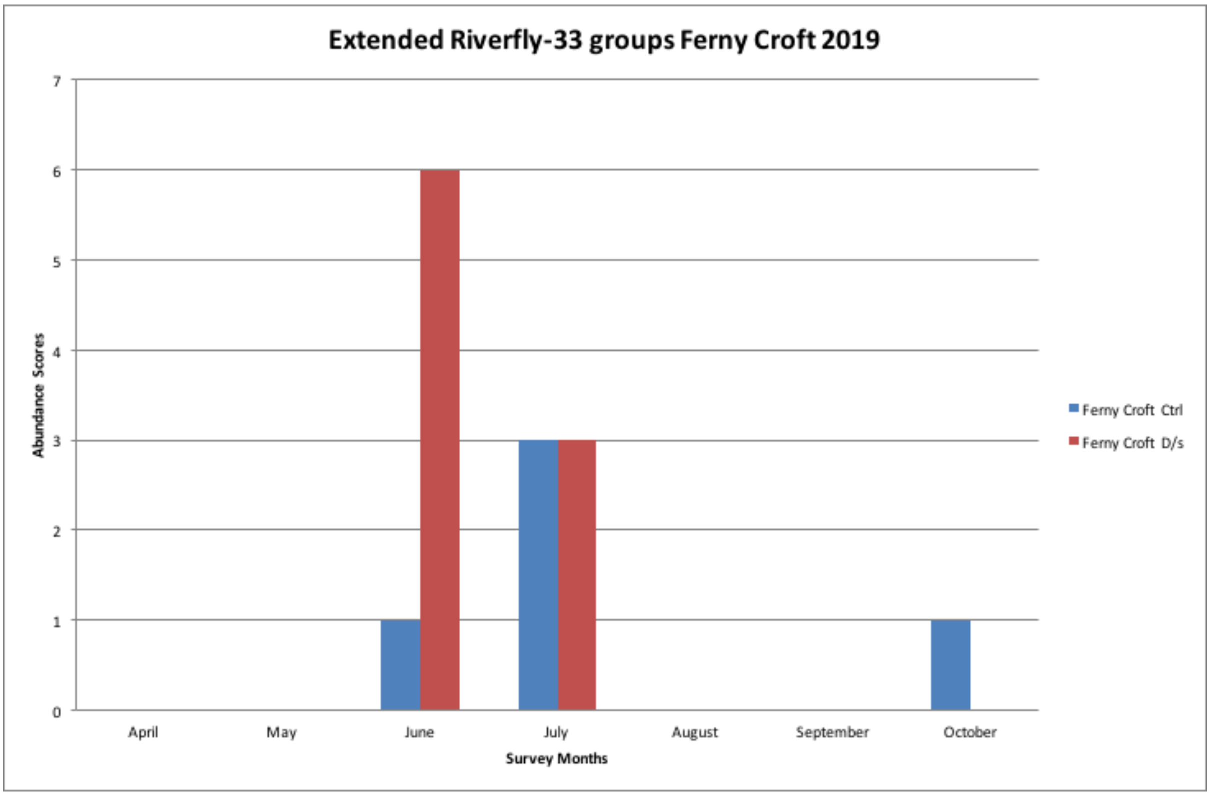


Figure 5.11: Riverfly Monthly Abundance Scores

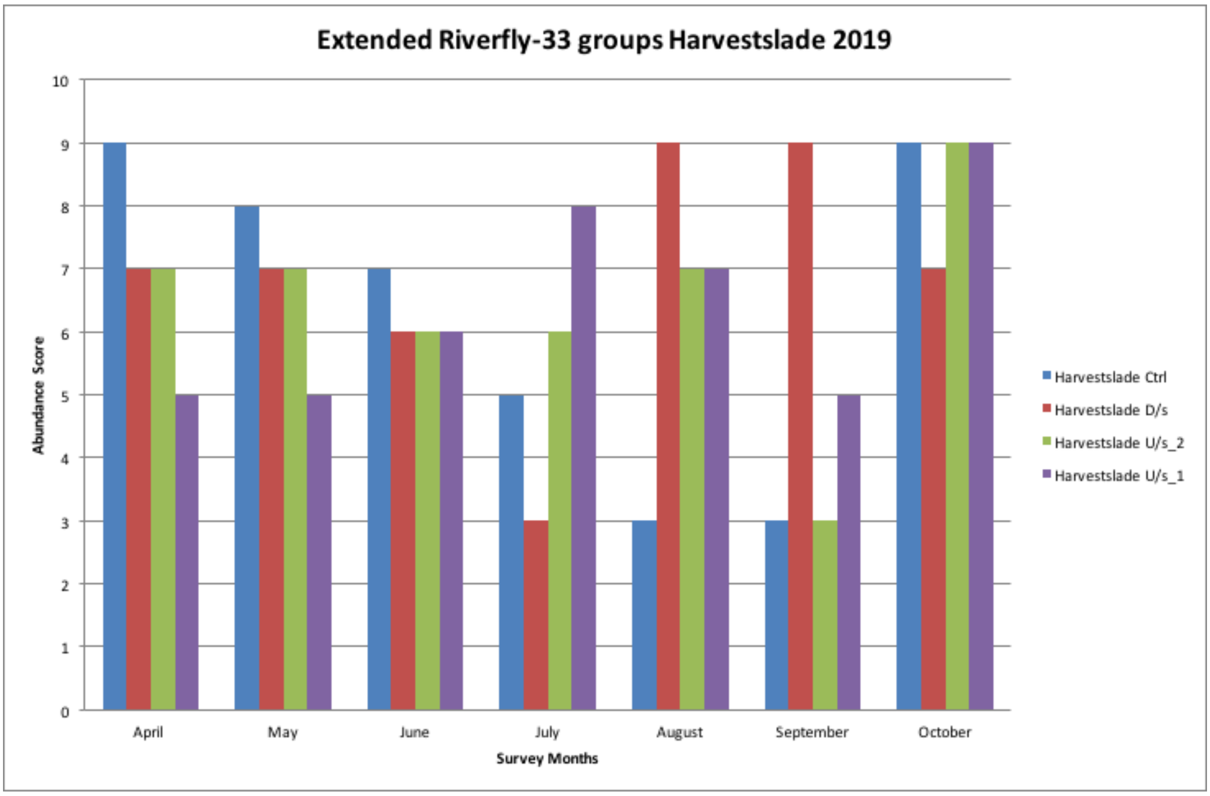
a)



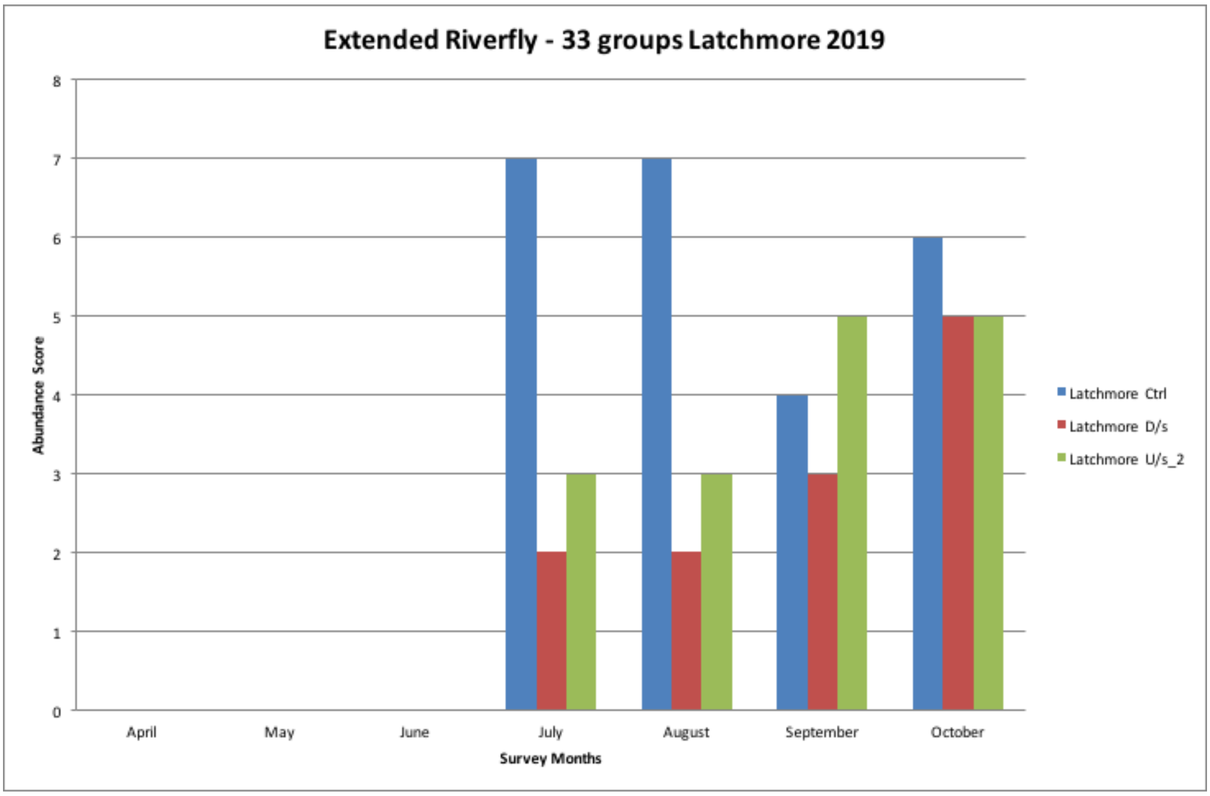
b)



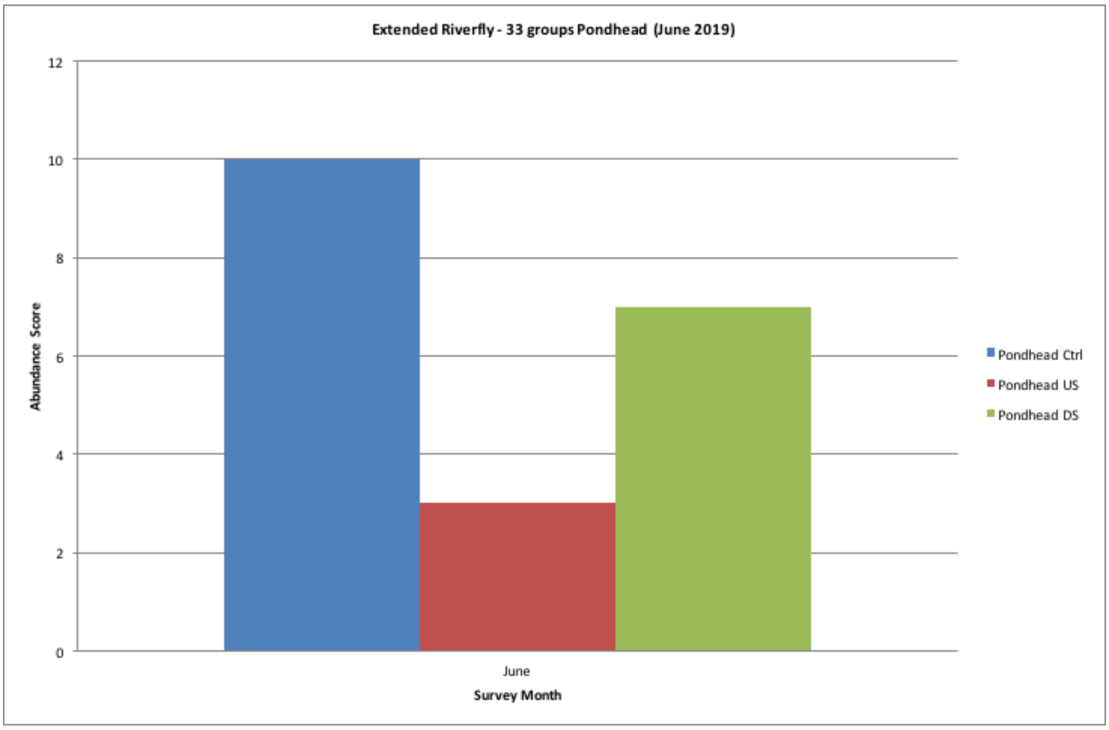
c)


Extended Riverfly-33 groups Harvestslade 2019
10
9
8
7
6
5
4
3
2
1
0
Abundance Score
April
May
June
July
August
September
October
Survey Months
Harvestslade Ctrl
Harvestslade D/s
Harvestslade U/s_2
Harvestslade U/s_1

d)

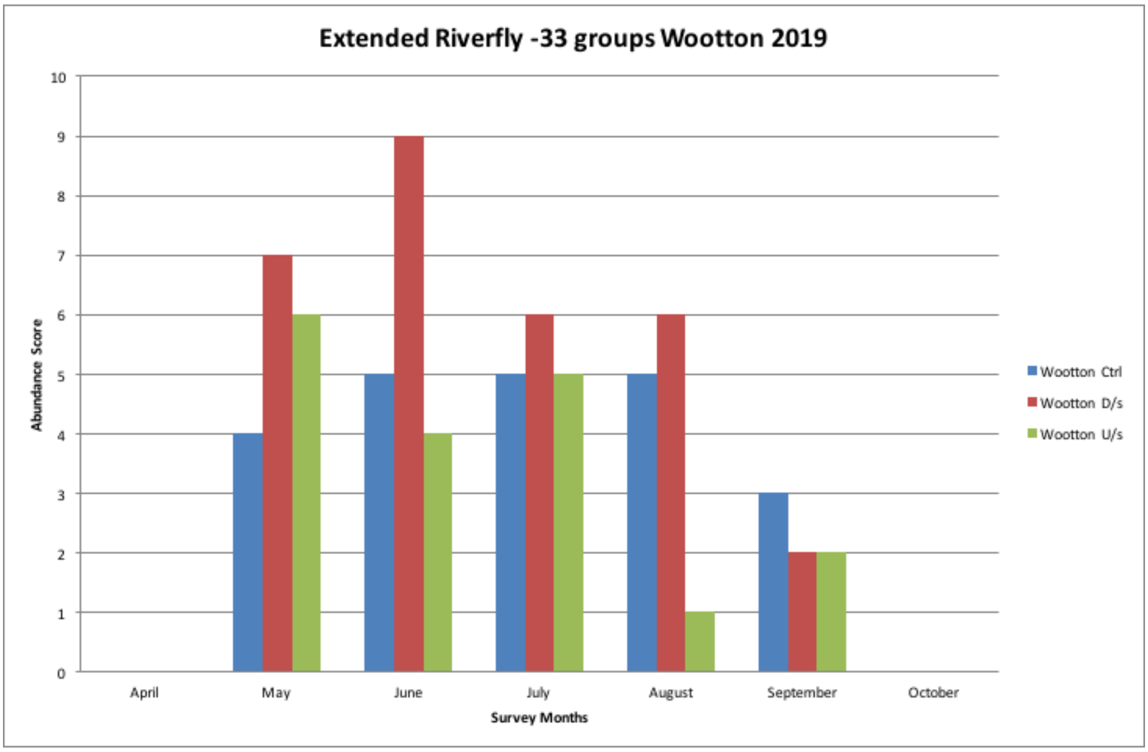

Extended Riverfly - 33 groups Latchmore 2019
8
7
6
5
4
3
2
1
0
Abundance Score
April
May
June
July
August
September
October
Survey Months
Latchmore Ctrl
Latchmore D/s
Latchmore U/s_2

e)



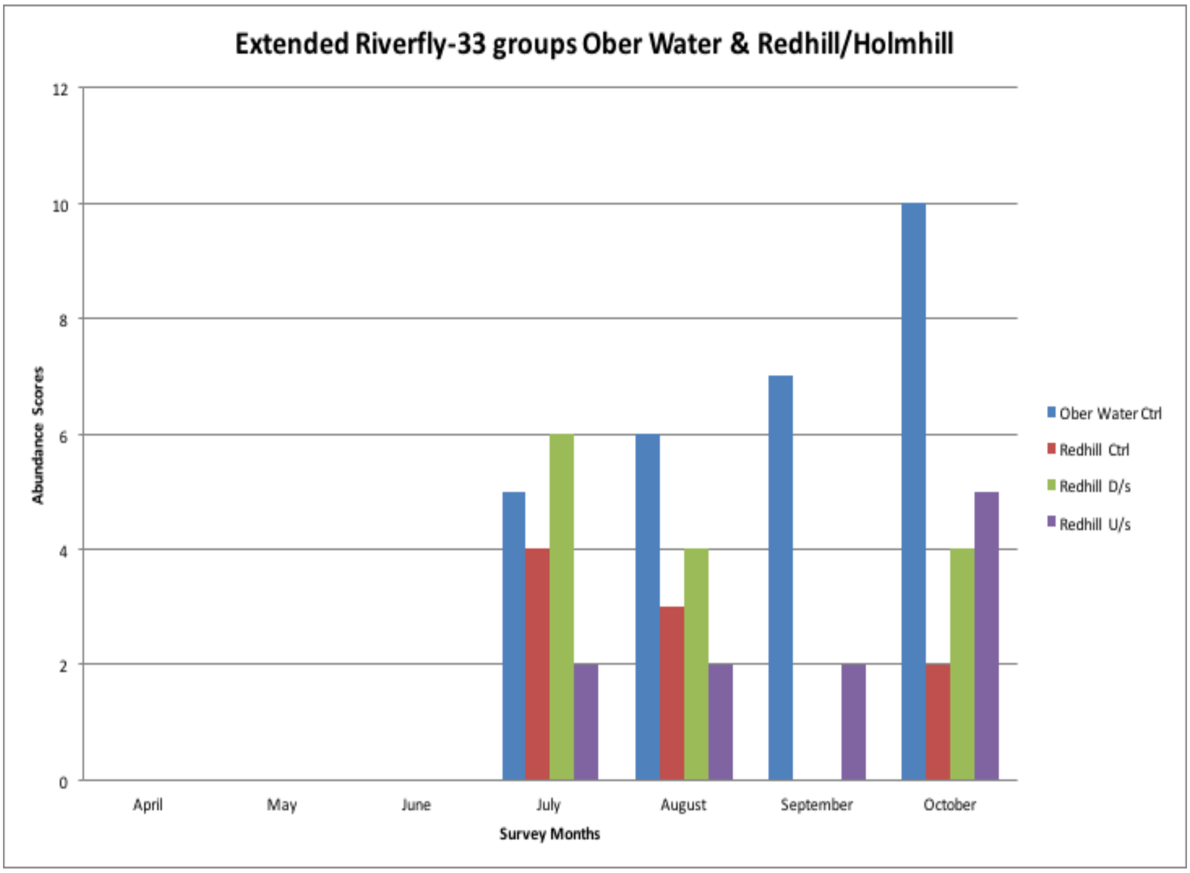
Extended Riverfly - 33 groups Pondhead (June 2019)
12
10
8
6
4
2
0
Abundance Score
June
Survey Month
Pondhead Ctrl
Pondhead US
Pondhead DS

f)



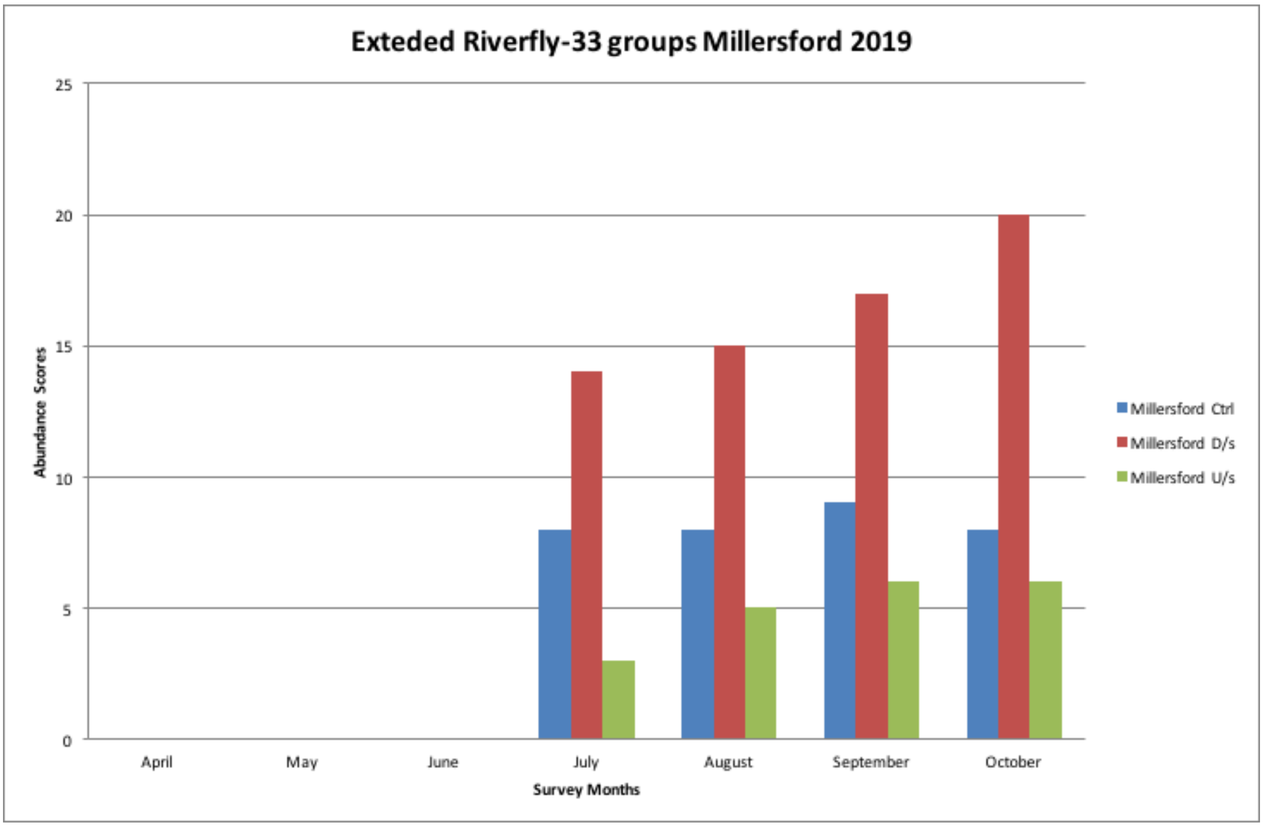
Extended Riverfly -33 groups Wootton 2019
10
9
8
7
6
5
4
3
2
1
0
Abundance Score
April
May
June
July
August
September
October
Survey Months
Wootton Ctrl
Wootton D/s
Wootton U/s

g)



Extended Riverfly-33 groups Ober Water & Redhill/Holmhill
Abundance Scores
0
2
4
6
8
10
12
April
May
June
July
August
September
October
Survey Months
Ober Water Ctrl
Redhill Ctrl
Redhill D/s
Redhill U/s

h)



Exteded Riverfly-33 groups Millersford 2019
Abundance Scores
0
5
10
15
20
25
April
May
June
July
August
September
October
Survey Months
Millersford Ctrl
Millersford D/s
Millersford U/s

Table 5-9: BUG RIVPACS environmental predictor variables for the September 2019 RIVPACS samples (input values for RIVPACS).

Variable	Dockens Water Upstream	Rakes Brakes Downstream	Ferny Croft Control	Ferny Croft Impact	Harvest Slade Control	Harvest Slade Site 1	Harvest Slade Site 2	Highland Water Upstream	Latchmore Site 1	Latchmore 2 Downstream	Thompson Castle Downstream	Thompson Castle Upstream	Millstream Upstream	Millersford Brook 1	Millersford Brook 2	Millersford Brook 3	Millersford Upstream Control	Ober Water Upstream	Pondhead Downstream	Redhill/Homhill Control	Redhill/Holmhill Downstream	Redhill/Holmhill Upstream	Wootton Phase 1 Site 1	Wootton Control	Wootton Phase 2 Site 1	Wootton Phase 2 Site 2
Sample date	26/09	19/09	24/09	24/09	25/09	25/09	25/09	26/09	18/09	17/09	18/09	18/09	19/09	17/09	16/09	16/09	17/09	30/09	20/09	24/09	24/09	24/09	27/09	27/09	23/09	23/09
Method	K/S	K/S	K/S	K/S	K/S	K/S	K/S	K/S	K/S	K/S	K/S	K/S	K/S	K/S	K/S	K/S	K/S	K/S	K/S	K/S	K/S	K/S	K/S	K/S	K/S	K/S
Duration (min)	3+1	3+1	3+1	3+1	3+1	3+1	3+1	3+1	3+1	3+1	3+1	3+1	3+1	3+1	3+1	3+1	3+1	3+1	3+1	3+1	3+1	3+1	3+1	3+1	3+1	3+1
Kick Sampler	CA	PD	CA	VDA	CA	CA	CA	CA	PD	AH	VDA	VDA	AH	AH	AH	AH	AH	AP	AH	AH	AH	AH	CA	CA	VDA	CA
Recorder	VDA	VDA	VDA	CA	VDA	VDA	VDA	VDA	VDA	VDA	PD	PD	VDA	VDA	VDA	VDA	BP	AH	VDA	VDA	VDA	VDA	VDA	VDA	CA	VDA
NGR	SU	SU	SU	SU	SU	SU	SU	SU	SU	SU	SU	SU	SU	SU	SU	SU	SU	SU	SU	SU	SU	SU	SZ	SU	SZ	SZ
	21853	22089	37744	37977	20584	20710	20629	26991	19081	18267	18527	18477	29558	19565	18312	18978	20300	25833	32402	26800	27069	26877	24837	23245	26318	25793
	12276	12374	05555	05418	05307	05605	05383	07639	12649	12470	12720	13063	09644	17527	16191	16825	17866	03717	06908	02250	02666	02294	99696	00427	98912	99435
Altitude (m)	65	67	9	8	58	61	59	30	47	43	45	45	32	75	55	65	95	28	23	30	25	29	28	35	22	25
Slope ($m\ km^{-1}$)	5.9	5.9	5.0	5.0	7.0	7.0	7.0	4.5	6.2	6.2	6.5	6.5	10.0	14.0	11.0	13.0	20.0	3.3	5.0	7.1	7.1	7.1	4.1	4.0	4.1	4.1
Discharge (category)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Velocity (category)	3	1	2	2	3	2	3	3	1	1	1	1	1	1	1	1	1	1	1	2	1	2	3	2	2	2
Distance from source (km)	3.7	3.5	0	0.3	1.4	1.1	1.3	6.5	6	7	5	5	8	1.3	3.2	2.4	0.5	17.5	3	0.2	0.8	0.3	6	4.3	7	6.6
Mean width (m)	1.5	1.8	2.0	1.6	1.9	3.0	1.6	3.0	2.0	1.9	0.5	1.2	2.0	1.3	2.1	1.4	0.4	3.0	1.5	0.6	1.5	4.0	1.8	1.9	2.0	1.8
Depth at ¼ width (cm)	19	55	15	5	19	25	10	11	30	14	5	1	7	3	18	10	3	40	3	20	60	31	25	21	15	10
Depth at ½ width (cm)	14	55	24	15	24	31	15	4	27	25	5	3	15	3	18	10	3	42	3	35	61	40	40	23	10	60
Depth at ¾ width (cm)	18	55	21	6	24	24	21	11	29	29	5	1	30	3	26	10	3	28	3	20	61	25	34	21	5	11
Mean depth (cm)	17.0	55.0	20.0	8.7	22.3	26.7	15.3	8.7	28.7	22.7	5.0	1.7	17.3	3.0	20.7	10.0	3.0	36.7	3.0	25.0	60.7	32.0	33.0	21.7	10.0	27.0
Boulders and cobbles (%)	0	0	0	0	0	0	0	0	5	1	0	10	20	10	10	10	0	0	0	0	0	0	0	0	0	0
Pebbles and gravel (%)	90	100	95	95	100	50	100	90	80	95	0	80	70	70	70	80	0	80	100	0	90	90	90	100	84	84
Sand (%)	10	0	5	5	0	50	0	10	0	2	0	5	5	10	10	5	50	20	0	10	5	10	10	0	8	8
Silt and clay (%)	0	0	0	0	0	0	0	0	15	2	100	5	5	10	10	5	50	0	0	90	5	0	0	0	8	8
pH	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Temperature (°C)	16.4	10.5	18.3	17.8	15.3	15.6	15.4	15.5	13.3	14.6	13.8	17.3	11.5	12.7	14.4	14.4	12.7	15.3	10.9	16.9	17.8	17.3	14.4	14.4	13.9	13.9
Conductivity (µs)	134.1	69.8	90.1	82.0	73.9	74.2	74.0	132.5	61.9	64.5	54.0	57.2	205.6	54.0	293.0	293.0	54.0	149.6	227.8	60.1	59.5	61.9	127.1	114.0	121.5	121.5
Dissolved Oxygen (%)	101.4	86.6	91.5	91.0	95.4	97.8	96.2	92.9	95.7	95.9	102.3	92.1	87.8	100.0	92.7	92.7	100.0	101.6	87.4	82.2	98.1	92.6	98.2	92.6	98.9	98.9
Dissolved Oxygen ($mg\ l^{-1}$)	9.92	9.86	8.60	8.70	9.55	9.68	9.60	9.23	10.20	9.69	10.60	8.10	9.52	10.30	9.44	9.44	10.30	10.12	9.62	7.92	8.71	8.85	10.40	9.47	10.09	10.09
Water clarity	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Turbid	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Turbid	Turbid	Clear	Clear
Water colour	Humic	Humic	Clear	Clear	Clear	Clear	Clear	Humic	Humic	Humic	Humic	Clear	Clear	Clear	Clear	Clear	Humic	Humic	Clear	Clear	Clear	Clear	Humic	Humic	Clear	Clear
Algae cover (%)	0	0	0	0	0	0	0	0	0	0	0	90	0	0	0	0	0	0	0	0	0	0	0	0	20	0
Moss cover (%)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	5
Higher plant cover (%)	60	0	1	0	0	95	0	0	15	0	100	0	0	0	0	0	0	0	0	100	0	50	0	3	0	0
Total cover (%)	60	0	1	0	0	95	0	0	15	0	100	90	0	0	0	1	0	0	0	100	0	50	0	3	20	5
Detritus	✓	✓	Absent	Absent	Absent	Absent	Absent	✓	✓	✓	Absent	Absent	✓	✓	✓	✓	✓	✓	✓	Absent	Absent	Absent	✓	✓	✓	✓

Source: BUG – 2020 report (Draft)

5.6 Conclusions

Macro-invertebrate data sets for individual sites are generally not consistent over a long enough period to allow meaningful statistical analysis. However potential trends can be observed based on visual comparison of data analysis in tables and graphs of BUG and Riverfly data leading to the following conclusions:

- Each site is unique and macro-invertebate populations naturally vary both annually and seasonally
- Substrate composition appears to be a key factor in influencing abundance of individual species/taxa.
- Most sites are significantly impacted immediately post restoration and species/taxa trends suggest sites will potentially take at least 5 years to recover or surpass pre-restoration diversity.
- Rates of recovery are potentially linked to the level of degradation of the site before restoration with higher quality sites recovering quicker probably due to the recolonization potential from adjacent bankside and river reaches.
- Seasonal variations shown in the Riverfly data suggest restored sites may retain better species richness in late summer months/early autumn months and therefore are potentially more robust during times of low flow or higher water temperatures.

In terms of future monitoring:

- Building consistent data sets from the same sample locations, using a replicated methodology will help improve the robustness of future trend analysis.
- It would be useful to re-survey Cowley's Heath to assess how this site has fared since the last post restoration survey in 2016
- Invertebrate communities and biological conditions of mire sites may not fit well with the RIVPAC model as these are unique habitats that are not replicated across the UK so further consideration may be required on how best to analyse these sites.

The Restoration Objective Traffic Light Status is **Amber.** Sites are showing movement towards the restoration objective of a more diverse macroinvertebrate community but trends and data are not yet conclusive enough with sites still undergoing recovery.