



UK Centre for
Ecology & Hydrology

UK Upland Waters Monitoring Network (UKUWMN) Progress Report to Welsh Government and Natural Resources Wales. April 2020 - March 2021

Llyn Llgi, Llyn Cwm Mynach, Afon Hafren
and Afon Gwy: Annual Summary

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Contents

1	Introduction	6
2	Sampling and analysis	8
2.1	Sampling overview.....	8
2.2	Water chemistry	9
2.2.1	Water chemistry sampling	9
2.2.2	Water chemistry analysis	9
2.3	Sediment Traps.....	9
2.4	Thermistors.....	9
2.5	Epilithic diatoms	10
2.6	Macroinvertebrates.....	10
2.7	Fish.....	10
2.8	Aquatic Macrophytes	10
3	Project Management.....	11
3.1	Data Management and Reporting	11
3.2	Development of the UWMN website	11
3.3	Annual UWMN Partnership meeting.....	11
4	Acknowledgements.....	12
	APPENDICES	13
A.	Llyn Llagi summary data to March 2020	13
	Llyn Llagi Summary spot sampled chemistry data	14
	Llyn Llagi Macroinvertebrate data	15
	Llyn Llagi Fish data (for outflow stream).....	16
	Llyn Llagi Epilithic diatom data.....	18
	Llyn Llagi Aquatic macrophyte data	19
	Llyn Llagi Sediment trap data	20
	Llyn Llagi Sediment trap thermistor data.....	21
	Llyn Llagi Thermistor chain data.....	22
B.	Llyn Cwm Mynach summary data to March 2020	23
	Llyn Cwm Mynach spot sampled chemistry data to March 2020	24
	Llyn Cwm Mynach Macroinvertebrate data.....	25
	Llyn Cwm Mynach Fish data (for outflow stream)	26

Llyn Cwm Mynach Epilithic diatom data	28
Llyn Cwm Mynach Aquatic macrophyte data,	29
Llyn Cwm Mynach Sediment trap data	30
Llyn Cwm Mynach Sediment trap thermistor data	31
Llyn Cwm Mynach Thermistor chain data	32
C. Afon Hafren summary data to March 2020	33
Afon Hafren Spot sampled chemistry data to March 2020	34
Afon Hafren Macroinvertebrate data	35
Afon Hafren Fish data.....	36
Afon Hafren Epilithic diatom data.....	38
Afon Hafren Aquatic macrophyte data	39
Afon Hafren Thermistor data (no data post 2017)	40
D. Afon Gwy summary data to March 2020.....	43
Afon Gwy spot sampled chemistry data to March 2020.....	44
Afon Gwy Macroinvertebrate data	45
Afon Gwy Fish data.....	46
Afon Gwy Epilithic diatom data.....	50
Afon Gwy Aquatic macrophyte data	51
Afon Gwy Thermistor data	52
.....	56

1 Introduction

This report summarises the activities of the UK Upland Waters Monitoring Network (UWMN) partnership over the period April 2020 – March 2021. More specifically, it details work of particular interest to Natural Resources Wales and Welsh Government targeted at the four Welsh UWMN sites, in addition to more generic tasks, including website development and network management that underpin the UWMN more widely. Site-focussed work is set out in the current UWMN Partnership Agreement and includes regular field visits to collect water chemistry and biological samples, downloading of water temperature and flow loggers, and the analysis, where possible, of samples. More generic tasks include network coordination and management, development of the UWMN database and the hosting of annual project meetings.

Activities on the project were disrupted this year in various ways by the imposition of Covid-19 related restrictions on fieldwork and other activities. The main impacts on UWMN were the inability to conduct macroinvertebrate sampling across the network, and the loss of a small number of water samples, as a consequence of travel and site access restrictions in the spring of 2020. The resulting data gaps are highlighted in this report.

The UWMN is founded on the UK Acid Waters Monitoring Network (AWMN) that began operating in 1988 with a Network of 22 sites (Patrick et al., 1995). The AWMN was originally funded wholly by the UK Government Department of the Environment to assess the impact of changes in acidic emissions to the atmosphere on the environmental health of upland lakes and streams.

The network was designed to cover both lakes and streams across gradients of acid deposition and geological sensitivity. The design also included geographically paired afforested and moorland sites, to assist investigations into the influence of forestry on water quality and recovery from acidification (e.g. Afon Hafren vs Afon Gwy). Samples for water chemistry analysis have been taken monthly from streams and quarterly from lakes since 1988, and for much of the monitoring period biological monitoring has included the annual sampling and analysis of epilithic diatoms, aquatic macrophytes, macroinvertebrates and fish. Material from annually emptied sediment traps deployed in the UWMN lakes has been used to compare the biological composition of contemporary sediment, on an annual frequency, with that in the historical record. The resulting data provide an indication of current ecosystem status relative to pre-industrial status and the rate of biological recovery from acidification. Sediment from these traps is also analysed for spheroidal carbonaceous particles, an industrial product of high temperature fossil fuel combustion.

The loss of all central government funding in 2015 was partially compensated by new support from Welsh Government (WG), Natural Resources Wales (NRW), Scottish Natural Heritage (SNH) and Forest Research (FR), with significant additional in-kind support provided by the NERC Centre for Ecology & Hydrology (CEH), ENSIS Ltd., the Environmental Change Research Centre (ECRC) UCL, QMUL and Marine Scotland.

Until March 2018, the UWMN was managed by ENSIS Ltd at UCL, with work undertaken by ENSIS and a number of partner organisations either under sub-contract or through in-kind contributions. Despite the recent change in name, reflecting a widening remit to address other impacts of environmental change including climate change, the UWMN has adhered to a central set of tightly defined monitoring protocols and quality control procedures since its inception.

Over the past decade CEH has continued to provide water chemistry analysis for UWMN, and became the sole analyst on the network in 2017. Following the cessation of operation of ENSIS Ltd in the spring of 2017, the UWMN partnership agreed that coordination of the network should pass to CEH – now UKCEH. All four current funding bodies (NRW, Welsh Government, Scottish Natural Heritage and Forest Research) agreed to continue to contribute resources in return for UKCEH maintaining its current level of in-kind support (predominantly

water chemistry). ECRC pledged to continue to support annual lake monitoring field campaigns for as long as in-house support was available. Marine Scotland have continued to provide water thermistor calibration.

In a significant development over the past year, Defra has funded the taxonomic analysis of a large number of macroinvertebrate and epilithic diatom samples. These had been archived since around 2014-15 as a consequence of funding cuts. Defra are also funding a UWMN data interpretation exercise, led by UKCEH, that is focussed on reporting on the most recent trends in water chemistry, macroinvertebrate and epilithic diatom communities.

In the following sections we set out all UWMN-related work of direct interest to NRW that has been carried out over the financial year 2020-21.

2 Sampling and analysis

2.1 Sampling overview

The UWMN sites in Wales are Llyn Llagi, Llyn Cwm Mynach, Afon Hafren and Afon Gwy. Most UWMN sampling protocols, with the exception of macroinvertebrate sampling, were completed successfully at the four sites over the period April 2020 – March 2021.

Despite disruptions resulting from Covid-19 related lockdowns, planned macrophyte surveys and epilithic diatom sampling were conducted at Afon Hafren, Afon Gwy, Llyn Cwm Mynach and Llyn Llagi in the summer/autumn of 2020 and sediment trap diatoms were sampled in Llyn Cwm Mynach and Llyn Llagi. Water sampling was carried out throughout most of the year with the exception of the spring of 2020 when access to the Plynlimon sites was prevented.

Macroinvertebrate sampling was not conducted at any UWMN site due to the Covid lockdown fieldwork restrictions during the spring, as explained in the amendment to the partnership agreement.

Water temperature has not been recorded in the Afon Hafren since the loss of the thermistor logger from the site in 2018.

No obvious changes have been observed over the period in the catchments of Llyn Llagi and Afon Gwy sampling stretches. Major felling of mature non-native coniferous plantation forest surrounding Llyn Cwm Mynach was reported last year and there was further felling in the Afon Hafren catchment (see Figure 3). Last year's report also noted that the wooden dam controlling the lake outflow was observed to have failed in March 2020. This has reduced the level of the already very shallow southern basin. Both changes could result in significant short and longer-term effects on lake physics, chemistry and ecology.

2.2 Water chemistry

2.2.1 Water chemistry sampling

Water chemistry sampling at the four Welsh sites was conducted on the dates provided in Table 1.

Table 1: Water chemistry sampling dates for Welsh UWMN sites: year 2020-21.

NS denotes no sample taken due to Covid-19 travel and/or site access restrictions

Afon Hafren	Afon Gwy	Llyn Llagi	Llyn Cwm Mynach
April – NS	April – NS		
May - NS	May - NS		
09/06/2020	09/06/2020	08/06/2020	09/06/2020
July - NS	07/07/2020		
04/08/2020	04/08/2020		
01/09/2020	01/09/2020	02/09/2020	09/09/2020
06/10/2020	06/10/2020		
03/11/2020	03/11/2020		
30/11/2020	30/11/2020	30/11/2020	03/12/2020
06/01/2021	06/01/2021		
01/02/2021	01/02/2021		
01/03/2021	01/03/2021	01/03/2021	01/04/2021

2.2.2 Water chemistry analysis

Water samples from all four sites have been analysed punctually by the UKCEH chemistry laboratory and data for the period 2020-21 have been subjected to standard quality control checks and archived in the UWMN database. In line with previous reporting, water chemistry time series for the four Welsh UWMN sites for the previous 12 months, i.e. up to March 2020, are provided in the Appendices.

2.3 Sediment Traps

Sediment traps from Llyn Llagi and Llyn Cym Mynach were recovered and replaced by volunteers from UCL and Nottingham University on the 11th of August and 8th August 2020 respectively. Spheroidal Carbonaceous Particles (SCPs) in the sediment retrieved from the traps are being analysed at UCL. The sediment trap diatoms have been archived and await funding for preparation and analysis.

2.4 Thermistors

The epilimnion (lake surface) thermistor and the thermistor chain were removed and replaced from Llyn Llagi and Llyn Cwm Mynach respectively on the 11th of August 2020 and 8th of August 2020 by volunteers from UCL and Nottingham University. All thermistors, with the exception of the lake surface thermistor in Llyn Llagi, had functioned well during the previous year. The thermistor chain data have been quality checked and sent to

MSS for inclusion in their thermistor water temperature database. Thermistor chain summary data have been made available online via the MSS Scottish River Temperature Monitoring Network (SRTMN) data portal: <https://scotland.shinyapps.io/sg-srtmn-data/>

The thermistor at the Afon Gwy was replaced on 10th August 2020. The thermistor at Afon Hafren was washed away in 2018 and has not been replaced. No temperature data were therefore retrieved for this site for the period of this report.

2.5 Epilithic diatoms

Epilithic diatom samples were retrieved by volunteers from UCL and Nottingham University from the three fixed littoral sampling locations around Llyn Llagi and Llyn Cwm Mynach on the 11th August and 8th August 2020 respectively, and at upper, mid and lower stream sections of Afon Hafren and Afon Gwy on the 10th August 2020. Samples were prepared for analysis during the spring of 2021. Archived epilithic diatom samples collected between 2016 and 2018 were analysed under separate funding from Defra during 2020 and the resulting updated time series are presented in the Appendices of this report. Samples collected between 2019 and 2020 are being prepared and analysed under a further round of funding from Defra.

2.6 Macroinvertebrates

Aquatic macroinvertebrates were not sampled in 2020 due to Covid-19 travel restrictions. Archived macroinvertebrate samples collected up to and including 2016 were analysed under separate funding from Defra during 2020 and the resulting updated time series are presented in the Appendices of this report. Samples collected between 2017 and 2019 have been prepared and analysed under a further round of funding from Defra.

2.7 Fish

Due to lack of resources no fish surveys have been performed at any site since 2014.

2.8 Aquatic Macrophytes

The aquatic macrophytes of Llyn Cwm Mynach were surveyed by Ewan Shilland on 9th August 2020 using both UKUWMN and CSM standard methodologies. The aquatic macrophytes of the Afon Hafren and Afon Gwy stream stretches were surveyed by Ewan Shilland on 10th of August 2020. The data from these surveys will be added to his PhD biological database and awaits microscope confirmation of bryophyte identifications.

The aquatic macrophytes of Llyn Llagi were not surveyed in 2020.

3 Project Management

3.1 Data Management and Reporting

No problems were encountered with the collation and transfer of funded data within methodological programmes, or to the UWMN databases, during the reporting period.

The contents of the UWMN biological database have been transferred to UKCEH. UKCEH have now upgraded the epilithic diatom and macroinvertebrate elements of the database but have yet to develop the other components.

Macrophyte data for 2020 for all four Welsh UKUWMN sites, produced by Ewan Shilland as part of his ongoing PhD research, have been added to the macrophyte summary diagrams shown here and have also been uploaded to the UKUWMN website. Bryophyte voucher IDs are still required for recent years at all four sites.

3.2 Development of the UWMN website

The domain of the official UWMN website has been transferred to UKCEH from Defra. The URL for the new site is uwmn.uk and went live during the summer of 2021.

3.3 Annual UWMN Partnership meeting

The annual meeting of the UWMN partnership was held remotely via Zoom on March 8th 2021. The meeting was led by the UKCEH project leader and also involved representatives from NRW, Welsh Government, Scottish Natural Heritage, Forest Research, Defra, QMUL, UCL and Marine Scotland.

4 Acknowledgements

James Shilland (UCL) and Lucy Roberts (University of Nottingham) both took leave from work to volunteer on the fieldwork in Wales, and their help during a period made particularly challenging by the Covid-19 epidemic is very gratefully received. The ENSIS Trust, administered by Rick Battarbee, contributed the bulk of the funding for UKUWMN Welsh summer field sampling in 2018 and 2019.

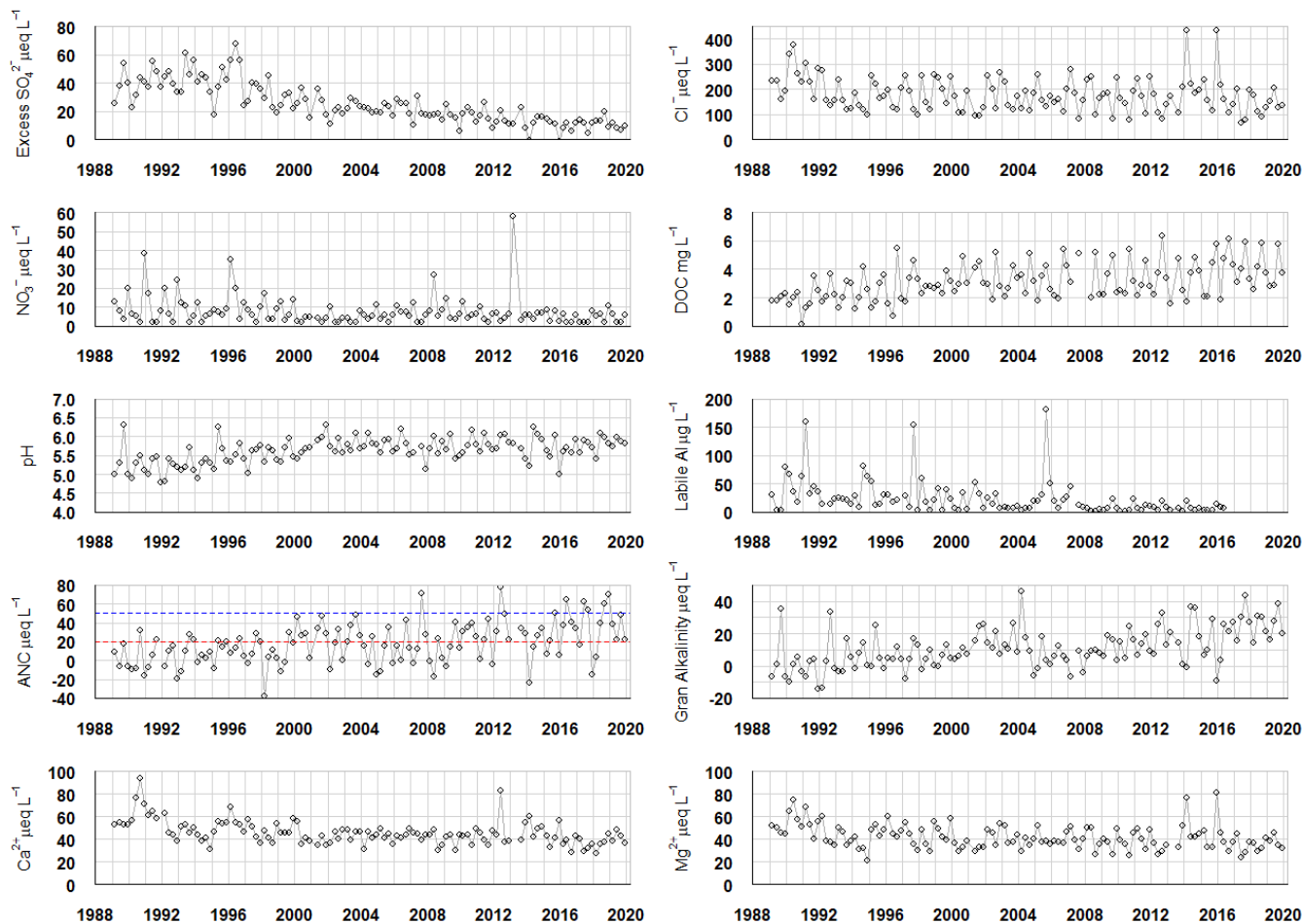
APPENDICES

A. Llyn Llagi summary data to March 2020



Figure 1. Llyn Llagi. looking North West from the South East shore, 12th August 2020. Photo: E.Shilland

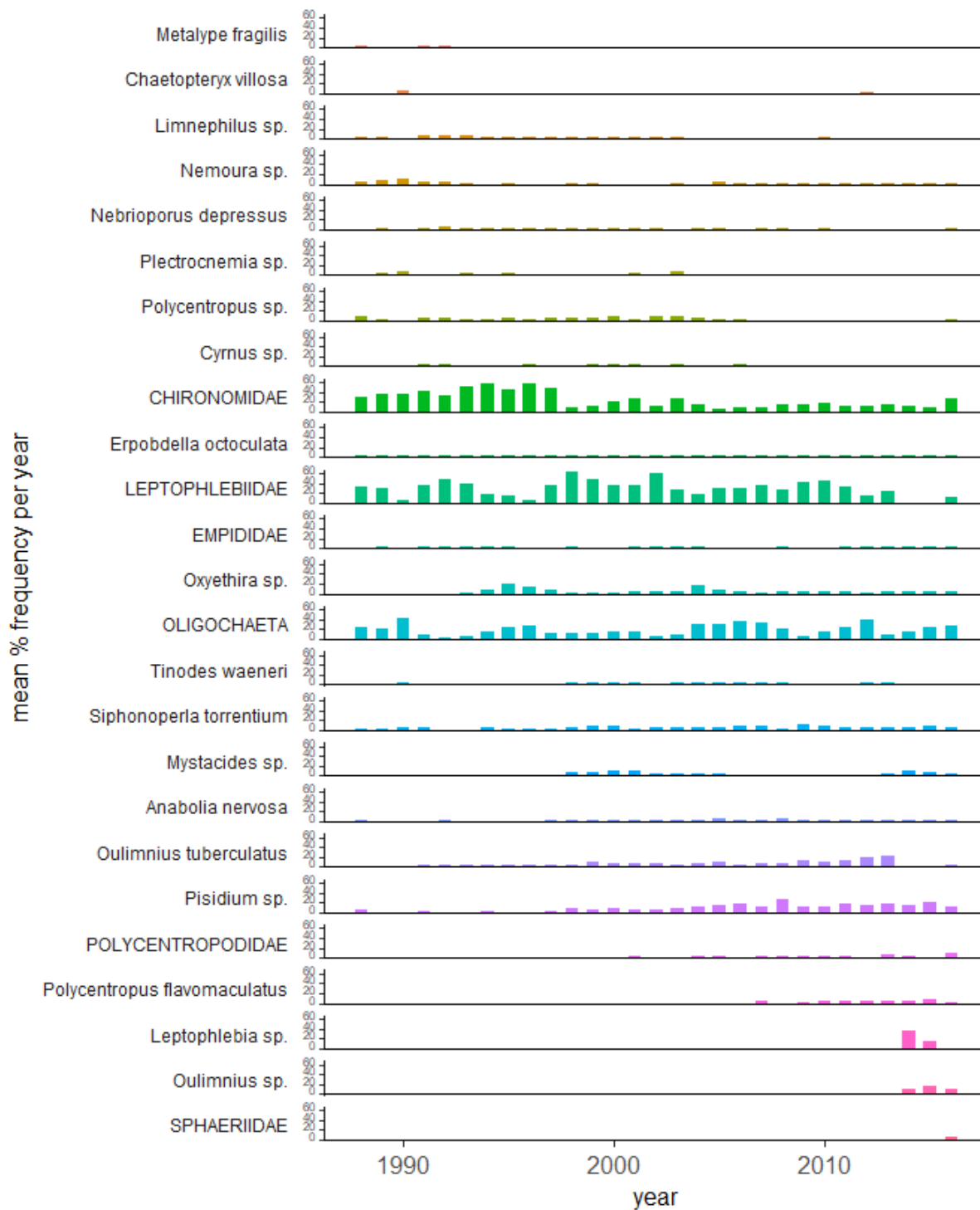
Llyn Llago Summary spot sampled chemistry data



$\mu\text{eq l}^{-1}$, $*\mu\text{g l}^{-1}$, $**\text{mg l}^{-1}$	pH	ANC	Ca ²⁺	Mg ²⁺	Na ⁺	K ⁺	*Soluble Al	*Labile Al	Cl ⁻	*SO ₄ ²⁻	xSO ₄ ²⁻	NO ₃ ⁻	**DOC
Mean 1 st 5 yrs	5.23	5.71	56.70	49.69	185.75	3.54	75.37	41.61	219.33	62.91	39.91	10.44	2.13
19-20 mean	5.77	24.05	41.44	39.11	149.64	3.72	NA	NA	181.18	25.68	6.84	3.00	3.70
19-20 std dev	0.25	17.92	5.31	6.83	39.67	2.03	NA	NA	58.85	4.22	3.22	1.71	1.47

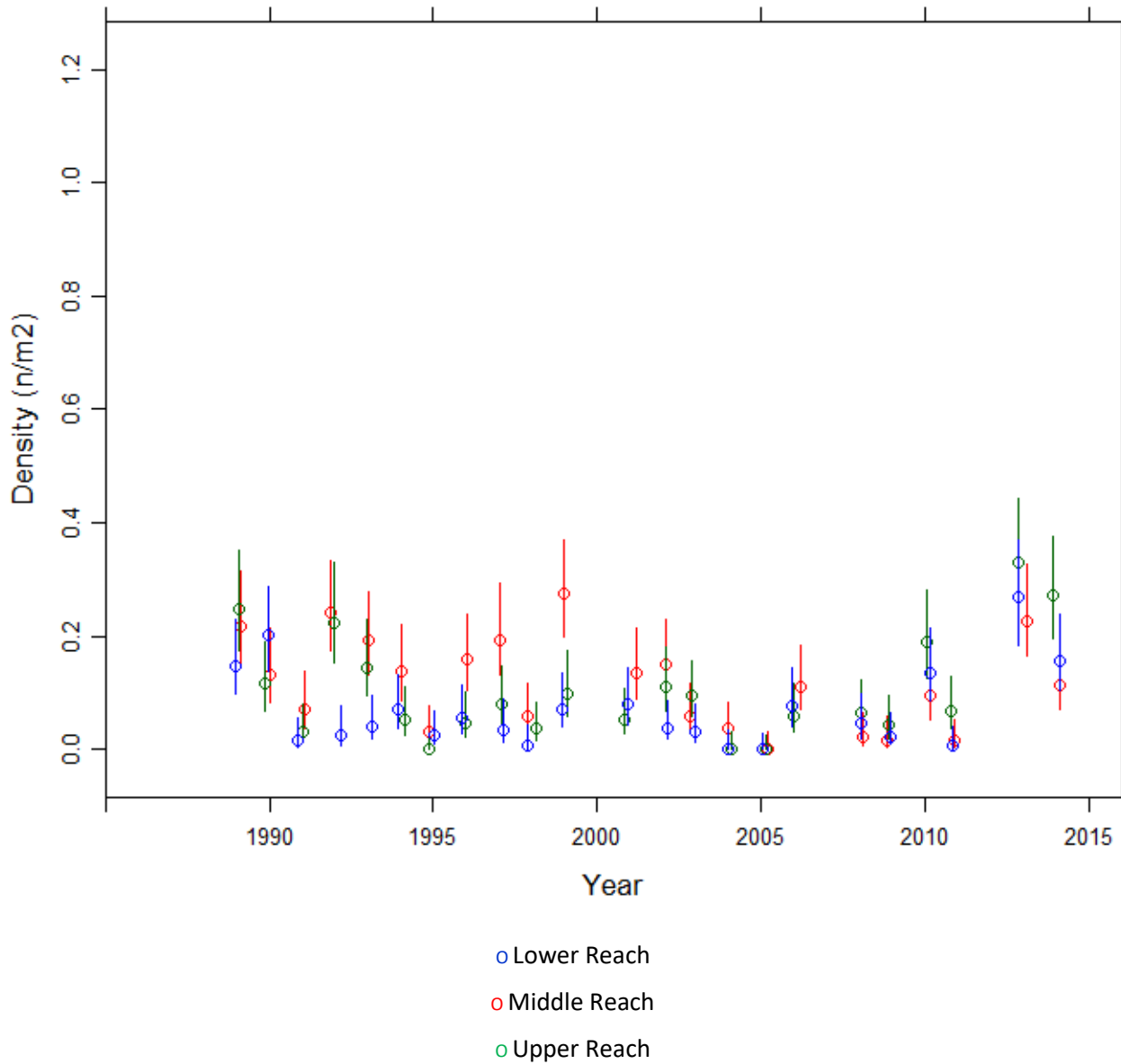
Llyn Llagi Macroinvertebrate data

Percentage abundance summary, Llyn Llagi



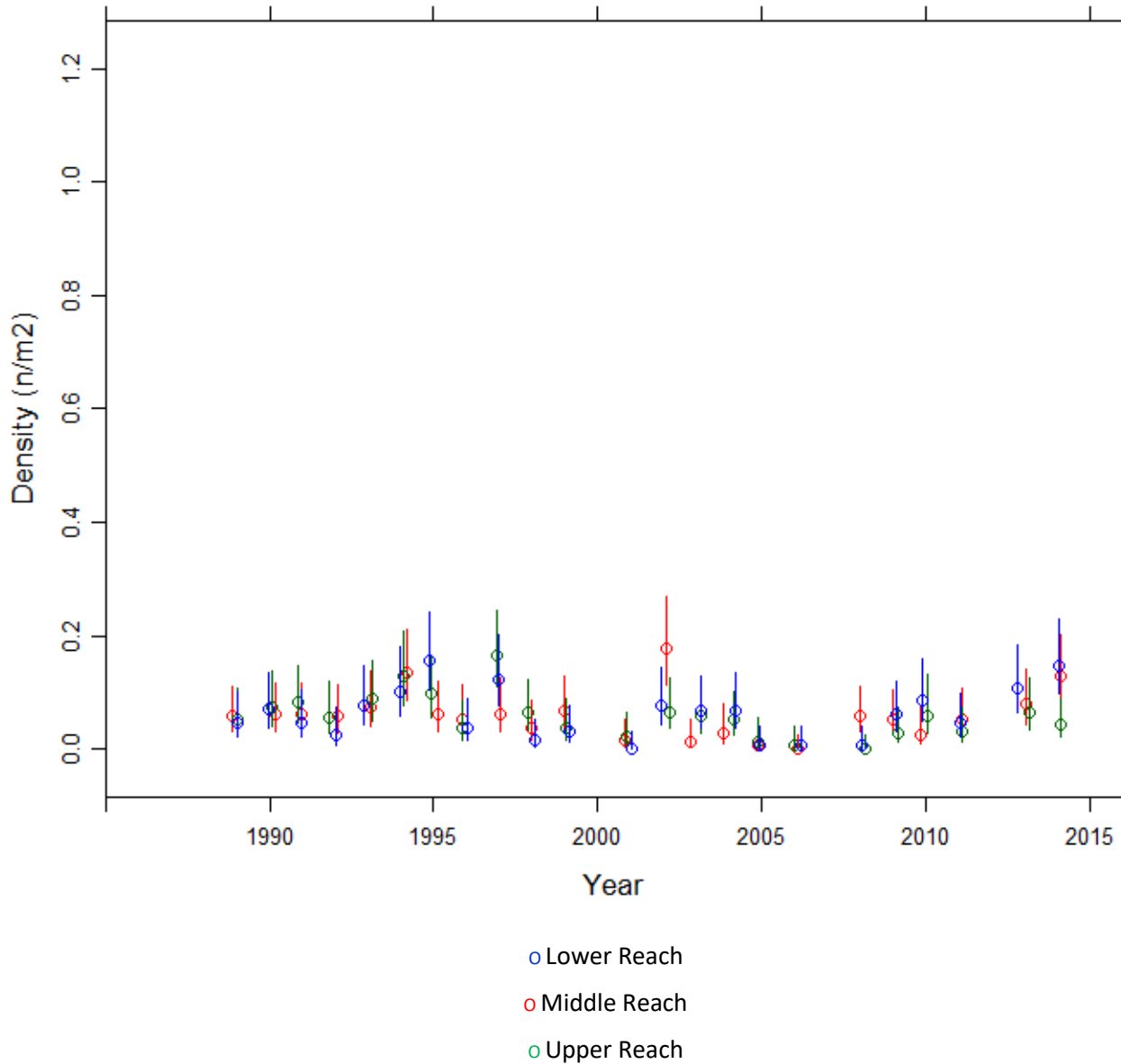
Llyn Llagi Fish data (for outflow stream)

Summary of Trout fry density (numbers m⁻²), Llyn Llagi



Fishing no longer funded after 2014.

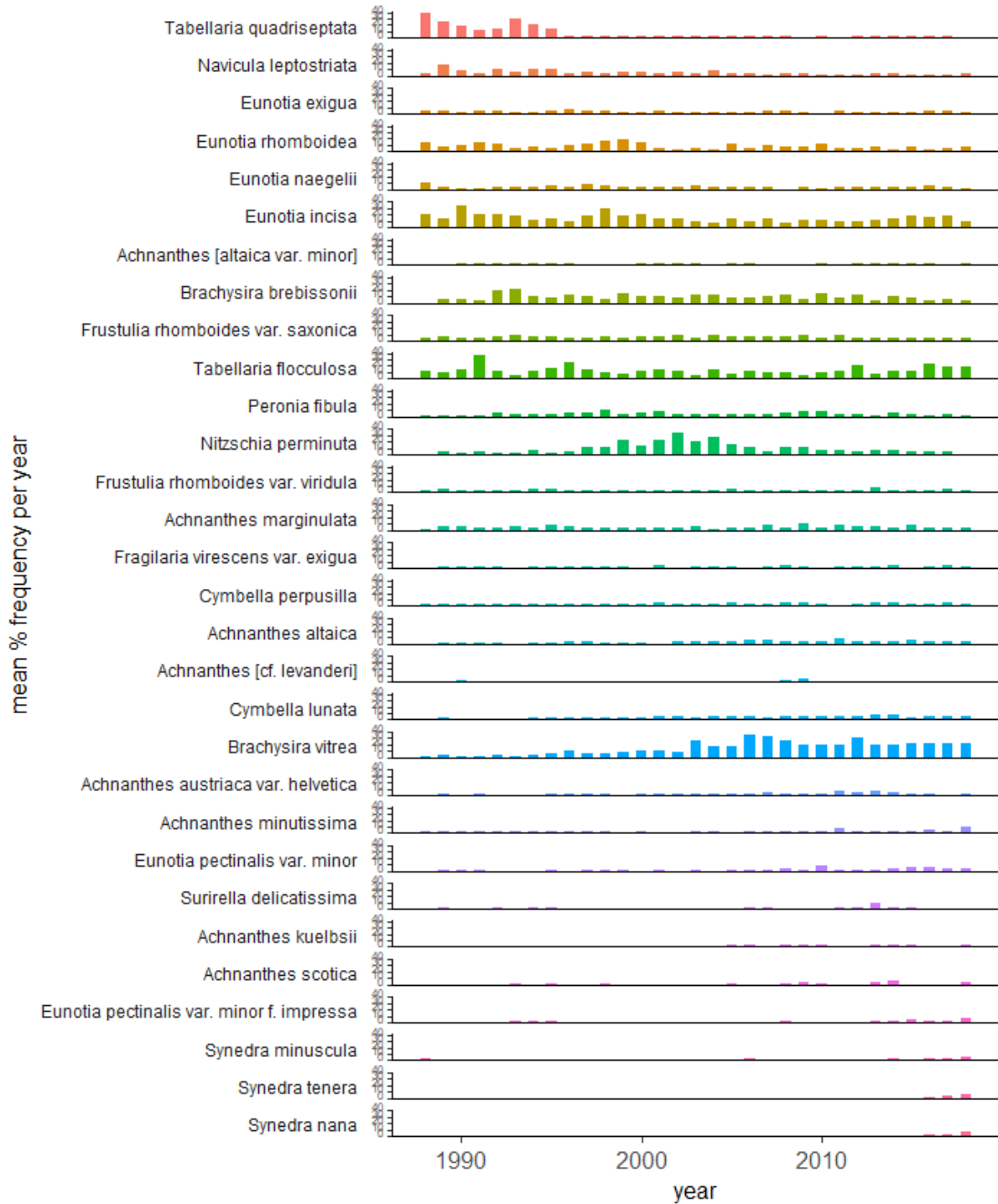
Summary of Trout parr density (numbers m⁻²), Llyn Llagi



Fishing no longer funded after 2014.

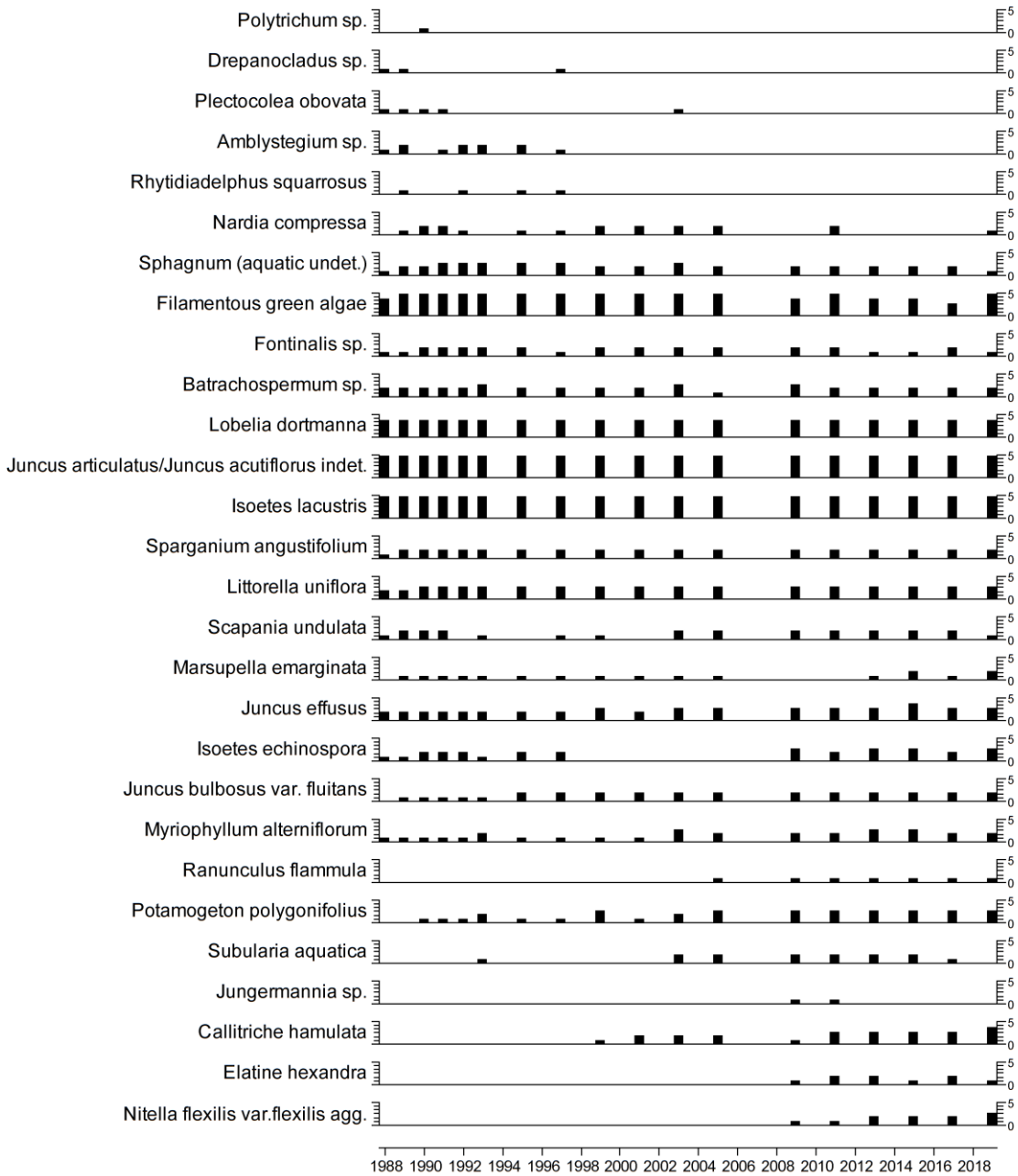
Llyn Llagi Epilithic diatom data

Percentage abundance summary, Llyn Llagi



Llyn Llgi Aquatic macrophyte data

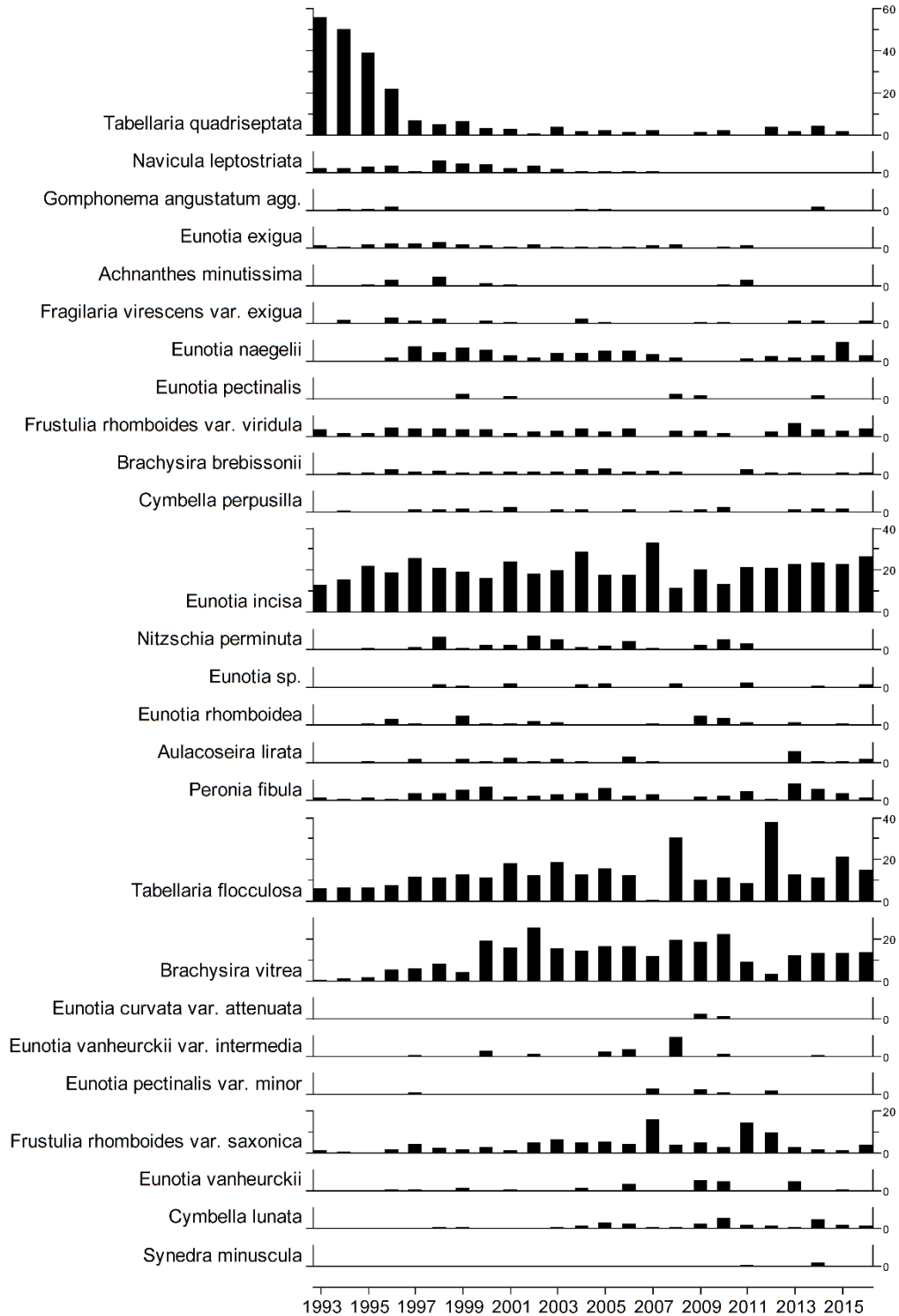
Species Scores (1-5)



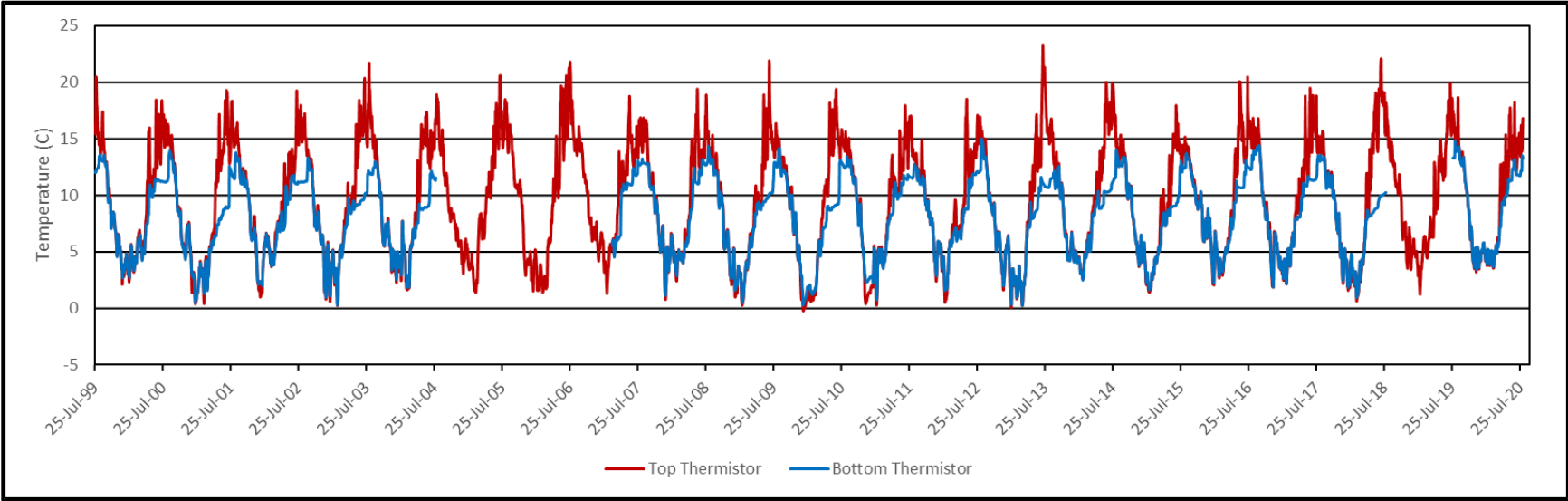
No survey in 2007 due to funding cuts

Llyn Llagi Sediment trap data

Relative percentage frequency of diatom taxa



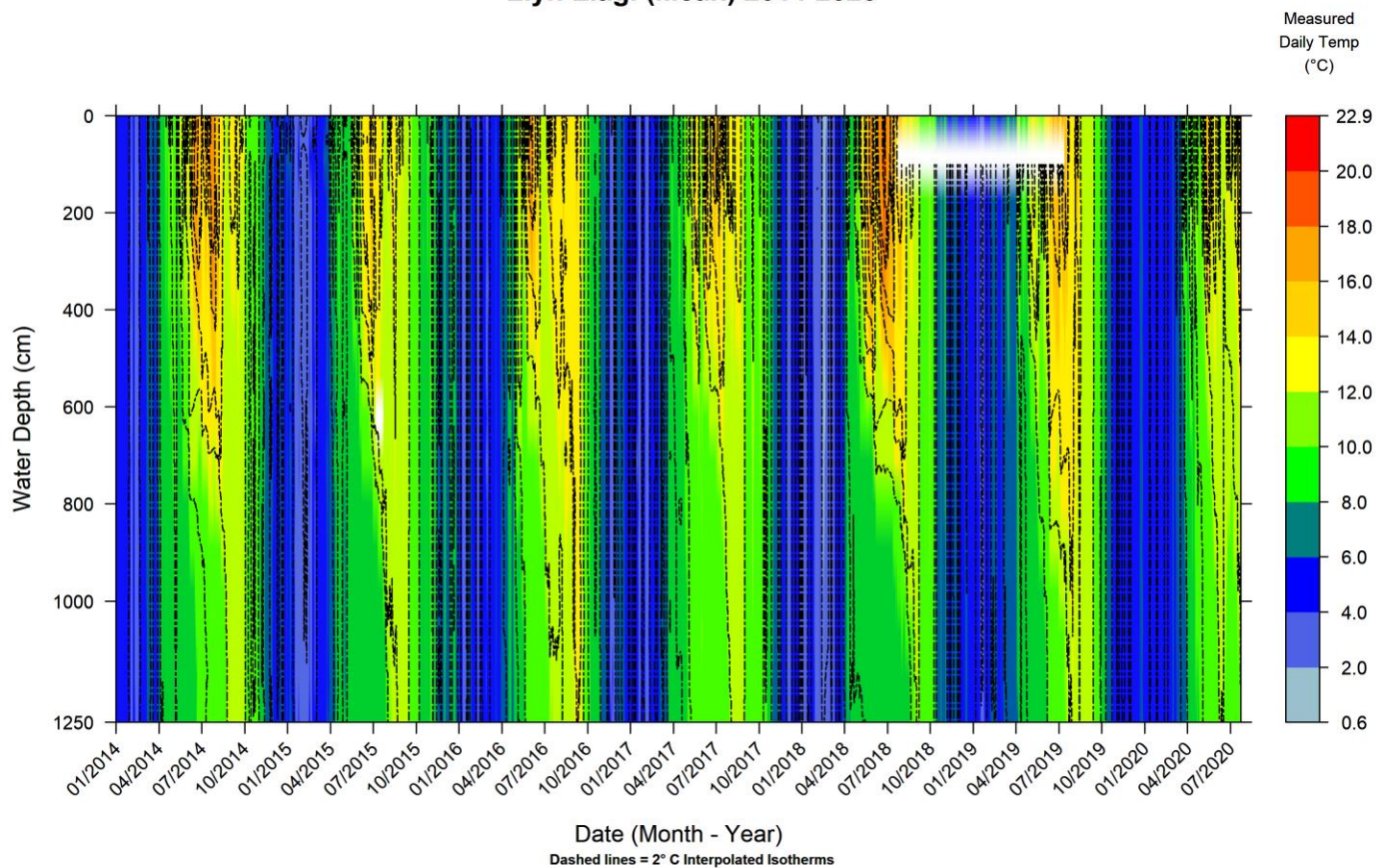
Llyn Llagi Sediment trap thermistor data



Llyn Llagi Thermistor chain data



Llyn Llagi (Mean) 2014-2020



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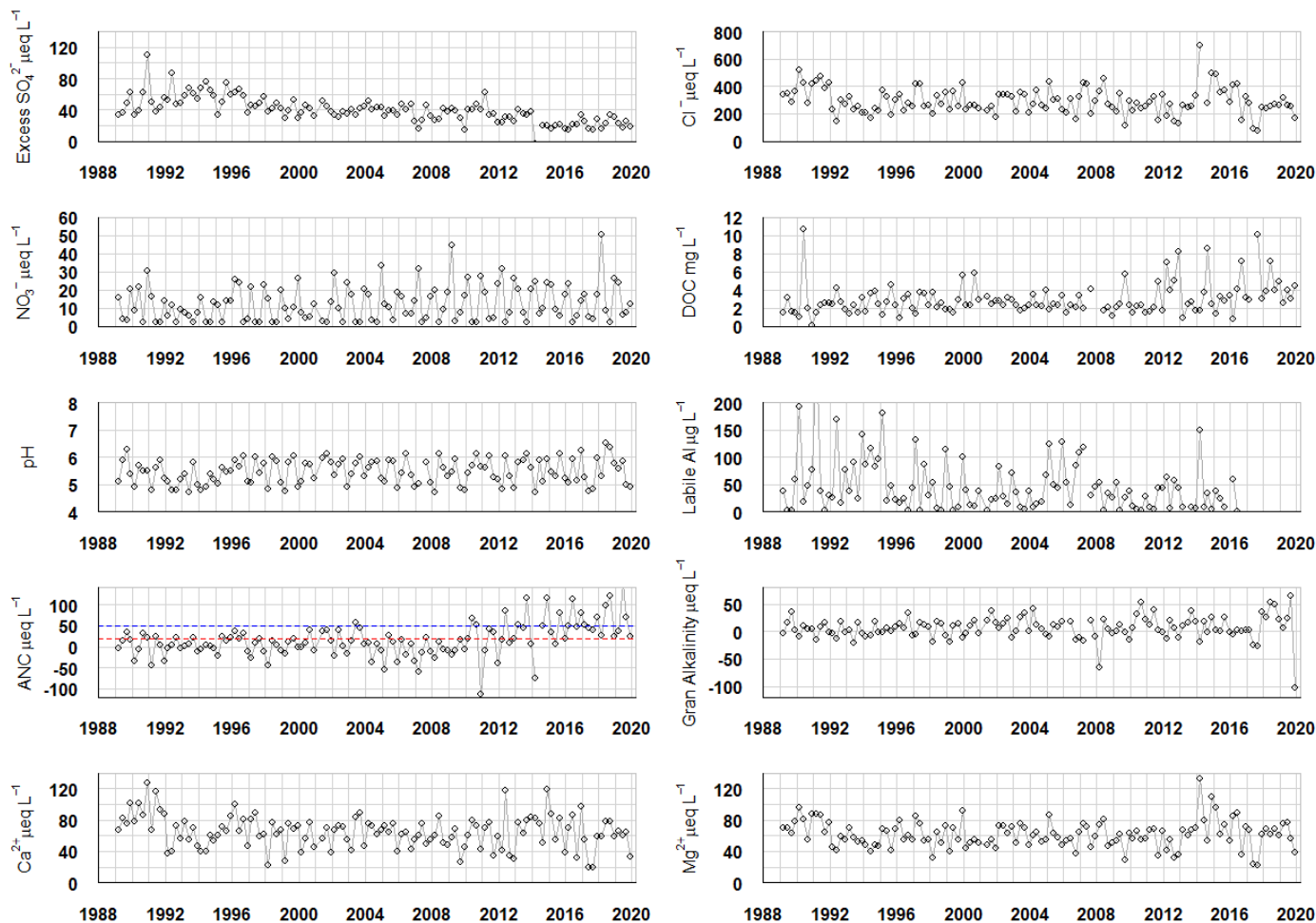
B. Llyn Cwm Mynach summary data to March 2020



Figure 1. Llyn Cwm Mynach. Looking South East from the North West end of the lake, 8th Aug 2020.

Photo: E.Shilland

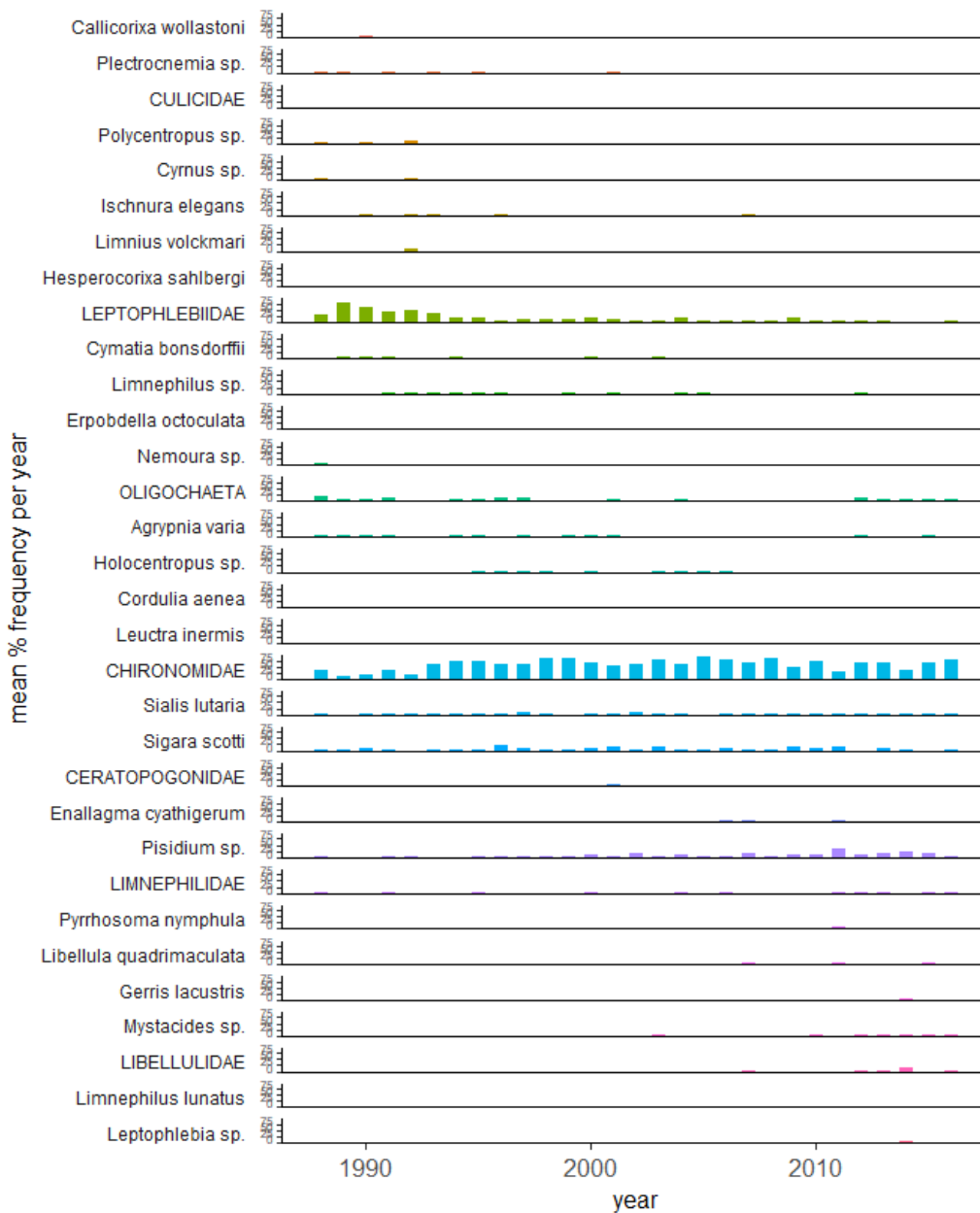
Llyn Cwm Mynach spot sampled chemistry data to March 2020



$\mu\text{eq l}^{-1}$, $^*\mu\text{g l}^{-1}$, $^{**}\text{mg l}^{-1}$	pH	ANC	Ca ²⁺	Mg ²⁺	Na ⁺	K ⁺	*Soluble Al	*Labile Al	Cl ⁻	*SO ₄ ²⁻	xSO ₄ ²⁻	NO ₃ ⁻	**DOC
Mean 1 st 5 yrs	5.35	7.68	77.79	67.45	291.02	3.36	110.75	66.58	337.67	88.32	52.91	9.40	2.50
19-20 mean	5.27	37.43	50.00	53.51	226.20	6.78	NA	NA	282.39	15.80	19.05	10.54	3.43
19-20 std dev	0.42	156.41	15.31	17.32	73.41	0.77	NA	NA	101.35	2.91	4.31	4.32	0.98

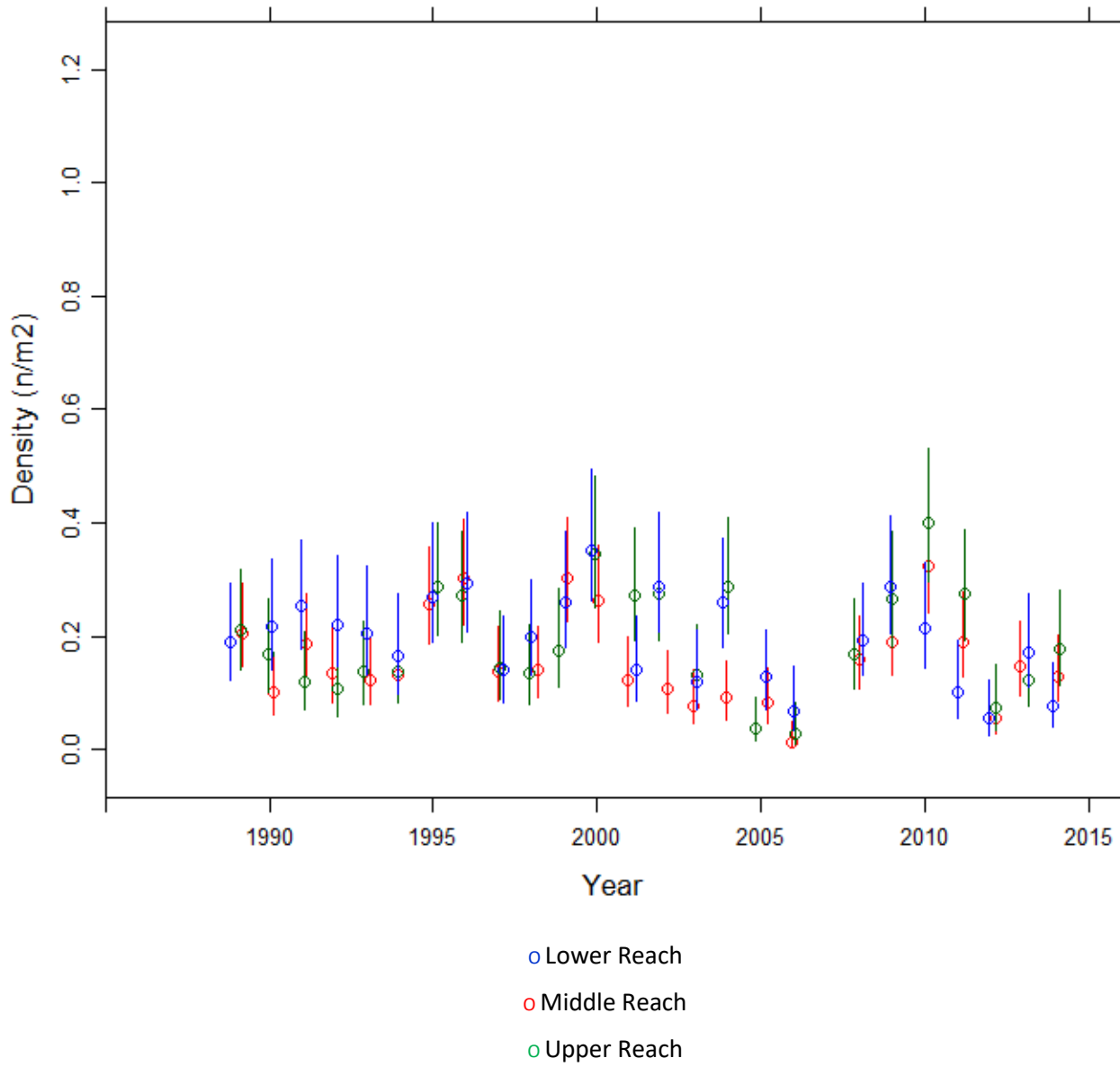
Llyn Cwm Mynach Macroinvertebrate data

Percentage abundance summary, Llyn Cwm Mynach



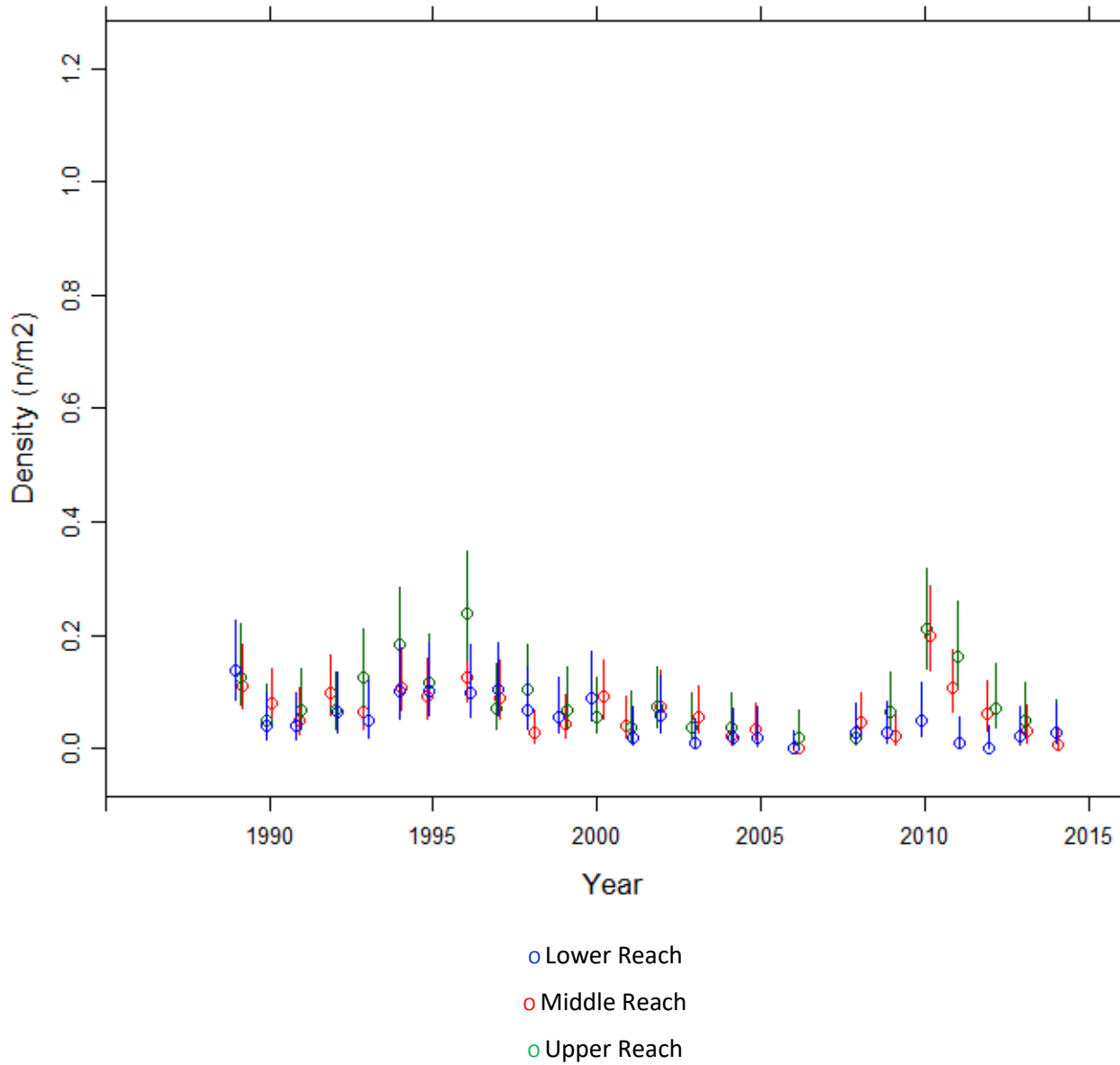
Llyn Cwm Mynach Fish data (for outflow stream)

Summary of Trout fry density (numbers m⁻²), Llyn Cwm Mynach



Fishing no longer funded after 2014.

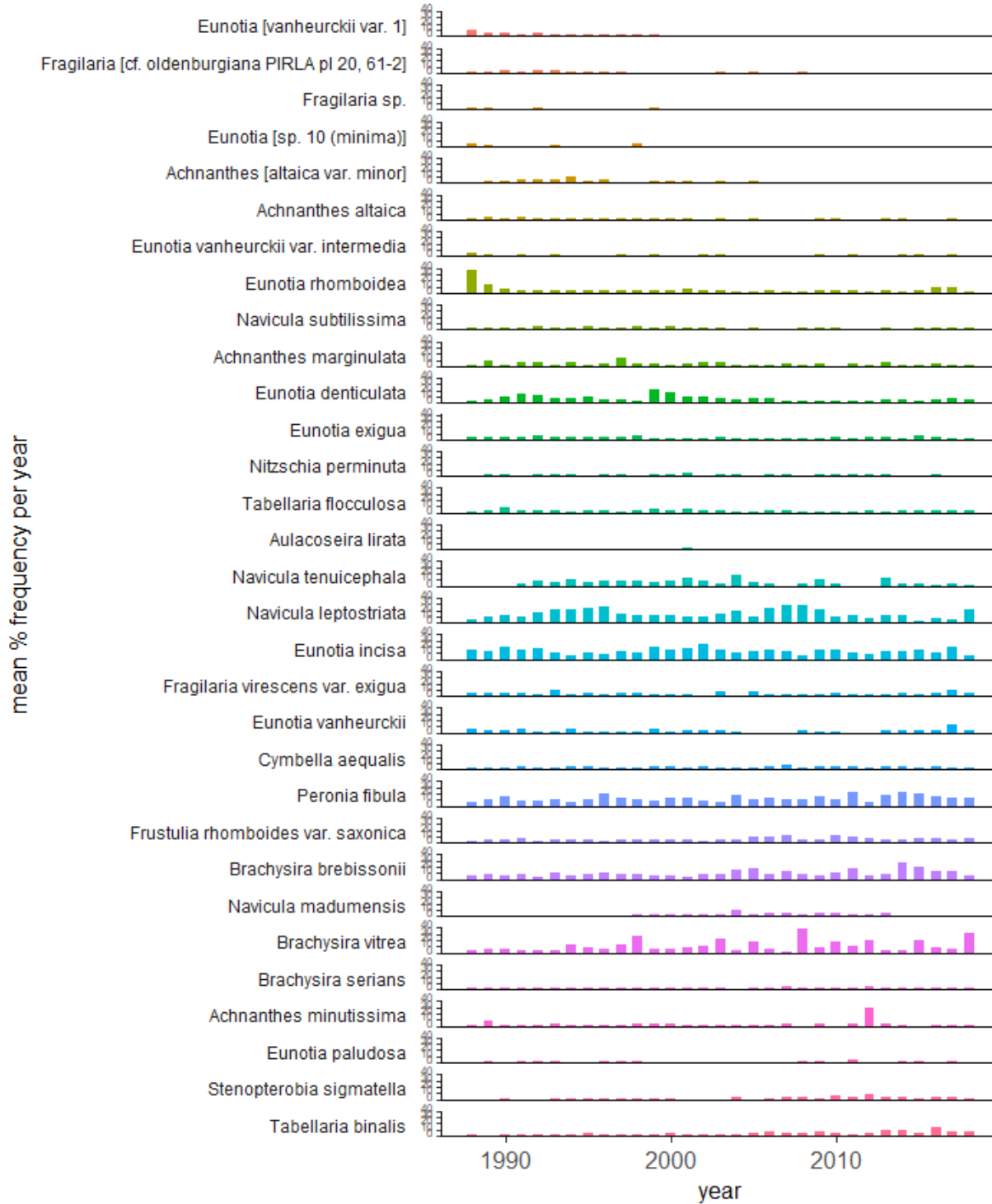
Summary of Trout parr density (numbers m⁻²), Llyn Cwm Mynach



Fishing no longer funded after 2014.

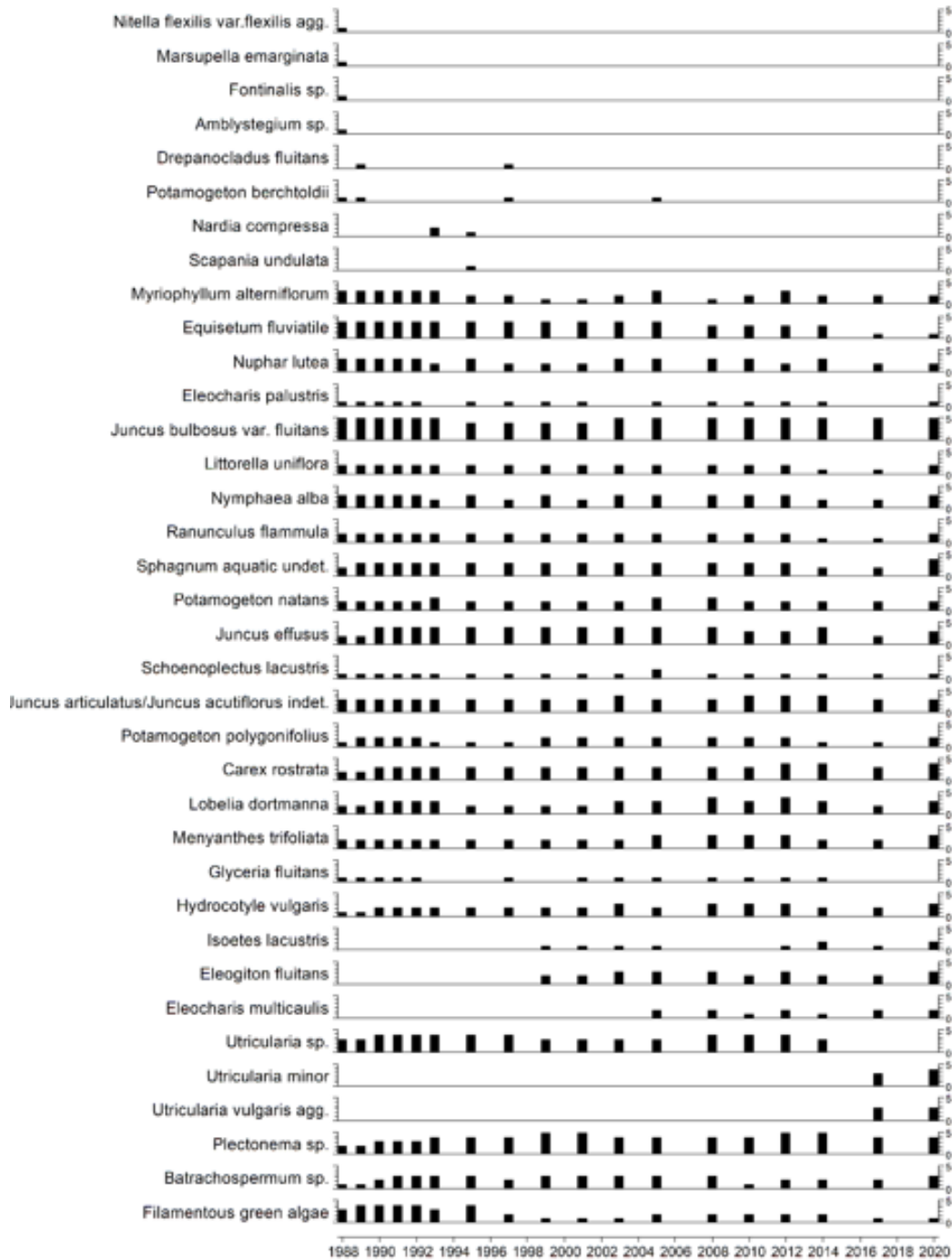
Llyn Cwm Mynach Epilithic diatom data

Percentage abundance summary, Llyn Cwm Mynach



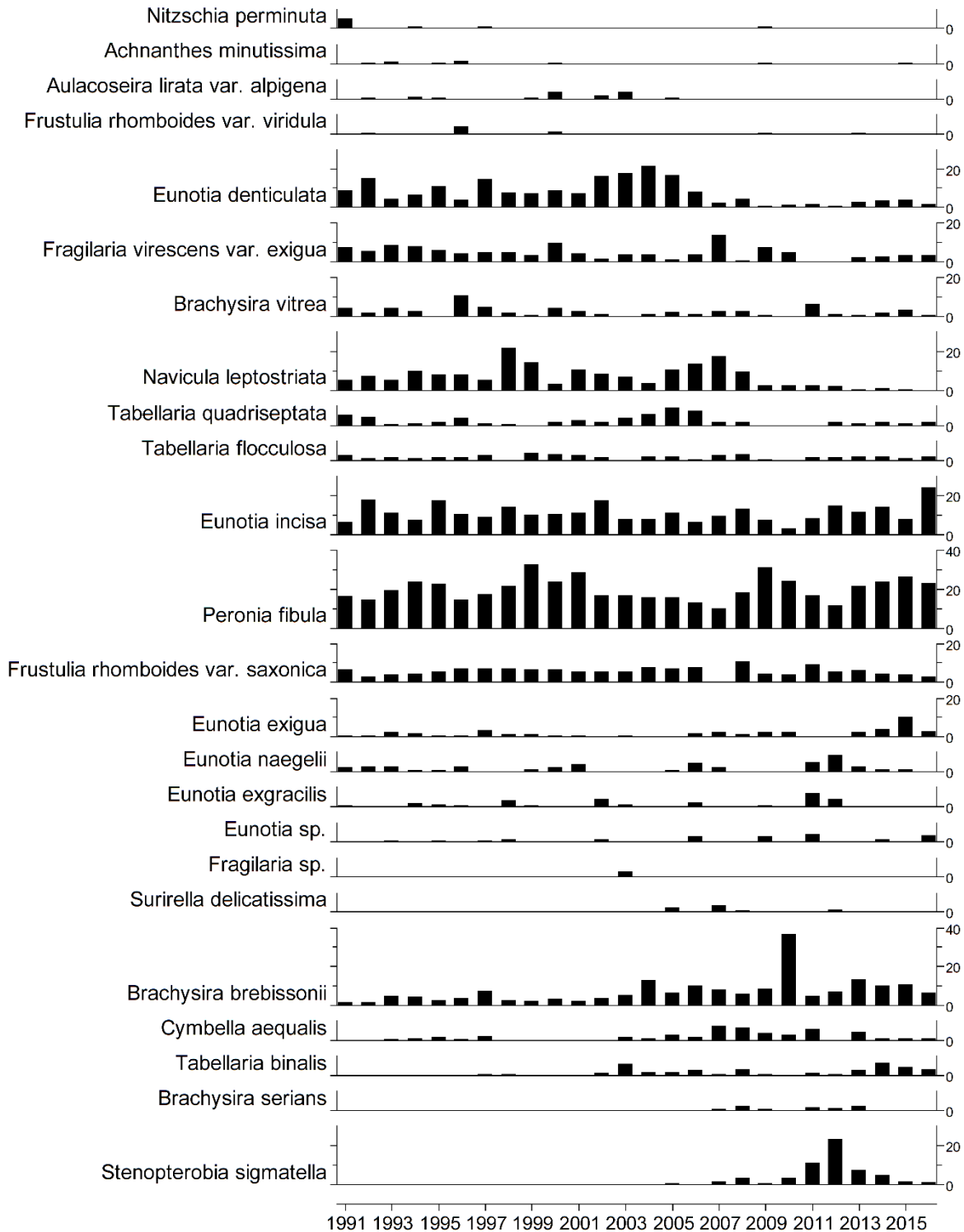
Llyn Cwm Mynach Aquatic macrophyte data,

Species Scores (1-5)

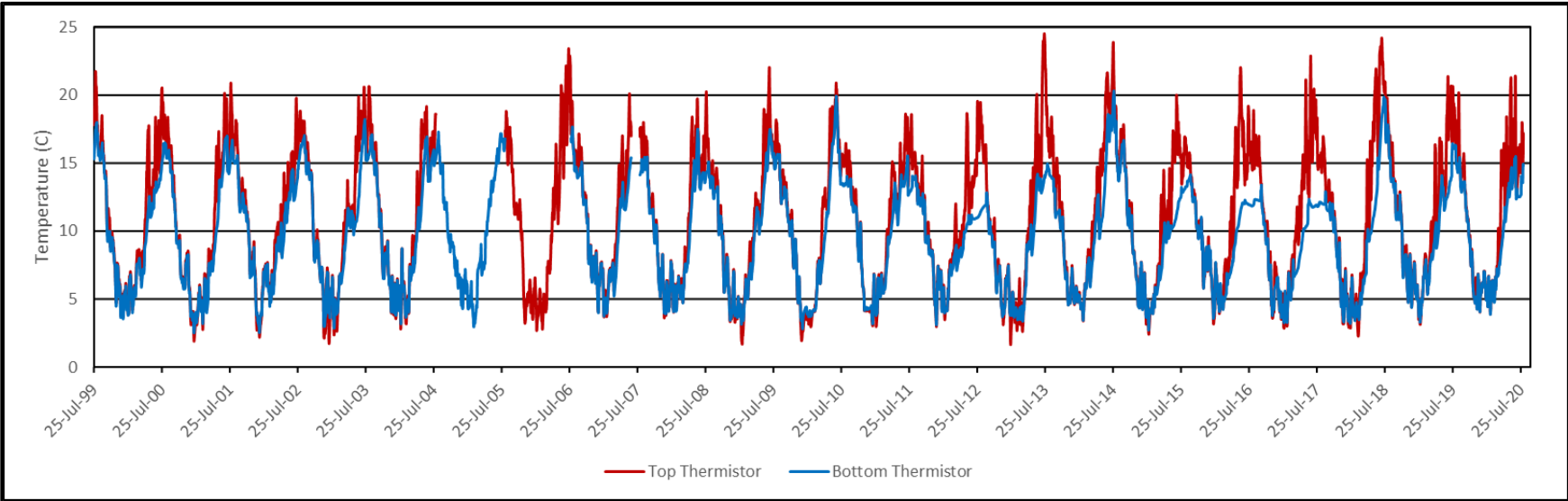


Llyn Cwm Mynach Sediment trap data

Relative percentage frequency of diatom taxa



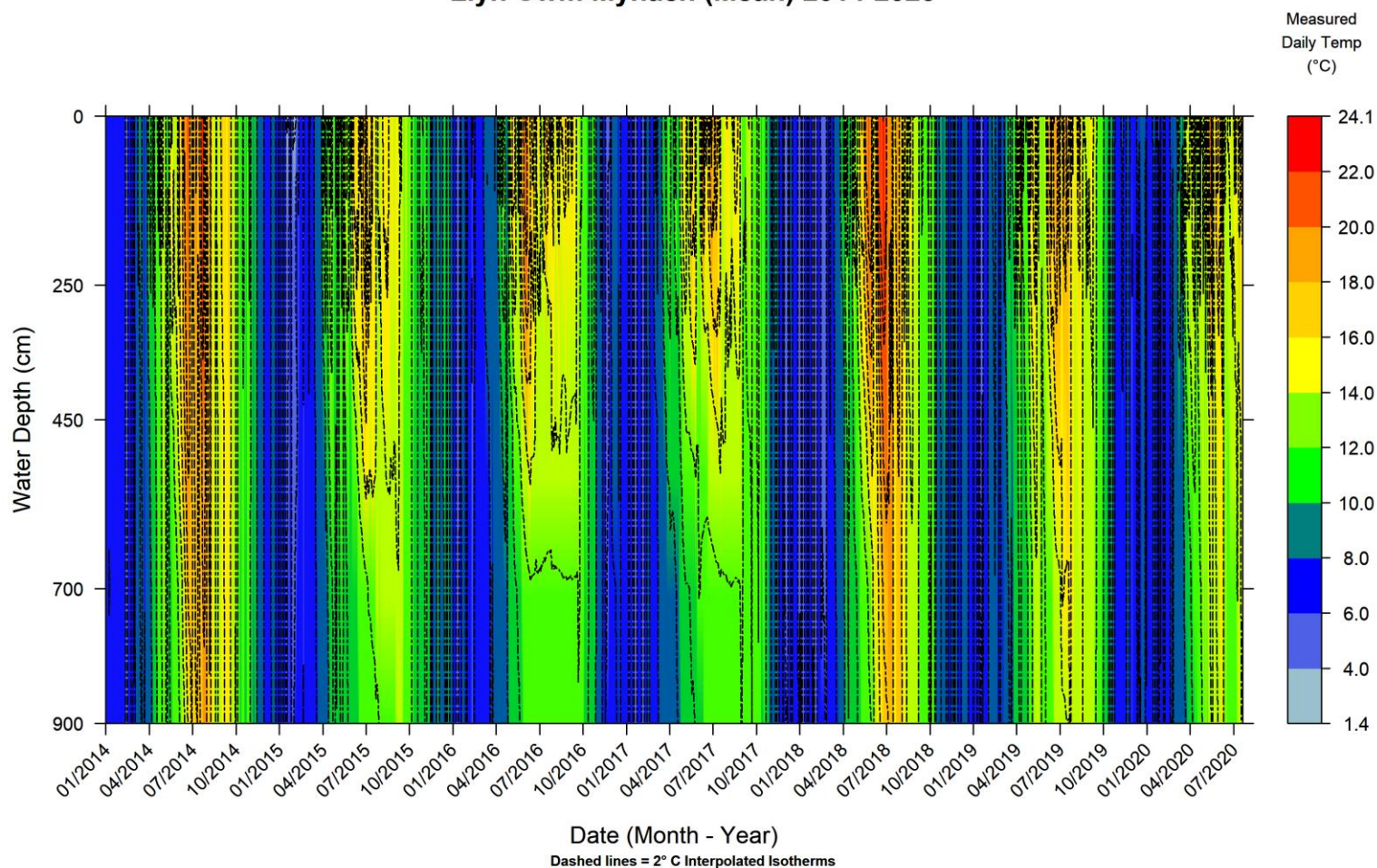
Llyn Cwm Mynach Sediment trap thermistor data



Llyn Cwm Mynach Thermistor chain data



Llyn Cwm Mynach (Mean) 2014-2020



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C. Afon Hafren summary data to March 2020

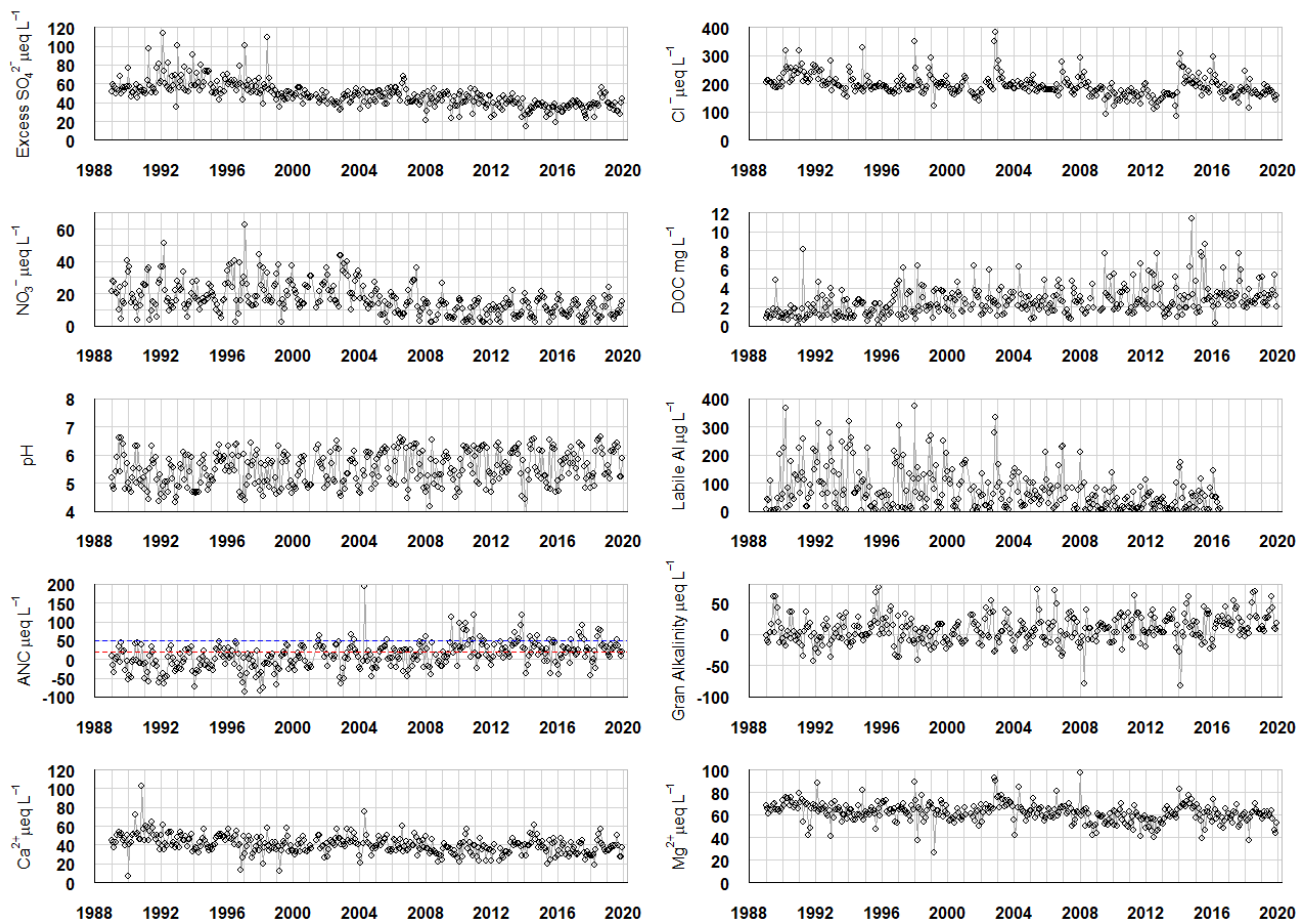


Figure 2 Afon Hafren biological survey section 10th August 2020. Photo: E. Shilland



Figure 3 Afon Hafren forestry operations. 10th August 2020. Photo: E. Shilland

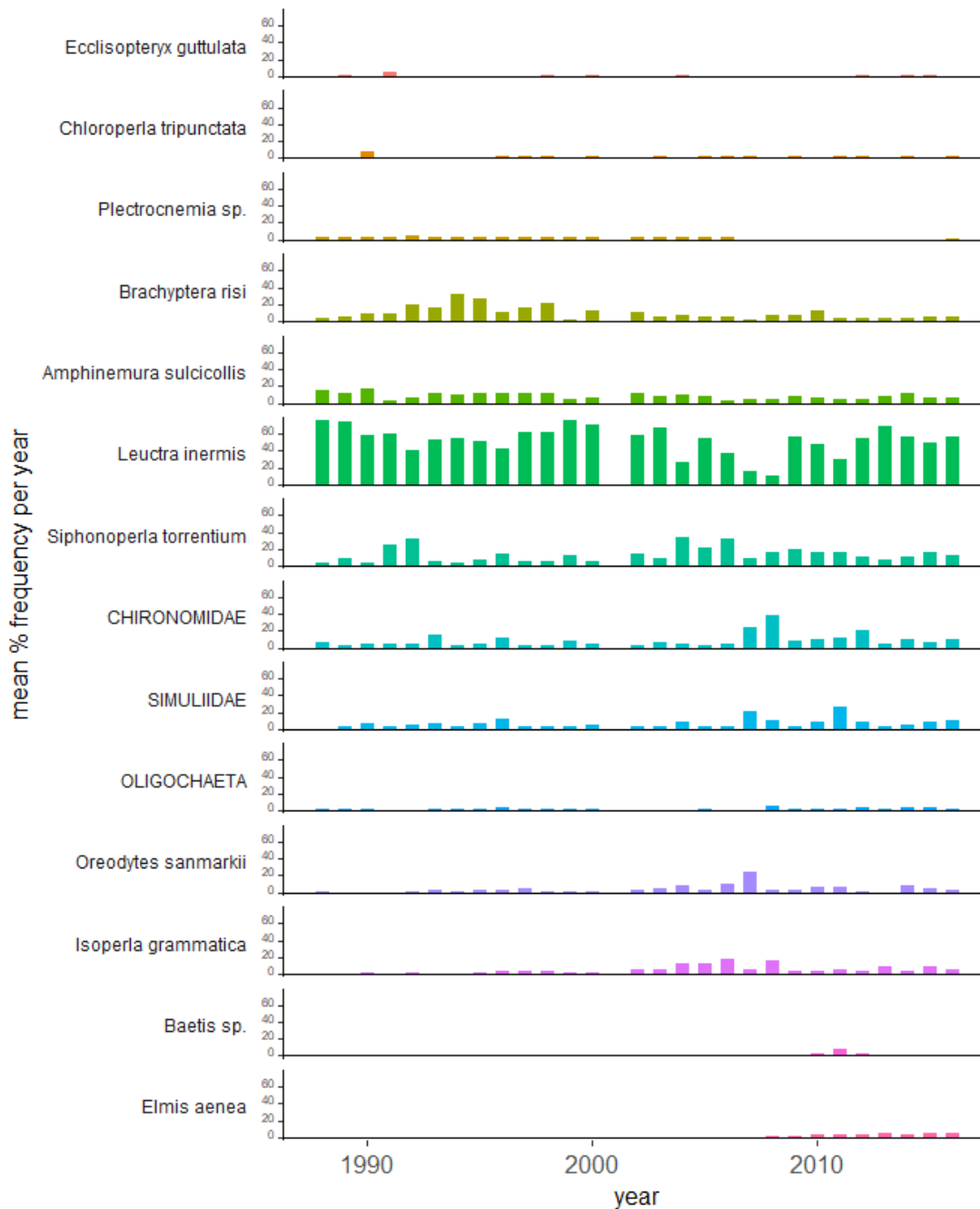
Afon Hafren Spot sampled chemistry data to March 2020



$\mu\text{eq l}^{-1}$, $^*\mu\text{g l}^{-1}$, $^{**}\text{mg l}^{-1}$	pH	ANC	Ca ²⁺	Mg ²⁺	Na ⁺	K ⁺	*Soluble Al	*Labile Al	Cl ⁻	*SO ₄ ²⁻	xSO ₄ ²⁻	NO ₃ ⁻	**DOC
Mean 1 st 5 yrs	5.29	-2.40	47.91	66.41	200.39	3.16	170.00	101.71	221.09	82.97	59.79	20.58	1.76
19-20 mean	5.86	23.76	36.47	55.90	161.68	3.85	NA	NA	171.26	53.23	35.42	9.64	2.94
19-20 std dev	0.45	15.79	6.28	5.93	8.77	1.08	NA	NA	15.84	4.54	4.73	3.63	0.99

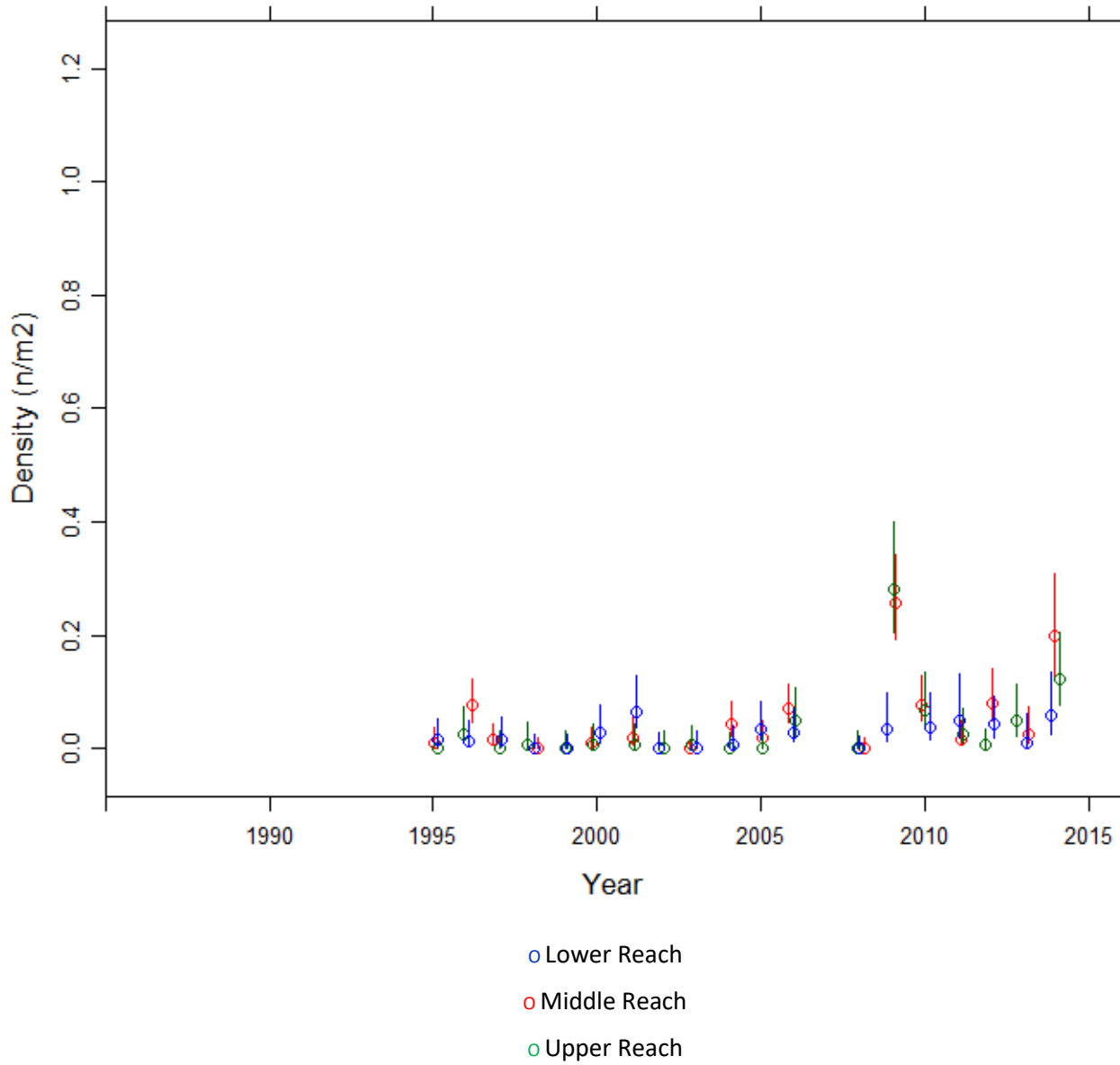
Afon Hafren Macroinvertebrate data

Percentage abundance summary, Afon Hafren



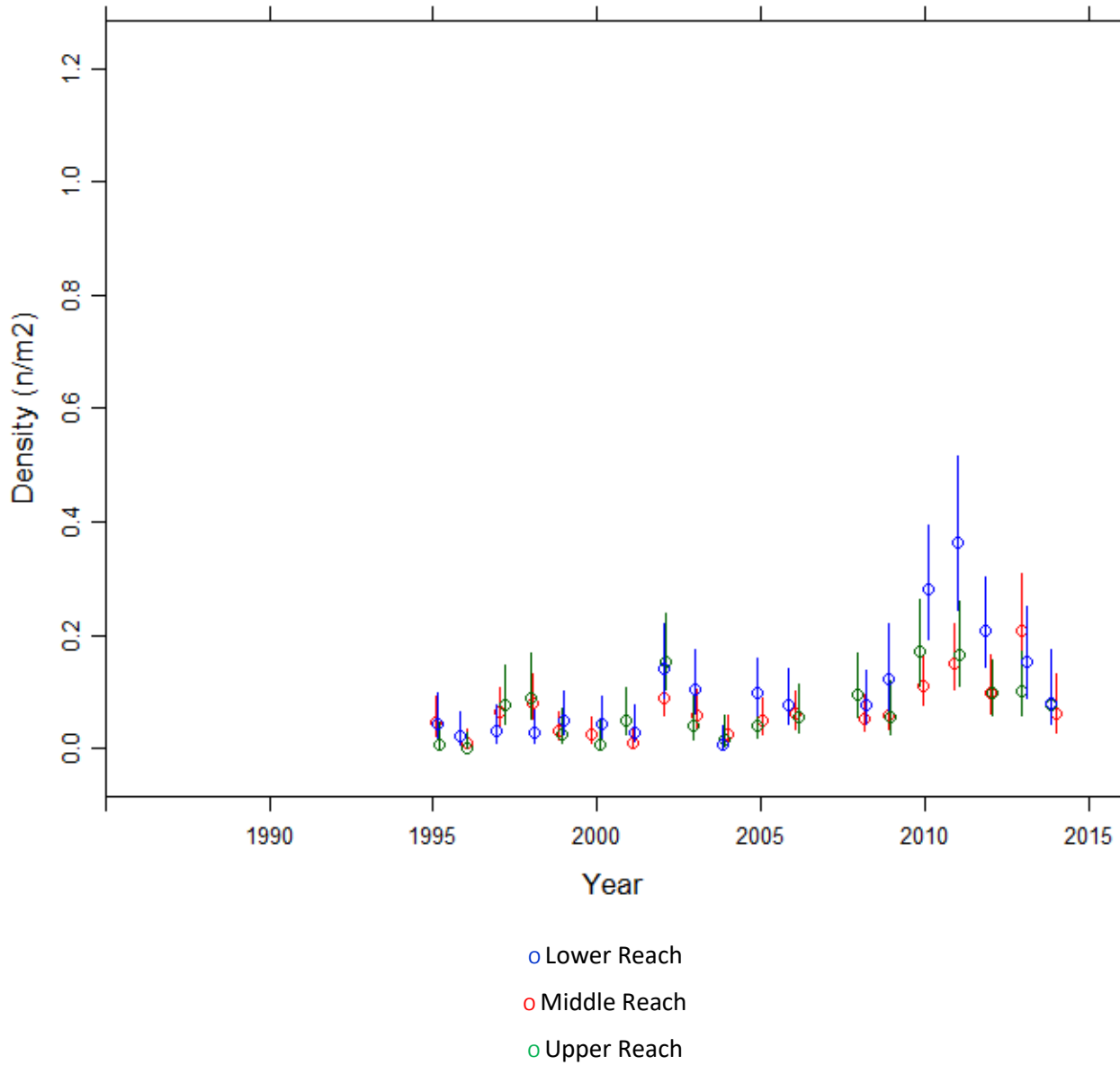
Afon Hafren Fish data

Summary of Trout fry density (numbers m^{-2}), Afon Hafren



Fishing no longer funded after 2014.

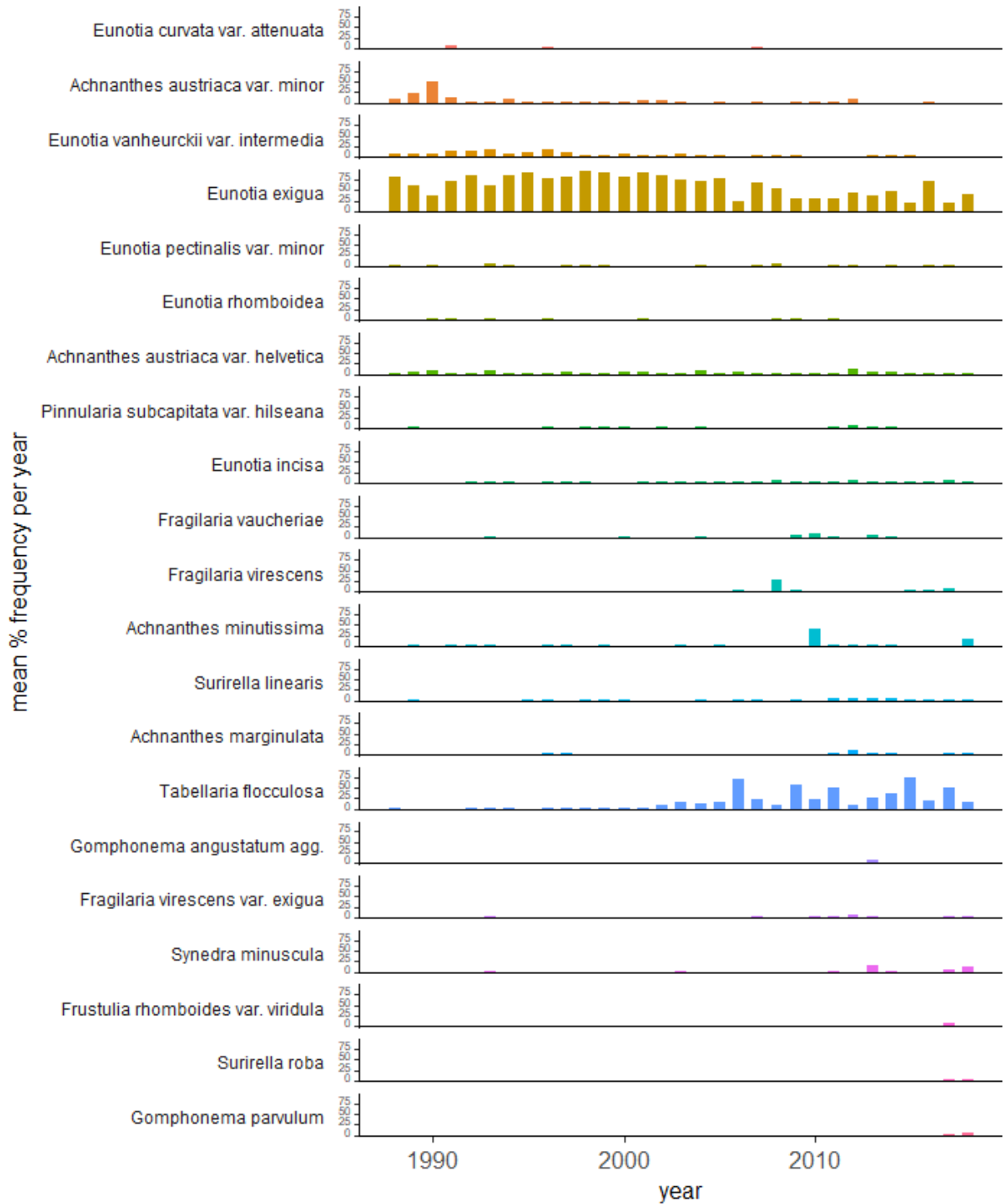
Summary of Trout parr density (numbers m⁻²), Afon Hafren



Fishing no longer funded after 2014.

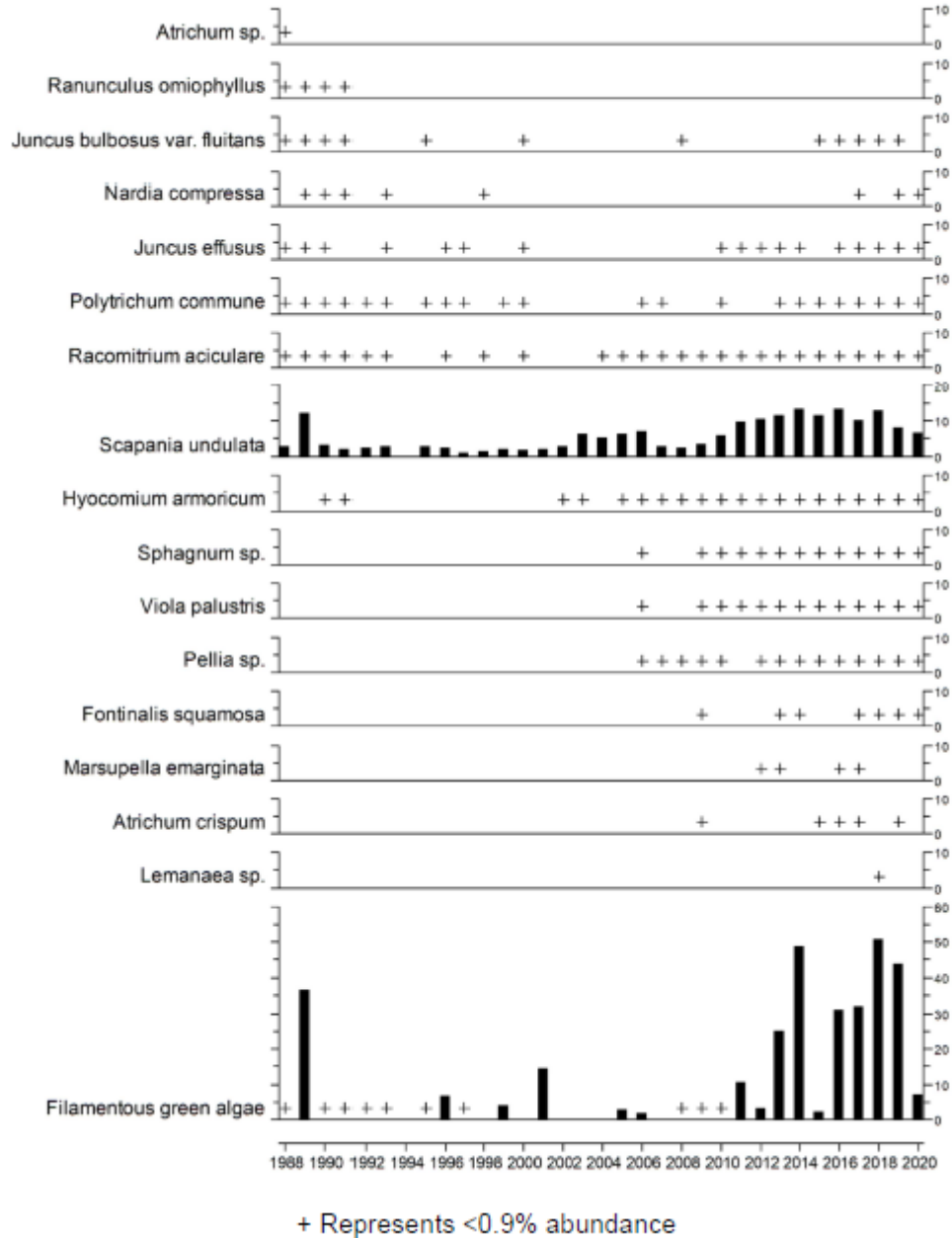
Afon Hafren *Epilithic diatom data*

Percentage abundance summary, Afon Hafren

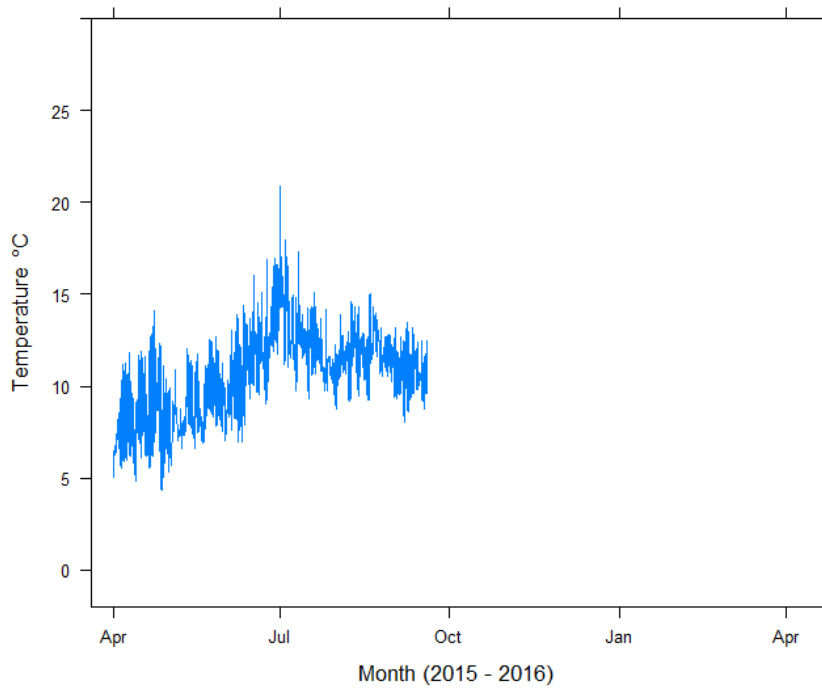
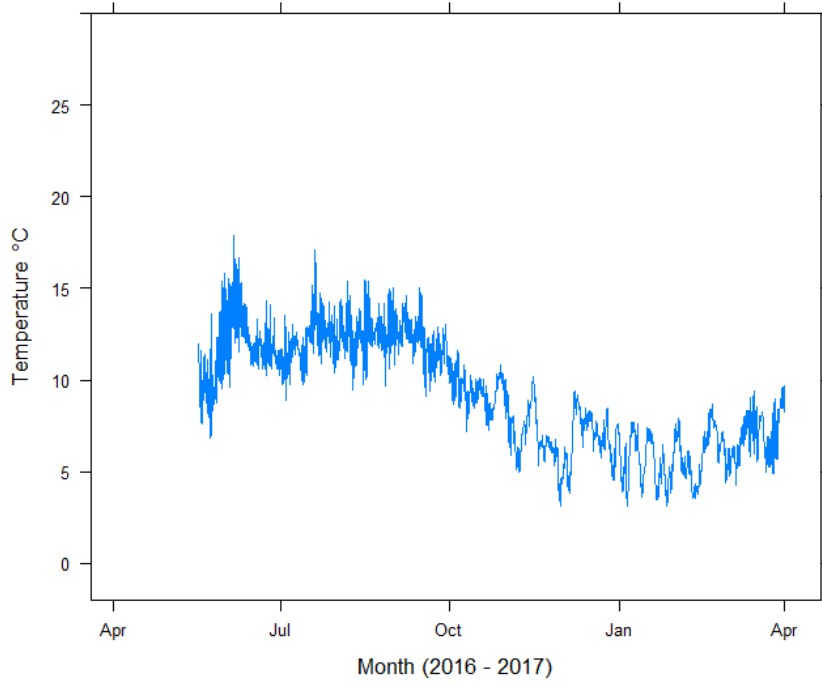


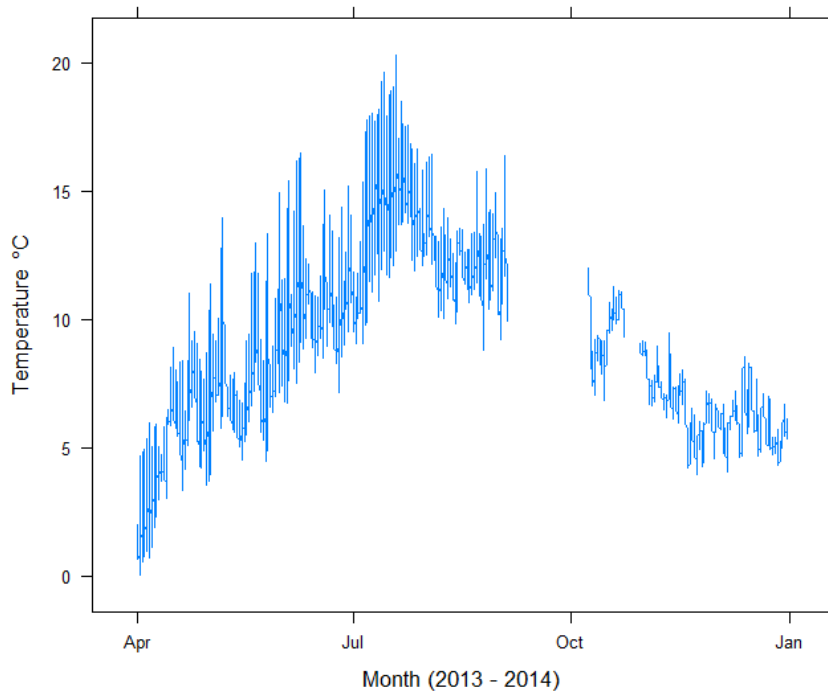
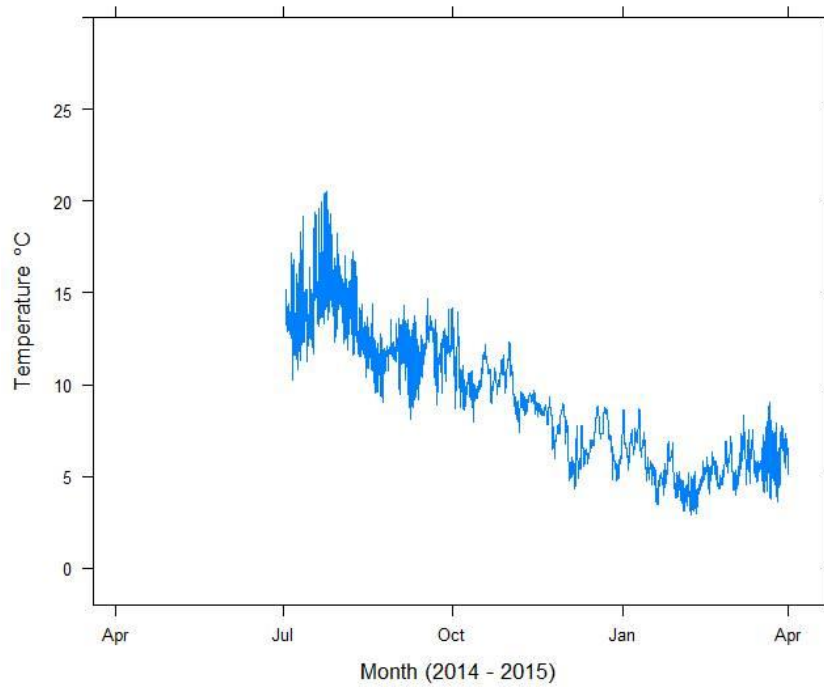
Afon Hafren Aquatic macrophyte data

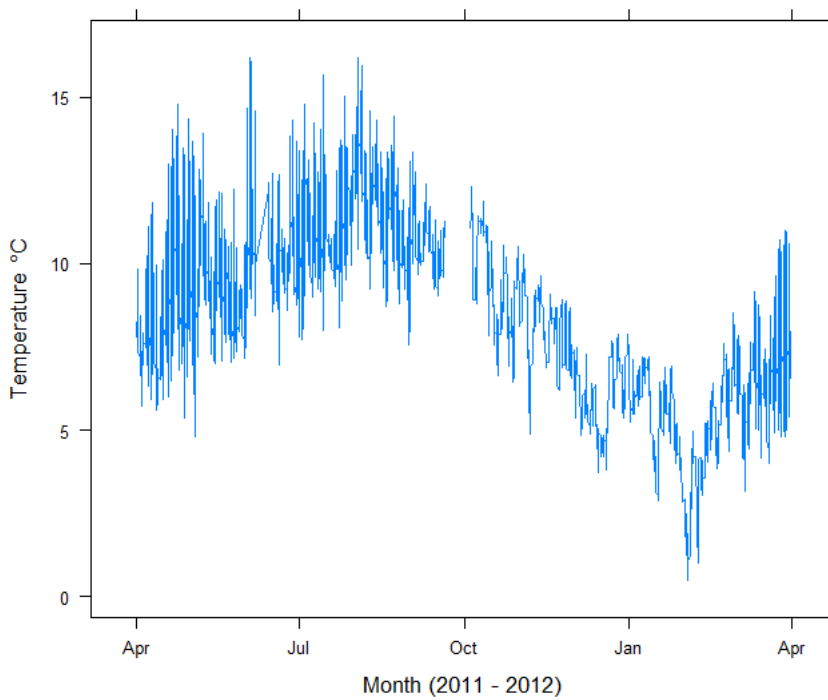
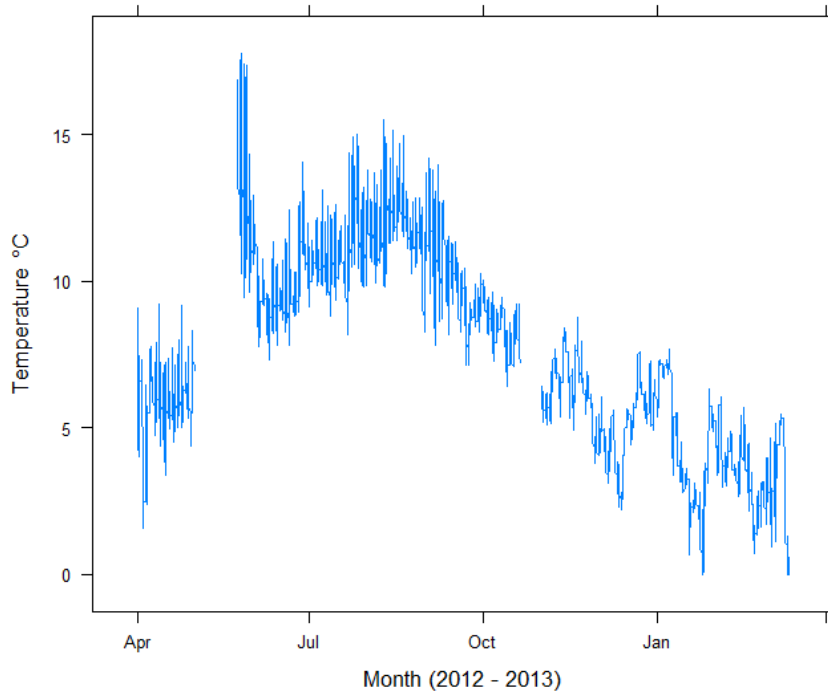
Percentage Species Cover



Afon Hafren Thermistor data (no data post 2017)







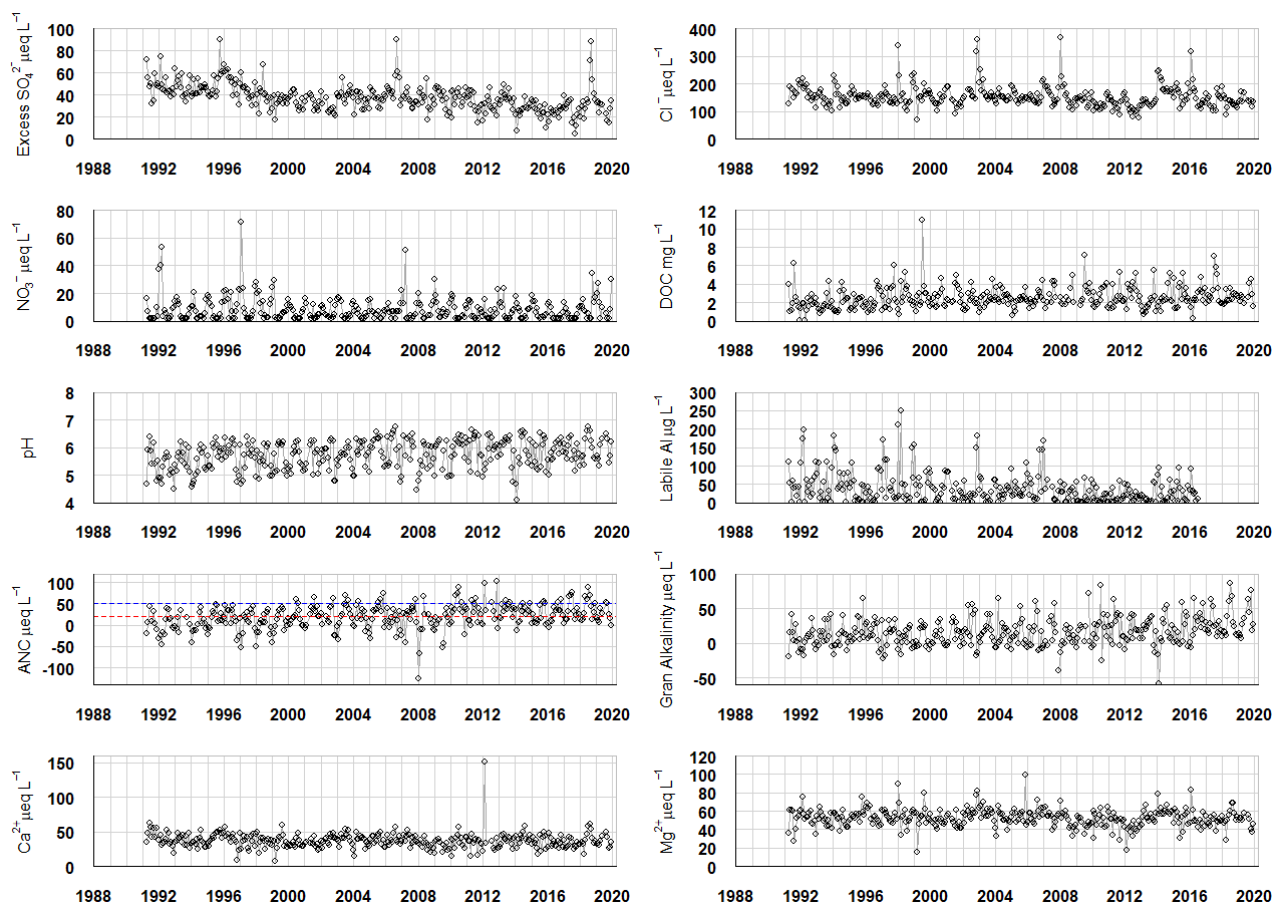
Gaps due to thermistor malfunction

D. Afon Gwy summary data to March 2020



Figure 3 Afon Gwy biological survey section 10th August 2020. Photo: E.Shilland

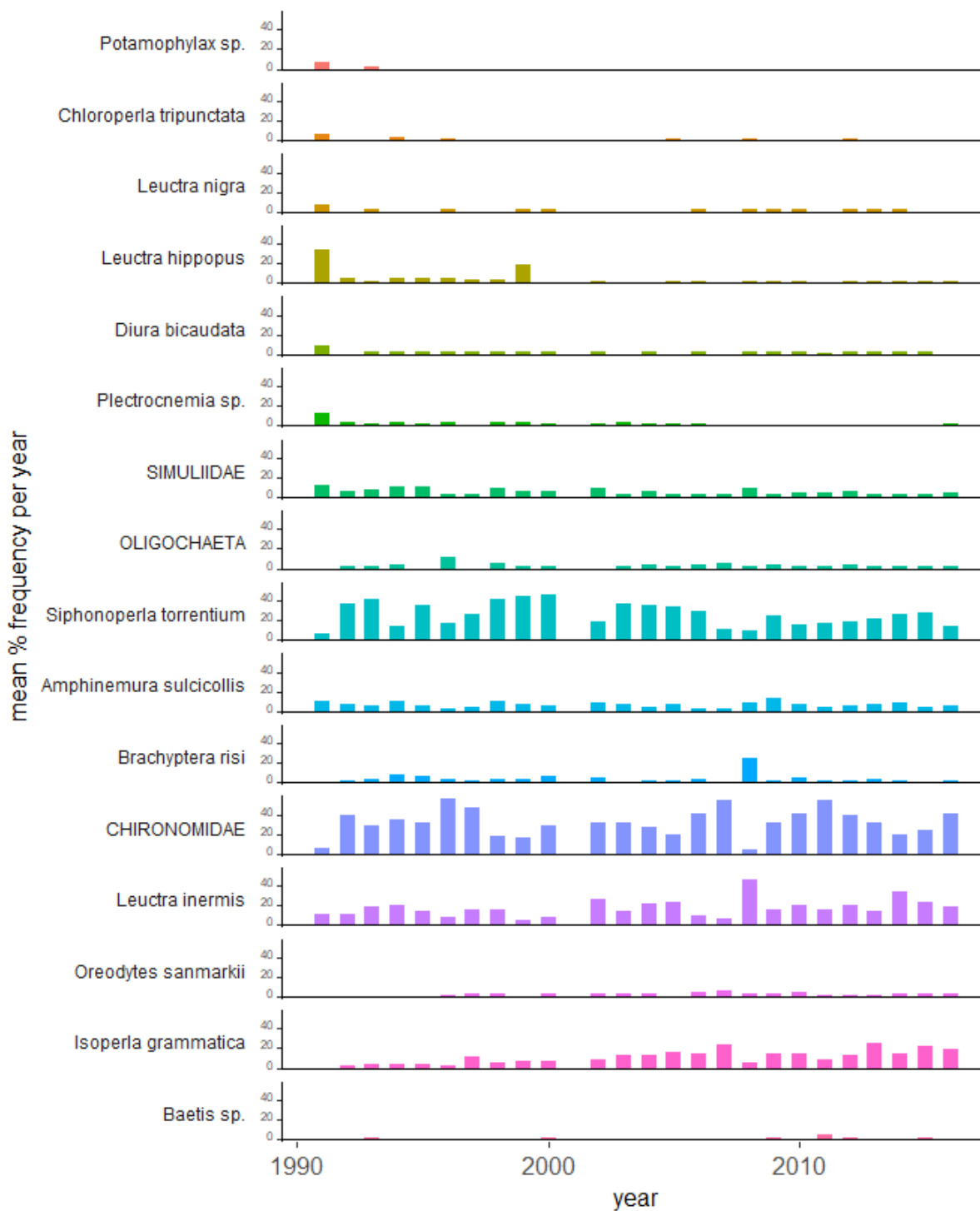
Afon Gwy spot sampled chemistry data to March 2020



$\mu\text{eq l}^{-1}$, $^*\mu\text{g l}^{-1}$, $^{**}\text{mg l}^{-1}$	pH	ANC	Ca ²⁺	Mg ²⁺	Na ⁺	K ⁺	*Soluble Al	*Labile Al	Cl ⁻	*SO ₄ ²⁻	xSO ₄ ²⁻	NO ₃ ⁻	**DOC
Mean 1 st 5 yrs	5.51	14.13	40.42	53.22	147.31	3.24	106.64	53.64	159.84	65.67	48.91	8.65	1.98
19-20 mean	6.05	23.62	36.66	49.25	132.28	2.53	NA	NA	146.43	40.44	25.21	10.23	2.66
19-20 std dev	0.34	21.41	6.60	5.80	11.12	1.03	NA	NA	20.41	7.34	6.49	8.75	0.90

Afon Gwy Macroinvertebrate data

Percentage abundance summary, Afon Gwy



2016 - 2018
archived
funding for

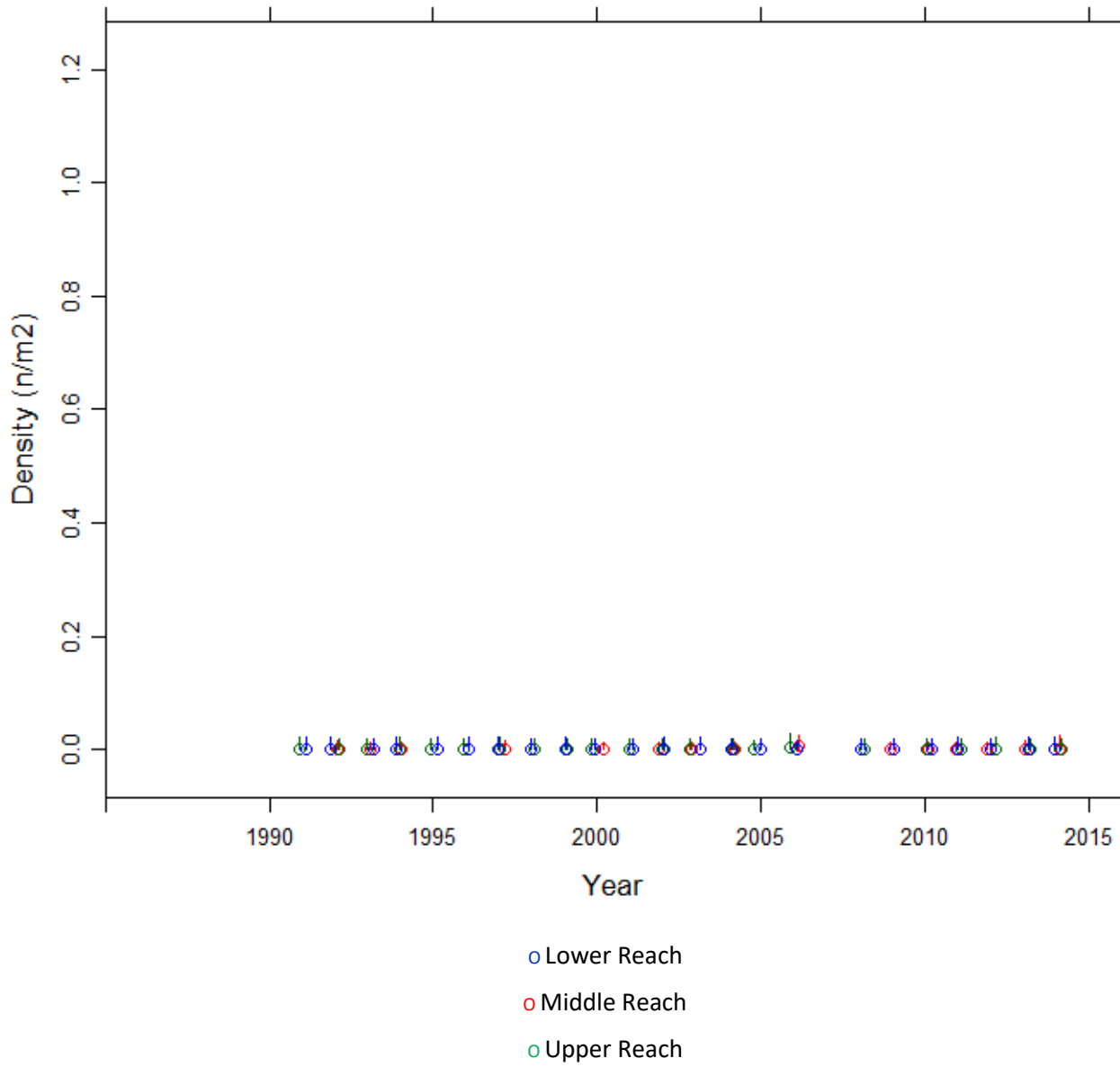
No sampling in
to Foot and
restrictions.

samples
awaiting
analysis

2001 due
Mouth

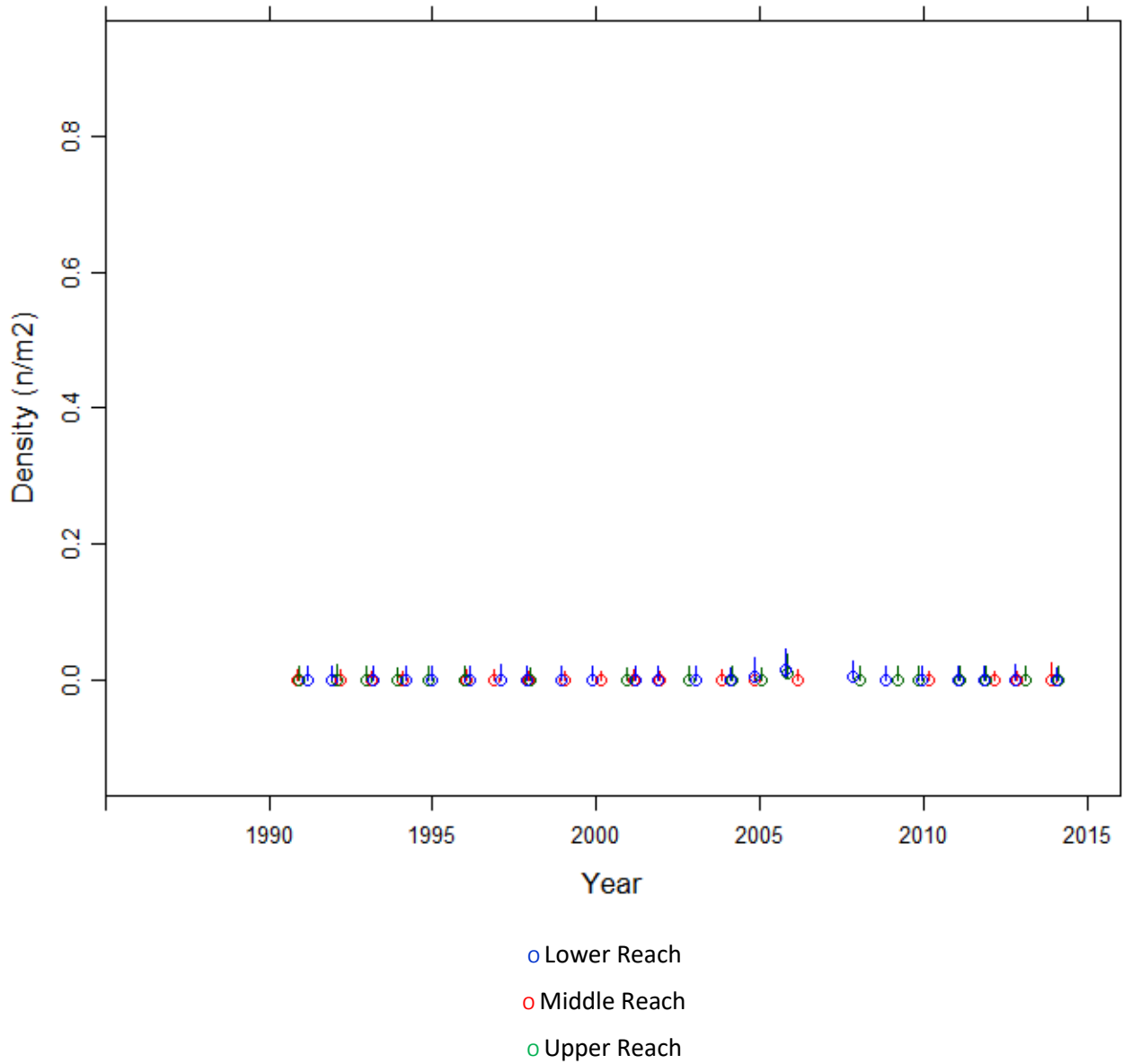
Afon Gwy Fish data

Summary of Salmon fry densities (numbers m⁻²), Afon Gwy



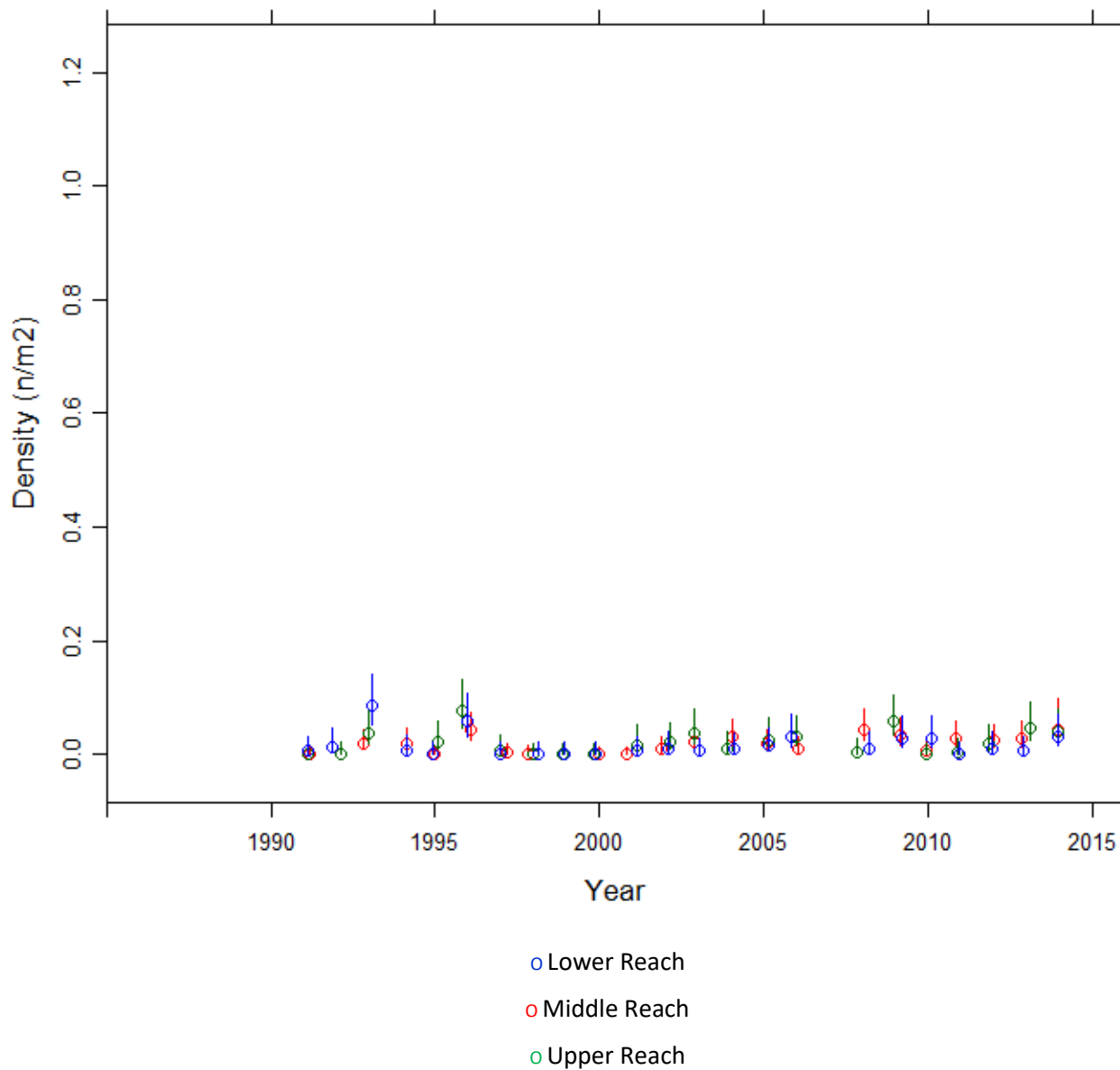
Fishing no longer funded after 2014.

Summary of Salmon parr densities (numbers m⁻²), Afon Gwy



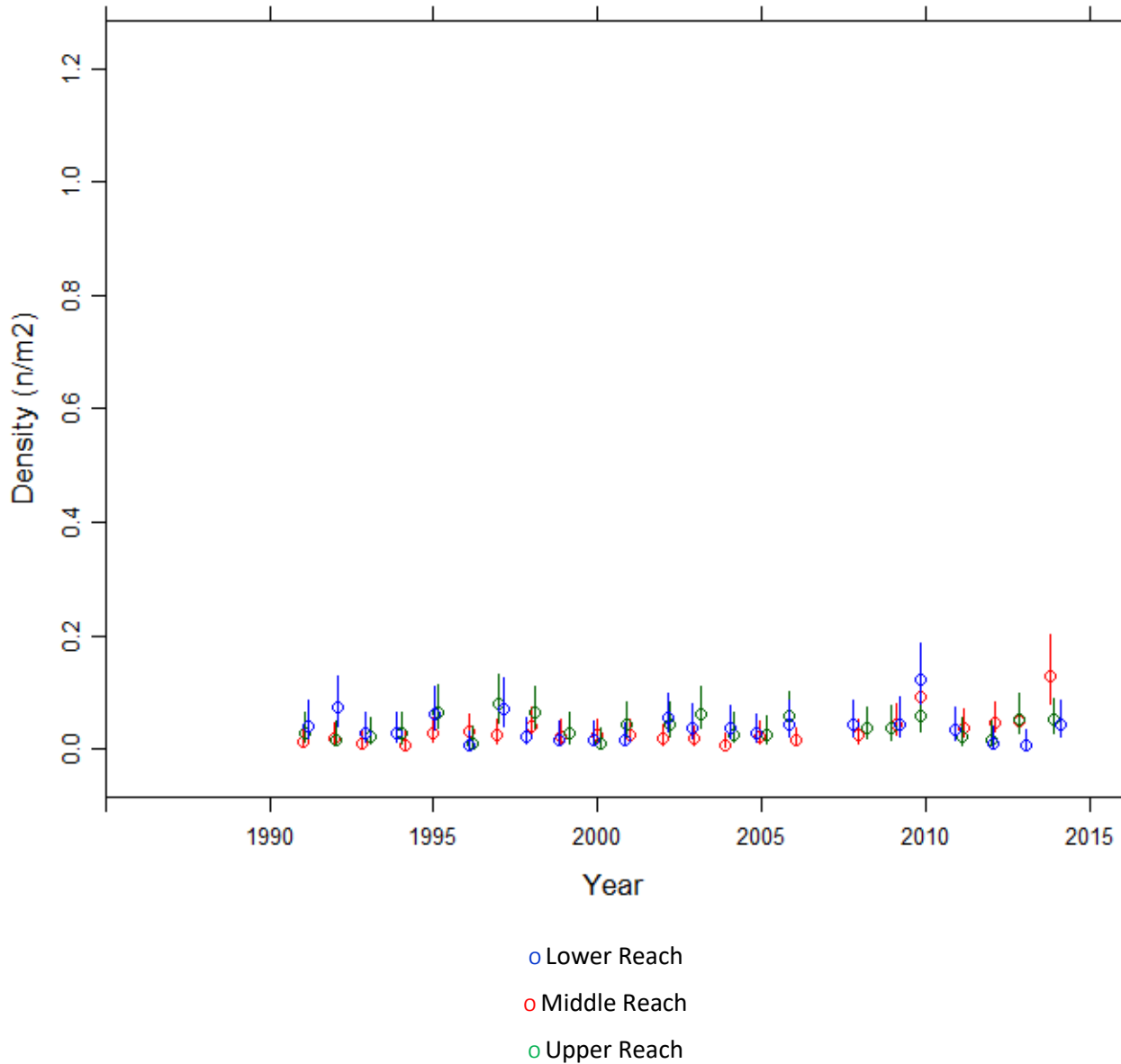
Fishing no longer funded after 2014.

Summary of Trout fry density (numbers m⁻²), Afon Gwy



Fishing no longer funded after 2014.

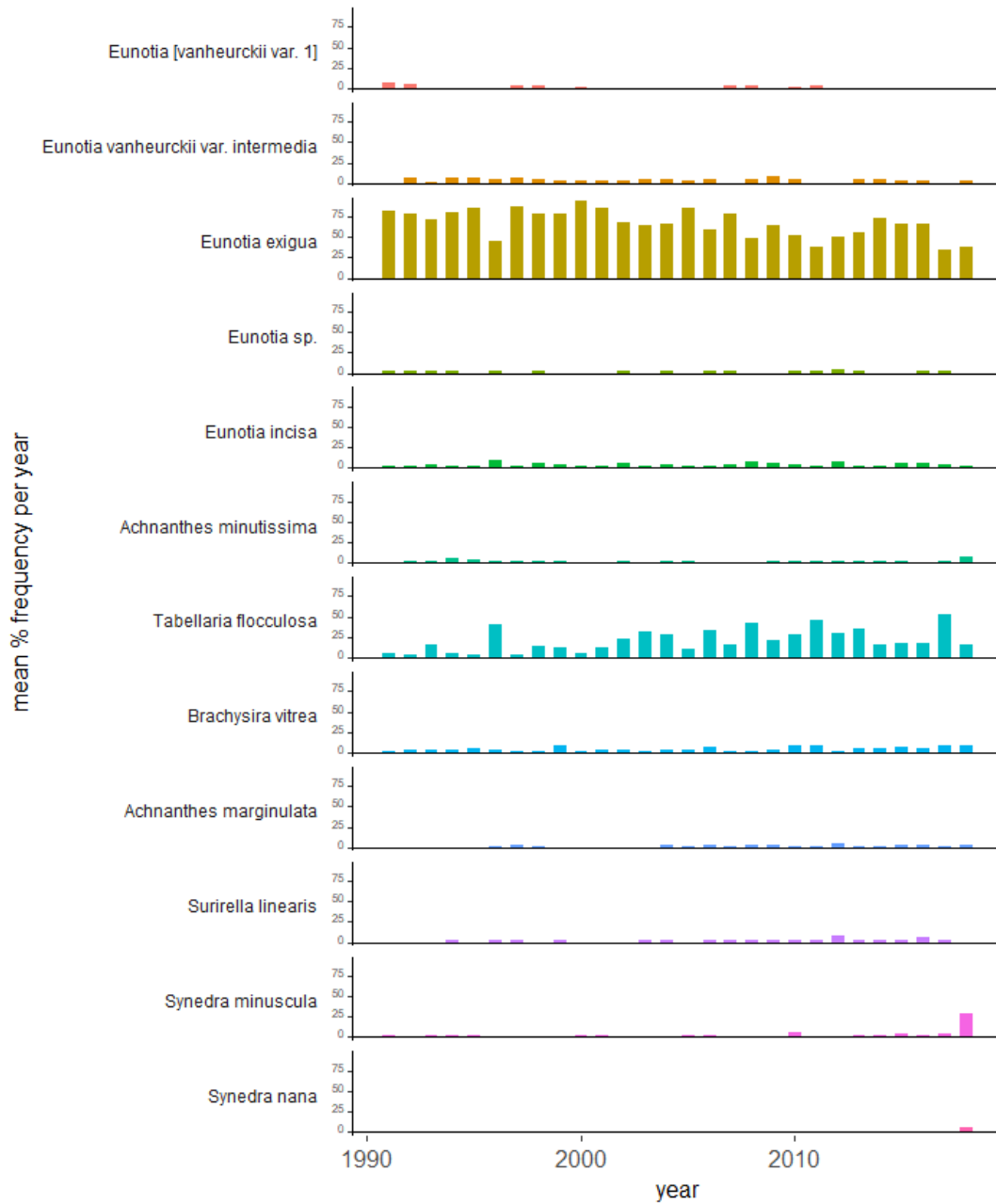
Summary of Trout parr density (numbers m⁻²), Afon Gwy



Fishing no longer funded after 2014

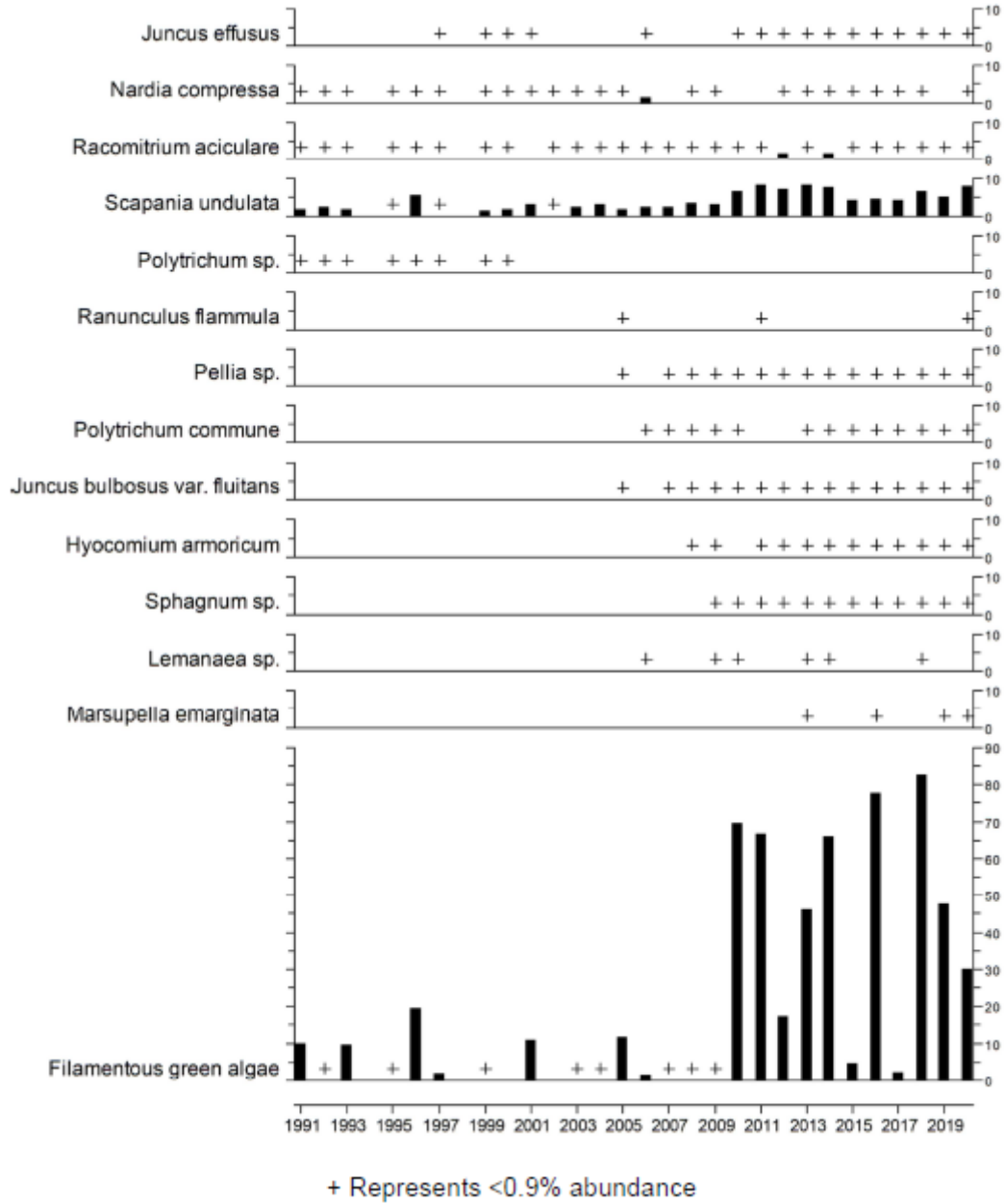
Afon Gwy Epilithic diatom data

Percentage abundance summary, Afon Gwy

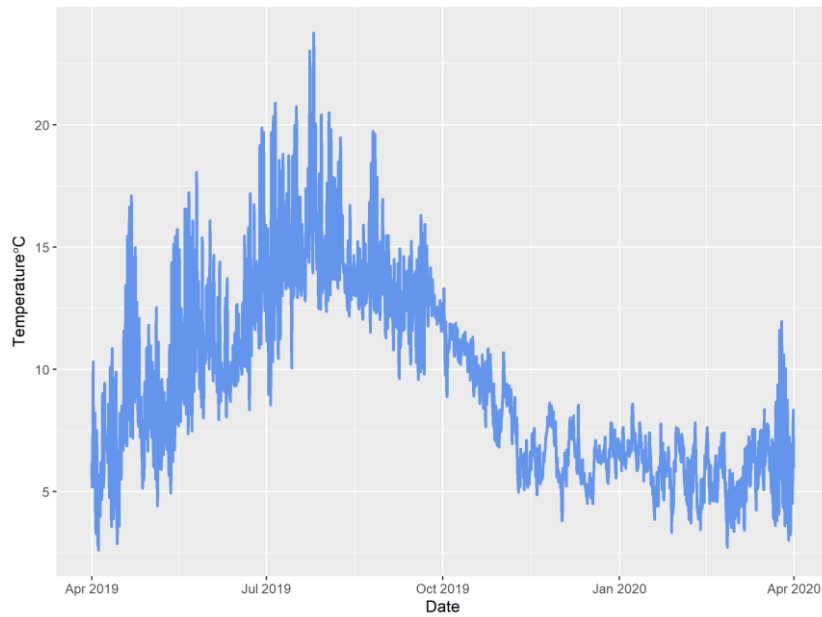


Afon Gwy Aquatic macrophyte data

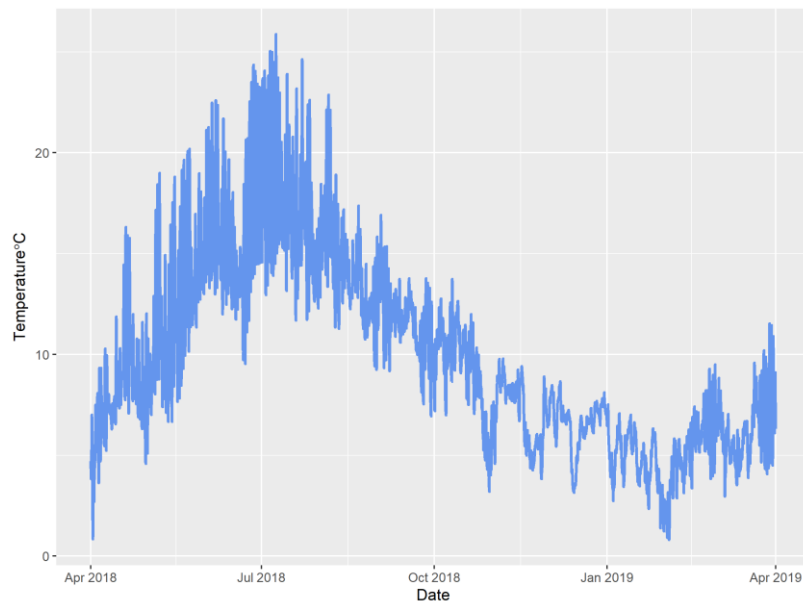
Percentage Species Cover



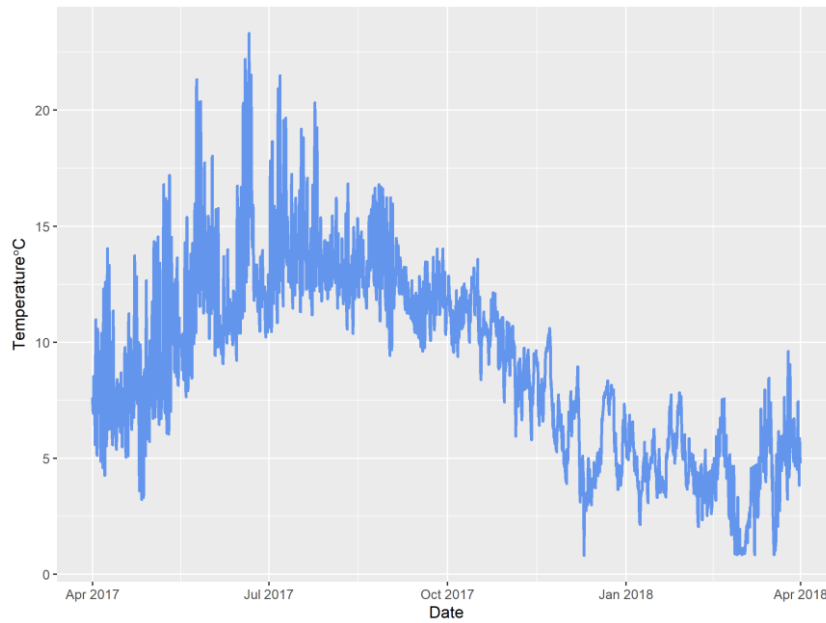
Afon Gwy Thermistor data



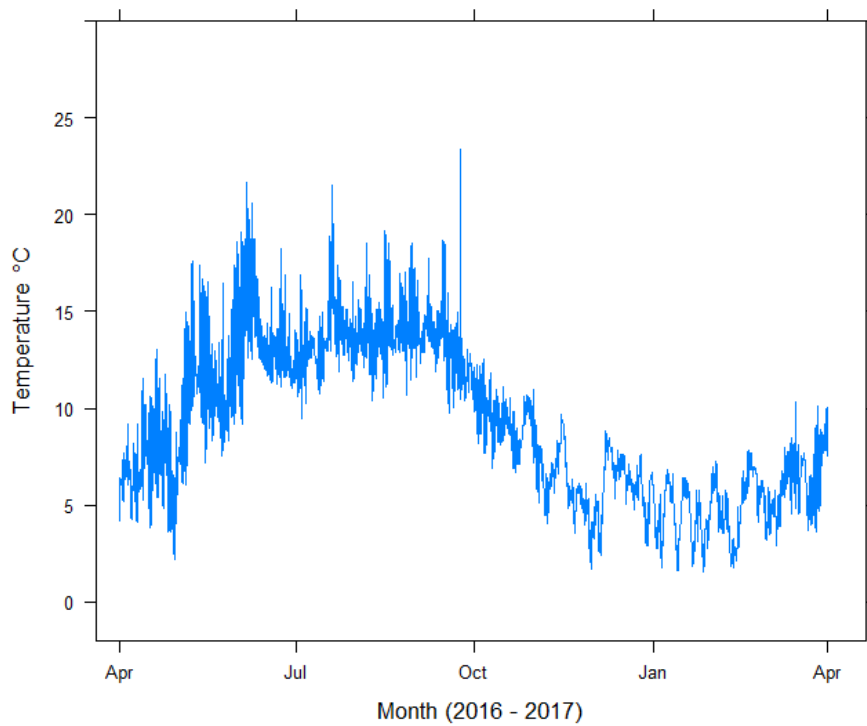
2019-2020

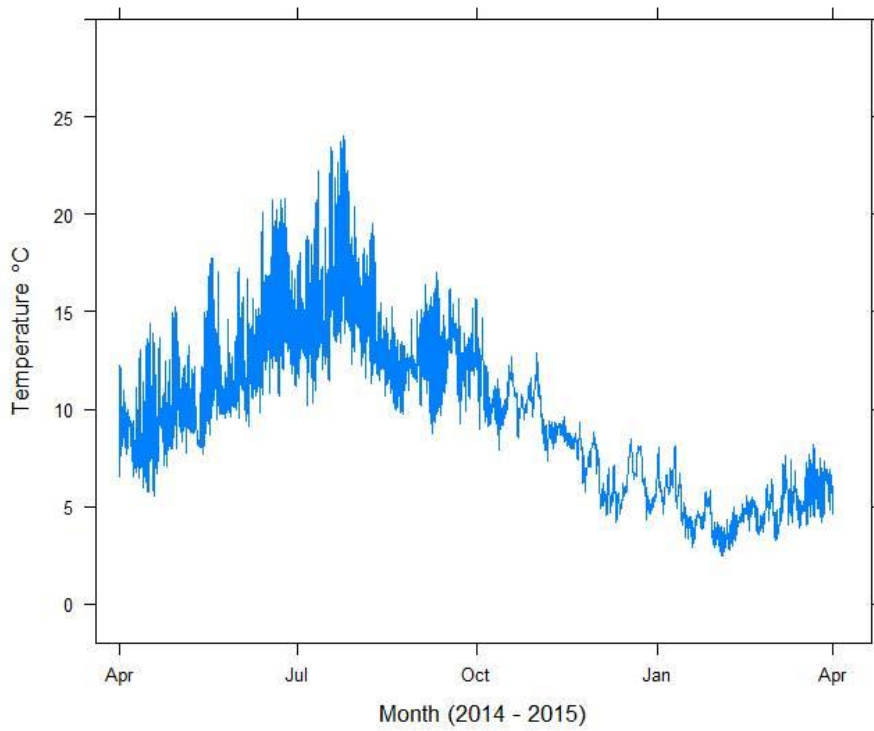
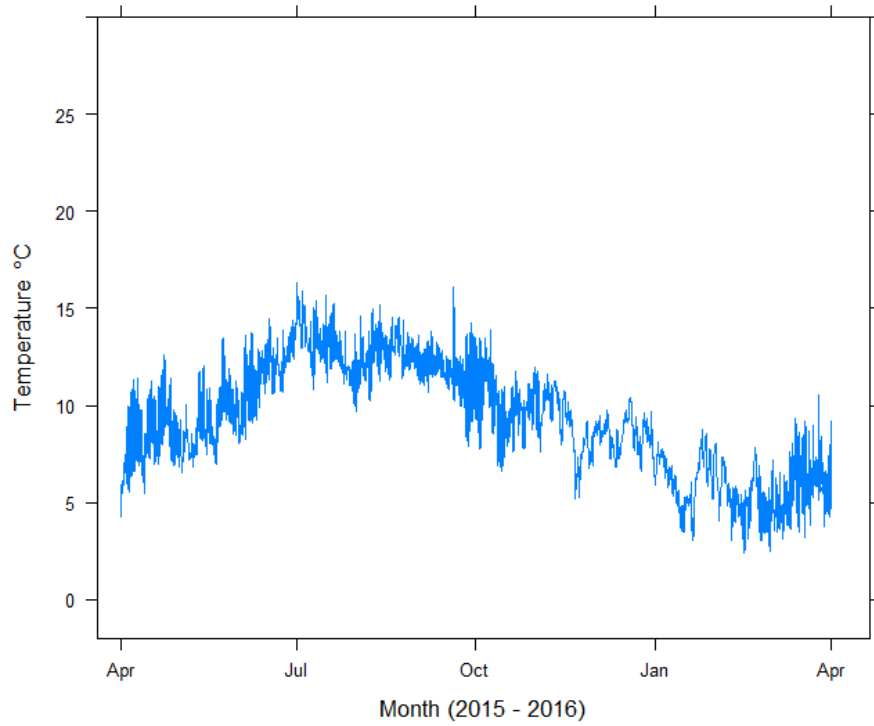


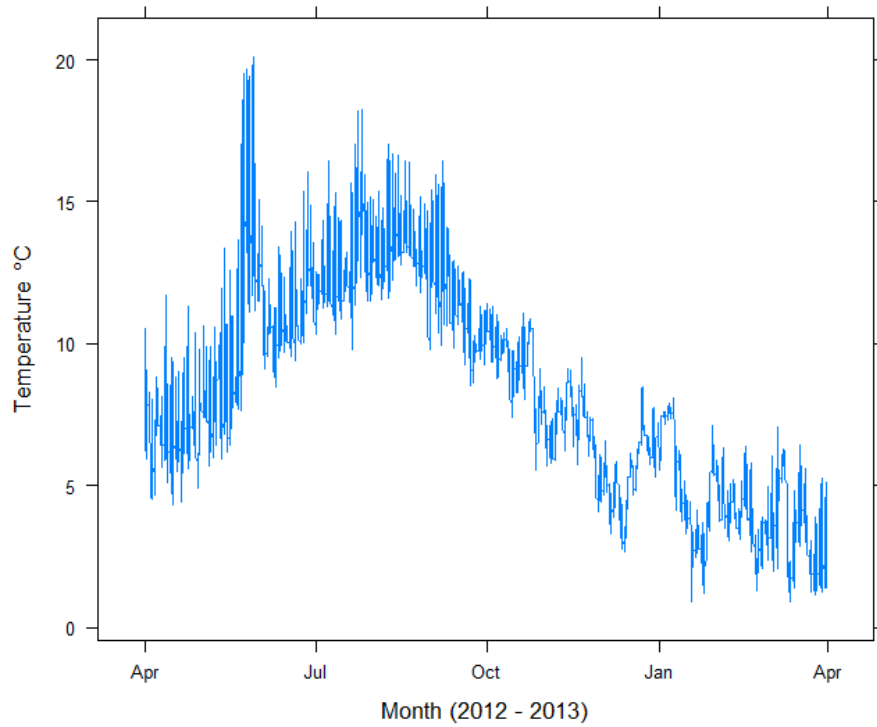
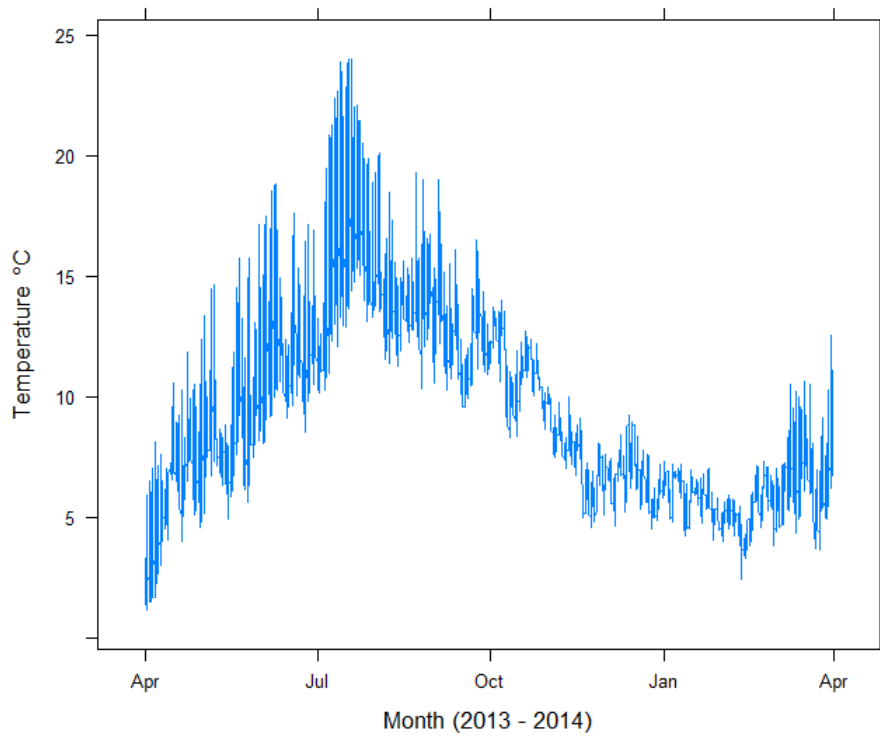
2018-2019



2017-2018









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