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**UK Upland Waters Monitoring Network (UKUWMN)
Llyn Llagi, Llyn Cwm Mynach, Afon Hafren and Afon Gwy
Annual Summary Progress Report. April 15 - March 16**

E. M. Shilland, D. T. Monteith, K. Millidine, I. A. Malcolm & D. A. Norris

March 2016

**UK UPLAND WATERS MONITORING NETWORK (UKUWMN) –
CONTRACT 22 01 249**

**LLYN LLAGI, LLYN CWM MYNACH, AFON HAFREN AND AFON
GWY**

ANNUAL SUMMARY PROGRESS REPORT April 2015 - March 2016

**REPORT TO THE WELSH ASSEMBLY GOVERNMENT AND
NATURAL RESOURCES WALES**

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March 2016

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Cover photo: macrophyte surveying at Llyn Llgi, July 2015.

3 Llyn Llagi



Figure 1 Llyn Llagi. Setting out a macrophyte transect, looking towards Snowdon, 29th July 2015.

3.1 Summary Overview

Chemical and biological sample collection, analysis and data collation, quality control and archiving proceeded without any problems at Llyn Llagi during the period from April 2015 to March 2016.

The Network was notified of an application for a micro-hydro scheme on the outflow of Llyn Llagi. Whilst the majority of monitoring occurs in the lake itself, the proposed hydro take-off would severely disrupt the outflow logger and the scheme would affect the outflow fish monitoring sections. Planning details and documents can be viewed [here](#).

3.2 Water Chemistry

Samples were collected by CEH in early June, September and December 2015, delivered to the analytical laboratories on schedule and have been analysed, quality controlled and archived in the UKUWMN central chemistry database at CEH Lancaster. March 2016 samples have been collected and are in the process of being analysed.

3.3 Sediment Traps

Sediment traps were recovered and replaced on the 29th of July 2015 by a team from ENSIS. Spheroidal Carbonaceous Particles in the sediment retrieved from the traps are currently being analysed. The sediment trap diatoms have been made into slides and await funding for analysis.

3.4 Thermistors

Lake top and bottom thermistors and the thermistor chain were removed and replaced on the 29th of July 2015 by a team from ENSIS. All had functioned well during the previous year and the data were added to the ENSIS and MS thermistor water temperature database.

3.5 Epilithic Diatoms

Epilithic diatoms were retrieved by a team from ENSIS from three sampling points around the lake on the 29th of July 2015. The samples have been made into slides.

3.6 Macroinvertebrates

Aquatic macroinvertebrates were sampled on the 15th April 2015 by a team from QMuL. Five 1 minute kick samples were performed. The samples were counted and the data sent to ENSIS Ltd. The data is in the process of being quality screened before being added to the UKUWMN biological database at ENSIS.

3.7 Fish

Due to resourcing cuts, fish surveying was not performed in Autumn 2015.

3.8 Aquatic Macrophytes

Aquatic macrophytes were surveyed by a team from ENSIS on 29th of July 2015 using both UKUWMN and CSM standard methodologies. Data will be added to the ENSIS biological database after microscope confirmation of bryophyte identifications.

3.9 Data Management and Reporting

No problems or hiatus occurred with the collation and transfer of data within methodological programmes, or to the UKUWMN databases, during the reporting period.

The 2014-2015 annual report has been uploaded to the UKUWMN web page. The section on Llyn Llagi appears in section 3.11 below.

The UKUWMN website page detailing Llyn Llagi can be found here:

http://awmn.defra.gov.uk/sites/site_15.php

Further publications from the contract period utilizing UKUWMN data from Llyn Llagi are detailed in section 3.10 below.

3.10 Llyn Llago Recent UKUWMN Output

Oosthoek, S. (2016) Global browning: Why the world's fresh water is getting murkier. *New Scientist* (3055), 34-35. Reed Business Information, London.

Battarbee, R. W. (2015) Remote lakes: pristine or polluted. UK and Ireland Lakes Network annual conference, Abergavenny. 4th March 2015.

Evans, C. D. (2015) UK and international freshwater monitoring. Swedish Agricultural University, Uppsala. 11th May 2015, Invited keynote. Meeting to mark 50 years of freshwater monitoring in Sweden, attended by the King and Crown Princess.

Evans, C. D., Monteith, D. T., Shilland, E. M., Battarbee, R. W., Patrick, S. T. & Malcolm, I. A. (2015) 35 years of upland water quality monitoring in the UK: Foreseen events, unforeseen events, non-events and extreme events. 9th International Conference on Acid Deposition, Rochester, New York. October 19-23, 2015.

Garmo, O. A., de Wit, H. A., Høgåsen, T., Lund, E., Wright, R. F., Aherne, J., Arle, J., Colombo, L., Fölster, J., Hruška, J., Indriksone, I., Jeffries, D. S., Krám, P., Monteith, D. T., Paterson, A., Rogora, M., Rzychon, D., Steingruber, S., Stoddard, J. L., Talkop, R., Ulanczyk, R. P. & Vuorenmaa, J. (2015) Trends in water chemistry. In: *ICP Waters Report 119/2015. Chemical and biological recovery in acid-sensitive waters: trends and prognosis*, 8-39, NIVA, Oslo, Norway.

Monteith, D. T., Henrys, P. A., Evans, C. D., Malcolm, I. A., Shilland, E. M. & Pereira, M. G. (2015) Spatial controls on dissolved organic carbon in upland waters inferred from a simple statistical model. *Biogeochemistry* 1-15.

Monteith, D. T., Battarbee, R. W., Hildrew, A. G., Malcolm, I. A., Shilland, E. M., Evans, C. D. & Kernan, M. (2015) Hindered, stubborn or confused? Explaining the patchiness of biological responses to the declining acidity of surface waters. 9th International Conference on Acid Deposition, Rochester, New York. October 19-23, 2015.

Pearce-Higgins, J. W., BREWER, M. J., Elston, D. A., Martay, B., Powney, G. D., Isaac, N. J. B., Monteith, D. T., Henrys, P. A., Vaughan, I. P., Ormerod, S. J., Green, S., Edwards, F. K., Johnston, A., Bell, J. R., Harrington, R., Brereton, T. M., Barlow, K. E., Battarbee, R. W. & Shilland, E. M. (2015) BICCO-Net II. Final report to the Biological Impacts of Climate Change Observation Network (BICCO-Net) Steering Group. 1-69. Defra, London.

Rose, N. L. (2015) Spheroidal Carbonaceous Fly Ash Particles Provide a Globally Synchronous Stratigraphic Marker for the Anthropocene. *Environmental Science & Technology*, **49**, 4155-4162.

Shilland, E. M., Monteith, D. T., Millidine, K., Malcolm, I. A. & Norris, D. A. (2015) UK Upland Waters Monitoring Network (UKUWMN) - Contract 22 01 249 Llyn Llago, Llyn Cwm Mynach, Afon Hafren and Afon Gwy Annual Summary Progress Report April 2014 - March

2015. Report to the Welsh Government and Natural Resources Wales. 1-71. ENSIS Ltd, Environmental Change Research Centre, University College London, London.

Shilland, E. M., Woolway, R. I., Monteith, D. T., Rose, N. L., Yang, H., Malcolm, I. A., Millidine, K. J., Hildrew, A. G., Evans, C. D., Sime, I., Hatton-Ellis, T., Kernan, M., Patrick, S. T., Turner, S. D. & Battarbee, R. W. (2015) Tracking the impact of climate change on UK surface waters recovering from acidification. Poster. 9th International Conference on Acid Deposition, Rochester, New York. October 19-23, 2015.

Winterbottom, J. H. & Orton, S. E. (2015) United Kingdom Acid Waters Monitoring Network Invertebrate Survey. Twenty Seventh Year: 2014. Summary of species identification and abundance. 1-13. School of Biological Sciences, Queen Mary University of London, London.

Woolway, R. I. (2015) Drivers, associations and consequences of the diel variability in high-resolution lake surface water temperature measurements. 1-351. Doctoral thesis, UCL (University College London).

Battarbee, R. W. (2014) The UK Upland Waters Monitoring Network: from acid rain to climate change. Scottish Freshwater Group, Stirling, March 27th, 2014.

Battarbee, R. W. (2014) SWAP: the aftermath. University of Bergen, April 25th 2014.

Battarbee, R. W. (2014) Upland waters in the UK: from acid rain to climate change. Seminar, University of St Andrews, March 26th 2014.

Battarbee, R. W., Shilland, E. M., Kernan, M., Monteith, D. T. & Curtis, C. J. (2014) Recovery of acidified surface waters from acidification in the United Kingdom after twenty years of chemical and biological monitoring (1988–2008). *Ecological Indicators*, **37, Part B**, 267-273.

Battarbee, R. W., Simpson, G. L., Shilland, E. M., Flower, R. J., Kreiser, A., Yang, H. & Clarke, G. (2014) Recovery of UK lakes from acidification: An assessment using combined palaeoecological and contemporary diatom assemblage data. *Ecological Indicators*, **37, Part B**, 365-380.

Curtis, C. J. & Simpson, G. L. (2014) Trends in bulk deposition of acidity in the UK, 1988–2007, assessed using additive models. *Ecological Indicators*, **37, Part B**, 274-286.

Curtis, C. J., Battarbee, R. W., Monteith, D. T. & Shilland, E. M. (2014) The future of upland water ecosystems of the UK in the 21st century: A synthesis. *Ecological Indicators*, **37, Part B**, 412-430.

Escudero-Onate, C. (2014) International Cooperative Programme on Assessment and Monitoring of Acidification of Rivers and Lakes. Intercomparison 1428:pH, Conductivity, Alkalinity, NO₃-N, Cl, SO₄,Ca, Mg, Na, K, TOC, Al, Fe, Mn, Cd, Pb, Cu, Ni and Zn. 1-88. NIVA, Oslo, Norway.

Fjellheim, A., Johannessen, A. & Svanevik Landes, T. (2014) International Cooperative Programme on Assessment and Monitoring of Acidification of Rivers and Lakes. Biological intercalibration: Invertebrates 1713. ICP Waters Report 118/2014, 1-25. NIVA, Oslo, Norway.

Garmo, O. A., Skjelkvale, B. L., Wit, H. A., Colombo, L., Curtis, C., Folster, J., Hoffmann, A., Hruska, J., Hogasen, T., Jeffries, D. S., Keller, W. B., Kram, P., Majer, V., Monteith, D. T., Paterson, A. M., Rogora, M., Rzychon, D., Steingruber, S., Stoddard, J., Vuorenmaa, J. & Worsztynowicz, A. (2014) Trends in Surface Water Chemistry in Acidified Areas in Europe and North America from 1990 to 2008. *Water Air and Soil Pollution*, **225**, 1-14.

Gray, C., Woodward, G. & Ma, A. (2014) Conserved substructure in a large collection of freshwater food webs as they recover from acidification. Poster. Joint British Ecological Society and Société d'Ecologie Annual Meeting. 11th December 2014, Lille, France.

Helliwell, R. C., Aherne, J., MacDougall, G., Nisbet, T. R., Lawson, D., Cosby, B. J. & Evans, C. D. (2014) Past acidification and recovery of surface waters, soils and ecology in the United Kingdom: Prospects for the future under current deposition and land use protocols. *Ecological Indicators*, **37, Part B**, 381-395.

Malcolm, I. A., Bacon, P. J., Middlemas, S. J., Fryer, R. J., Shilland, E. M. & Collen, P. (2014) Relationships between hydrochemistry and the presence of juvenile brown trout (*Salmo trutta*) in headwater streams recovering from acidification. *Ecological Indicators*, **37, Part B**, 351-364.

Monteith, D. T., Shilland, E. M., Battarbee, R. W., Evans, C. D., Hildrew, A. G. & Malcolm, I. A. (2014) Recovery of water chemistry and biology in the UK: latest status and emerging issues. Proceedings of the 26th Meeting of the ICP Waters Task Force in Grimstad, Norway October 8-10 2014.

Monteith, D. T., Evans, C. D., Henrys, P. A., Simpson, G. L. & Malcolm, I. A. (2014) Trends in the hydrochemistry of acid-sensitive surface waters in the UK 1988-2008. *Ecological Indicators*, **37, Part B**, 287-303.

Murphy, J. F., Winterbottom, J. H., Orton, S., Simpson, G. L., Shilland, E. M. & Hildrew, A. G. (2014) Evidence of recovery from acidification in the macroinvertebrate assemblages of UK fresh waters: A 20-year time series. *Ecological Indicators*, **37, Part B**, 330-340.

Rowe, E. C., Tipping, E., Posch, M., Oulehle, F., Cooper, D. M., Jones, T. G., Burden, A., Hall, J. & Evans, C. D. (2014) Predicting nitrogen and acidity effects on long-term dynamics of dissolved organic matter. *Environmental Pollution*, **184**, 271-282.

Shibata, H., Branquinho, C., McDowell, W. H., Mitchell, M. J., Monteith, D. T., Tang, J., Arvola, L., Cruz, C., Cusack, D. F., Halada, L., Kopacek, J., Maguas, C., Sajidu, S., Schubert, H., Tokuchi, N. & Zahora, J. (2014) Consequence of altered nitrogen cycles in the coupled human and ecological system under changing climate: The need for long-term and site-based research. *AMBIO* 1-16.

Shilland, E. M., Irvine, L., Millidine, K. & Malcolm, I. A. (2014) UK Upland Waters Monitoring Network (UKUWMN) - Contract 22 01 249 Llyn Llaji, Llyn Cwm Mynach, Afon Hafren and Afon Gwy Annual Summary Progress Report April 2013 - March 2014. Report to the Welsh Government and Natural Resources Wales. 1-64. ENSIS Ltd, Environmental Change Research Centre, University College London, London.

Shilland, E. M., Monteith, D. T., Millidine, K. & Malcolm, I. A. (2014) The United Kingdom Upland Waters Monitoring Network Data Report for 2012-2013 (year 25). Report to the Department for Environment, Food and Rural Affairs (Contract EPG 1/3/160). 1-259. ENSIS Ltd. Environmental Change Research Centre, University College London, London.

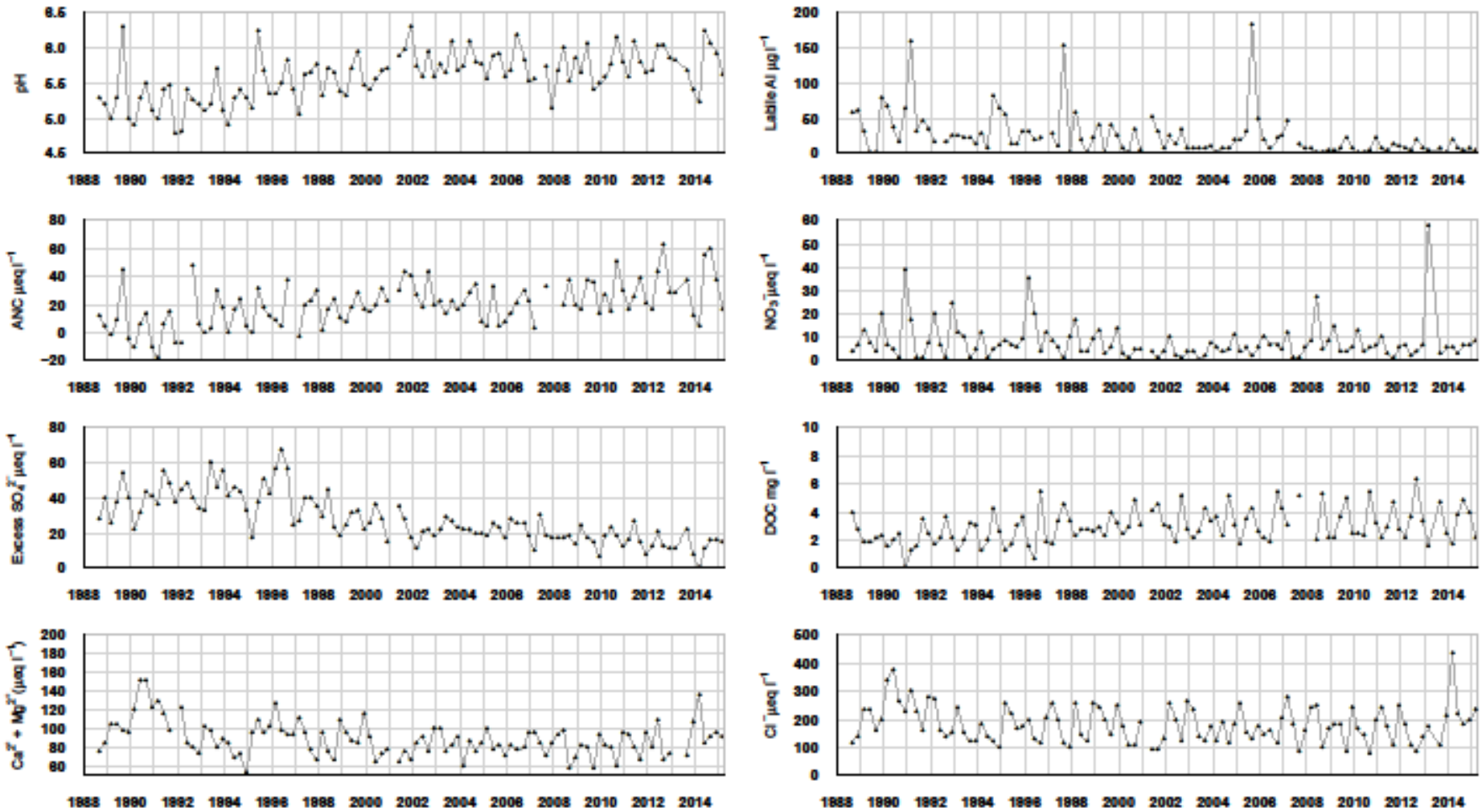
Shilland, E. M., Monteith, D. T., Millidine, K. & Malcolm, I. A. (2014) The United Kingdom Upland Waters Monitoring Network Data Report for 2013-2014 (year 26). Report to the Department for Environment, Food and Rural Affairs (Contract EPG 1/3/160). 1-282. ENSIS Ltd. Environmental Change Research Centre, University College London, London.

Stockdale, A., Tipping, E., Fjellheim, A., Garmo, +. A., Hildrew, A. G., Lofts, S., Monteith, D. T., Ormerod, S. J. & Shilland, E. M. (2014) Recovery of macroinvertebrate species richness in acidified upland waters assessed with a field toxicity model. *Ecological Indicators*, **37**, Part B, 341-350.

Winterbottom, J. H. & Orton, S. E. (2014) United Kingdom Acid Waters Monitoring Network Invertebrate Survey. Twenty Seventh Year: 2014. Summary of species identification and abundance. 1-10. School of Biological Sciences, Queen Mary University of London, London.

3.11 Llyn Llgi Summary Data to March 2015

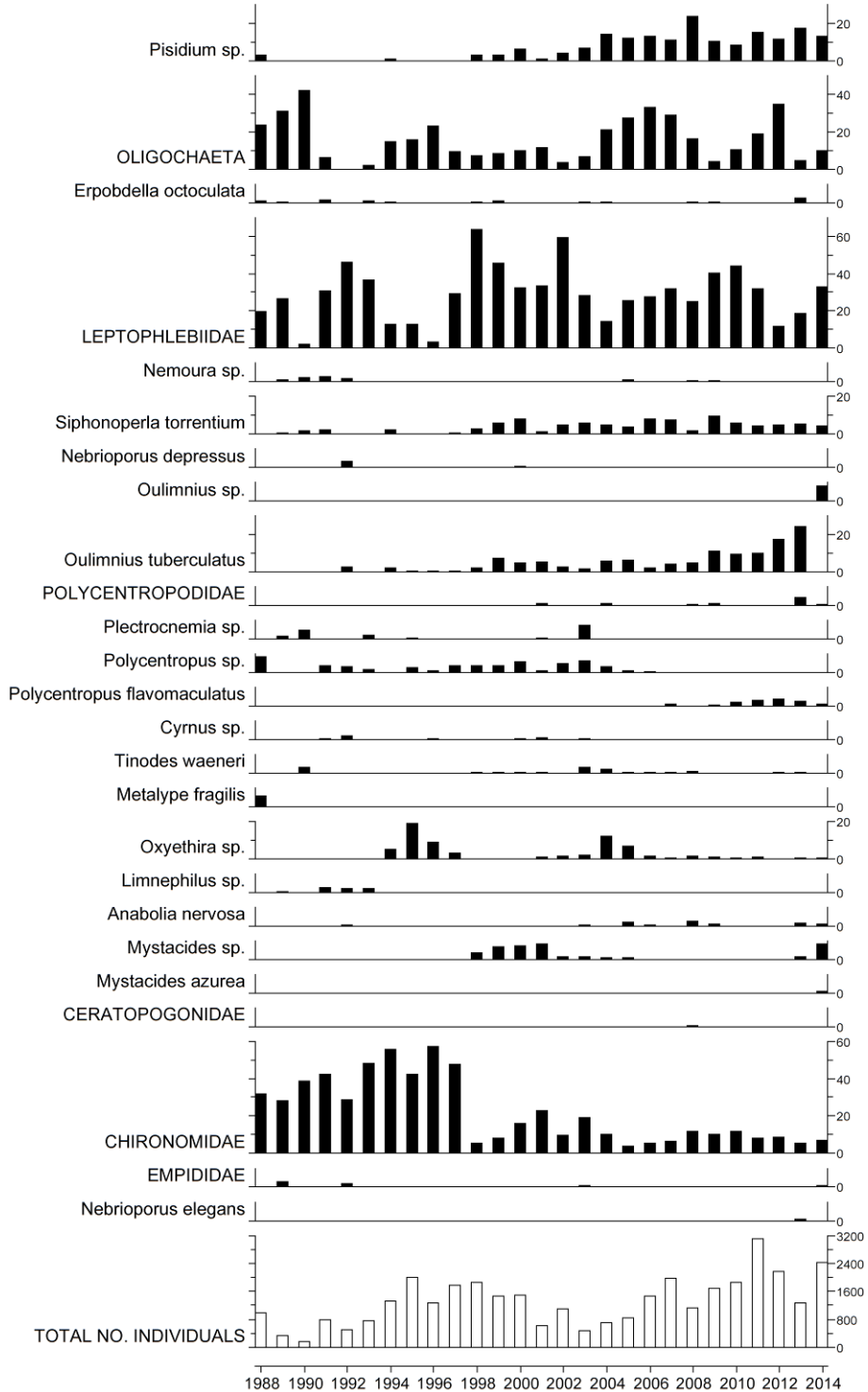
3.11.1 Spot sampled chemistry data



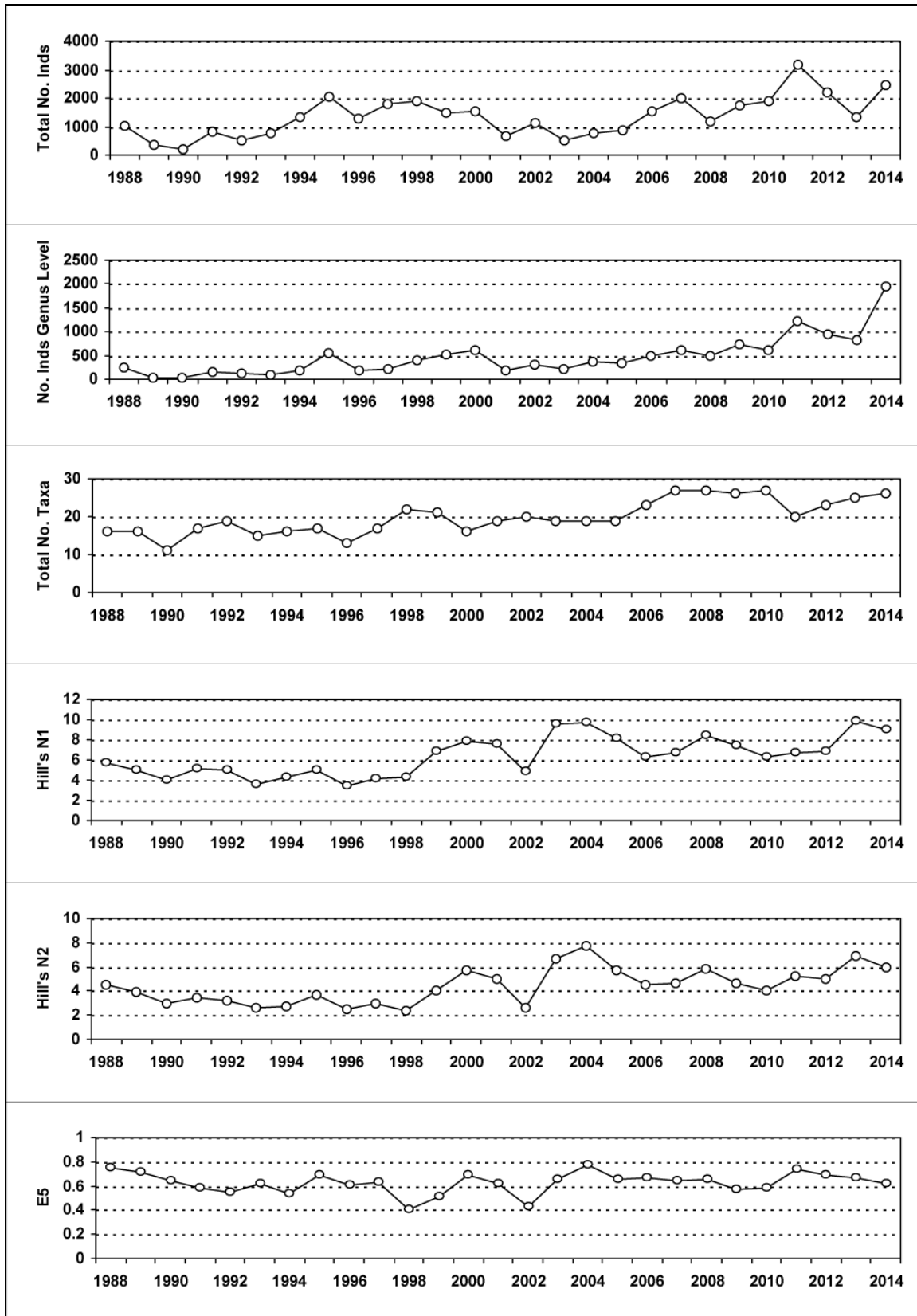
$\mu\text{eq l}^{-1}$, $^*\mu\text{g l}^{-1}$, $^{**}\text{mg l}^{-1}$	pH	ANC	Ca ²⁺	Mg ²⁺	Na ⁺	K ⁺	*Soluble Al	*Labile Al	Cl ⁻	*SO ₄ ²⁻	xSO ₄ ²⁻	NO ₃ ⁻	**DOC
Mean 1 st 5 yrs	5.23	5.71	56.70	49.69	185.75	3.54	75.37	41.61	219.33	62.91	39.91	10.44	2.13
14-15 mean	5.97	41.96	46.51	44.13	180.85	2.59	25.25	5.00	210.31	36.60	14.54	6.43	3.64
14-15 std dev	0.26	19.46	4.51	2.72	16.86	2.17	7.32	1.83	24.78	2.33	2.17	2.12	1.12

3.11.2 Macroinvertebrate data

3.11.2.1 Percentage abundance summary, Llyn Llagi

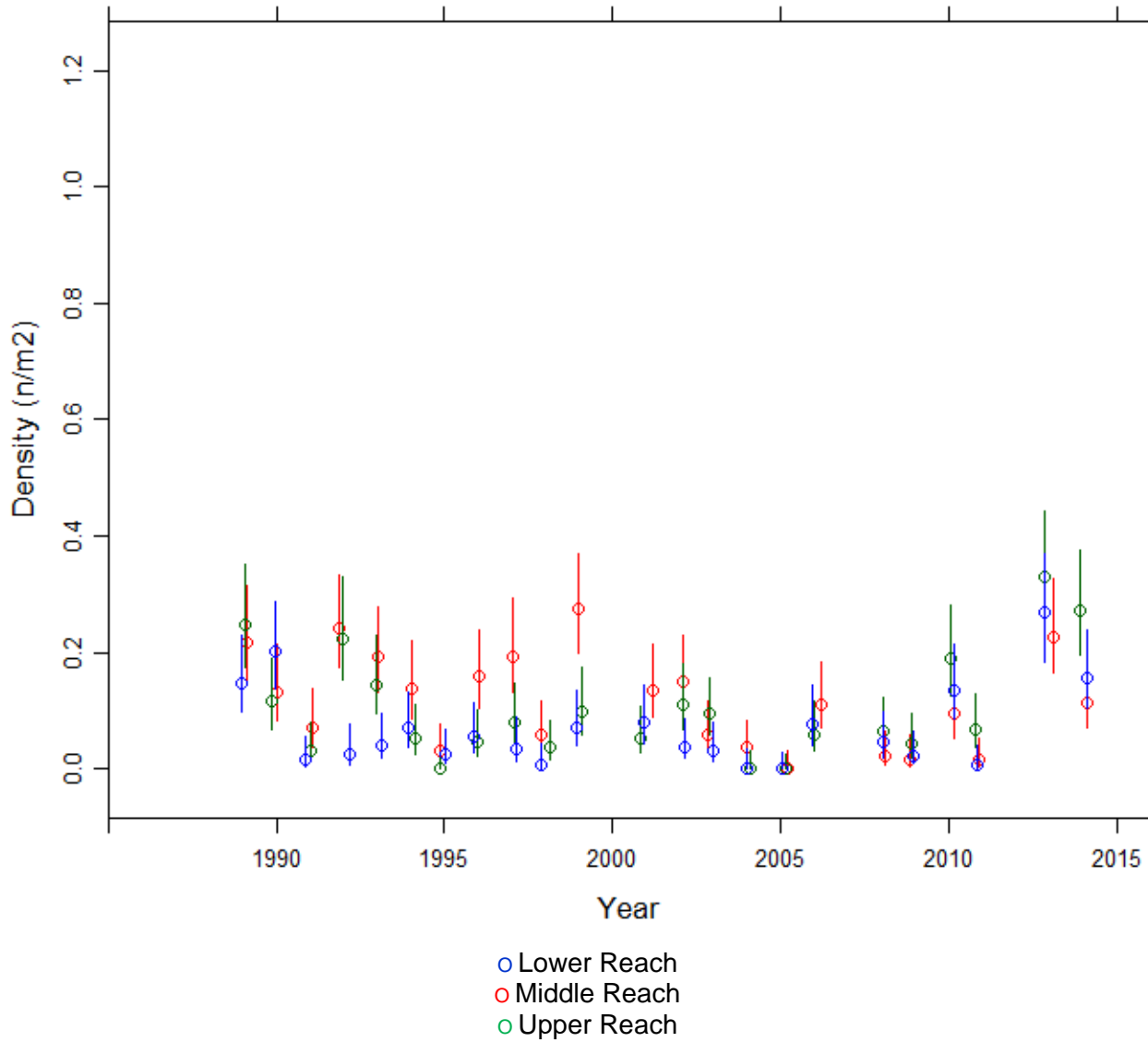


3.11.2.1 Macroinvertebrate summary statistics, Llyn Llgi



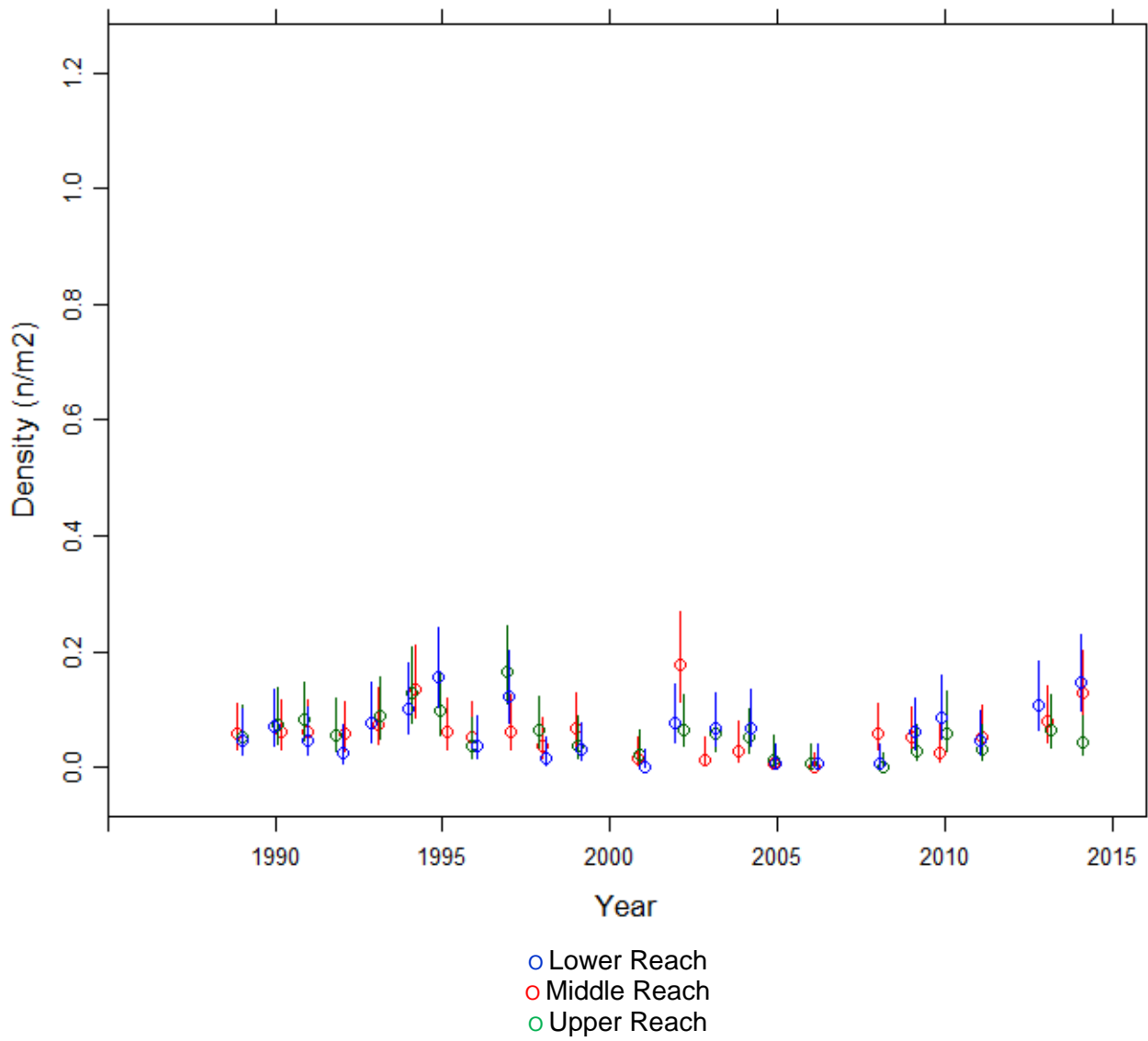
3.11.3 Fish data (for outflow stream)

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



Fishing no longer funded after 2014.

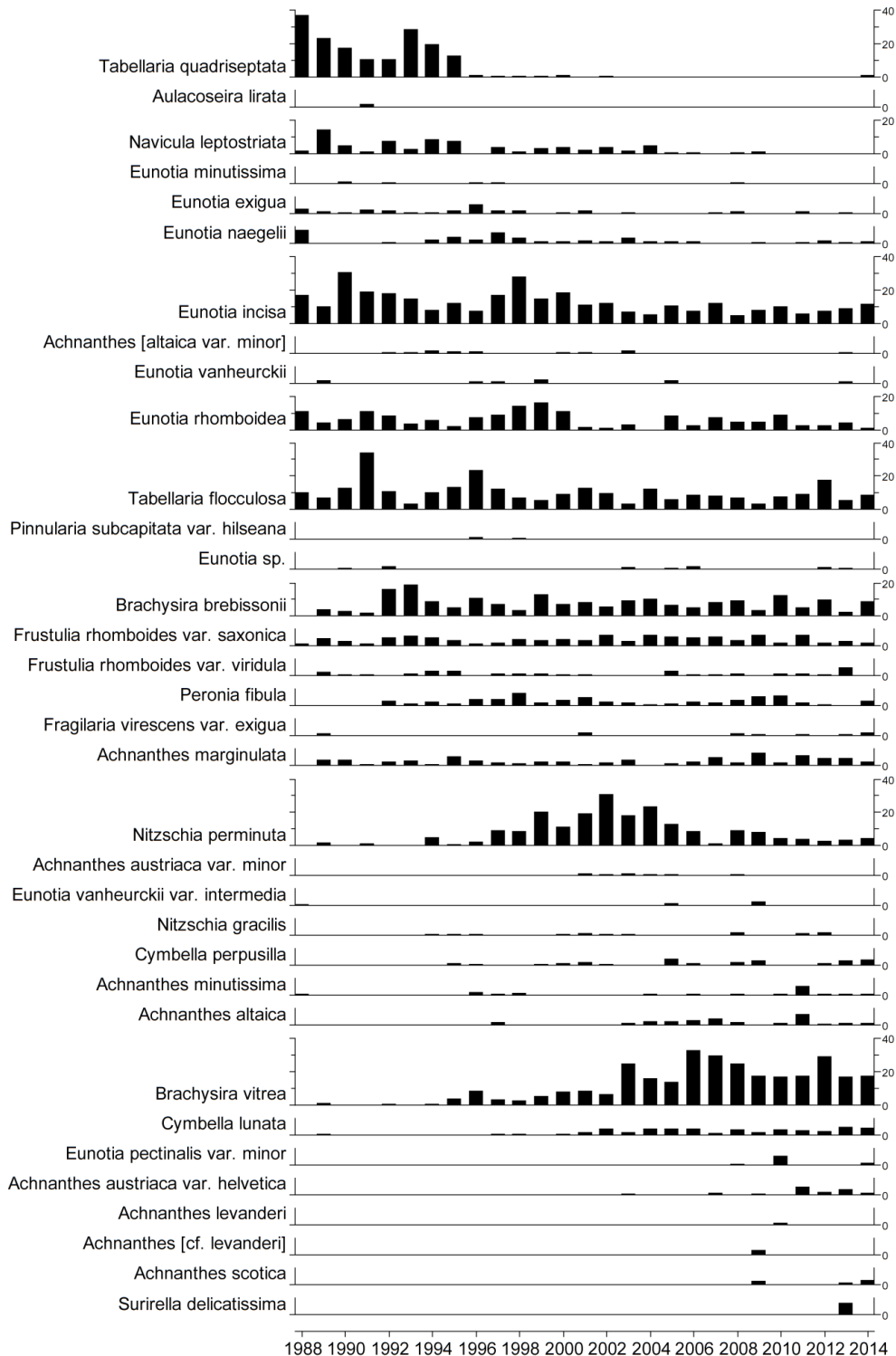
3.11.3.2 Summary of Trout parr density (numbers m⁻²), Llyn Llgi



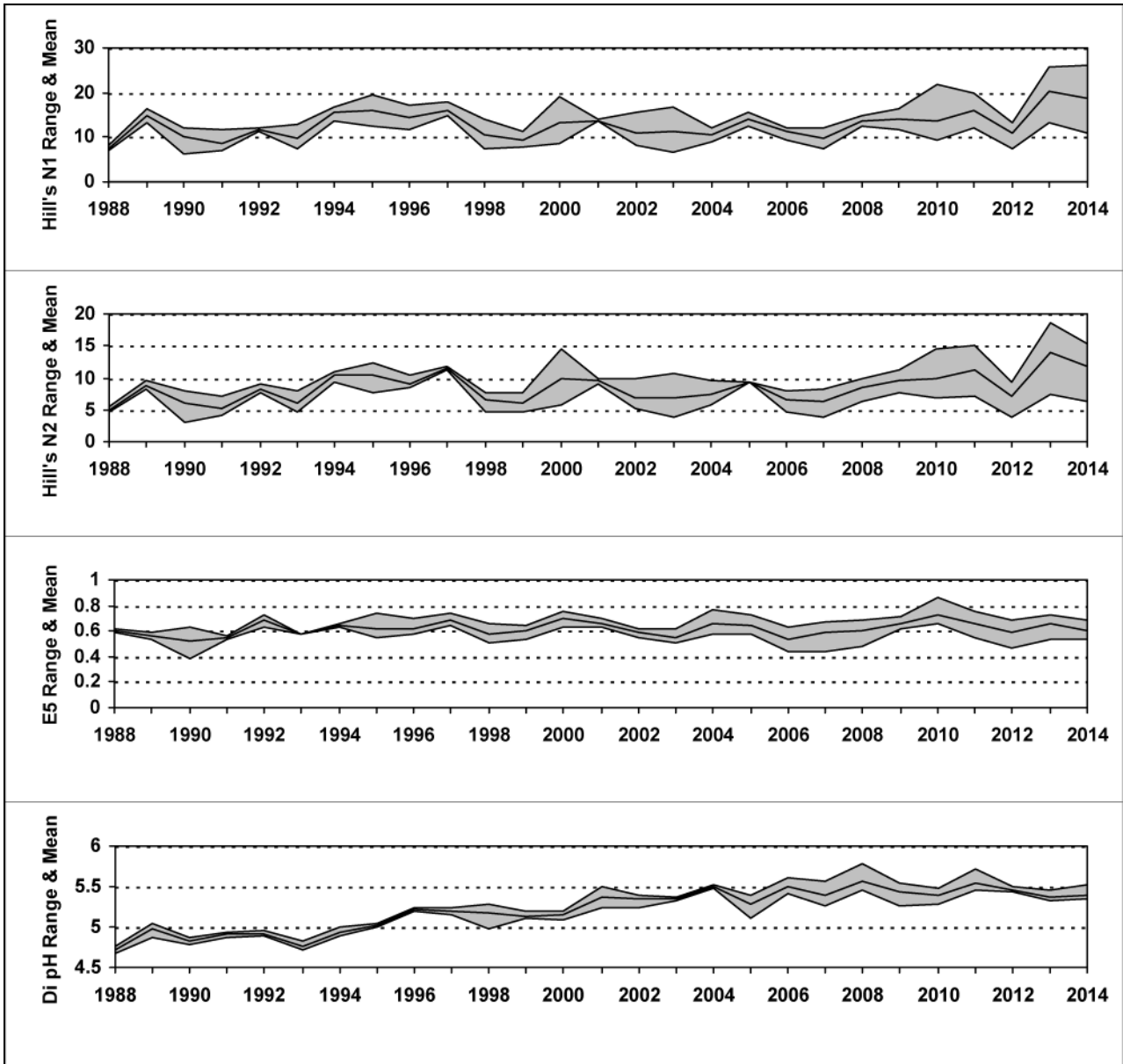
Fishing no longer funded after 2014.

3.11.4 Epilithic diatom data

3.11.4.1 Percentage abundance summary, Llyn Llaji

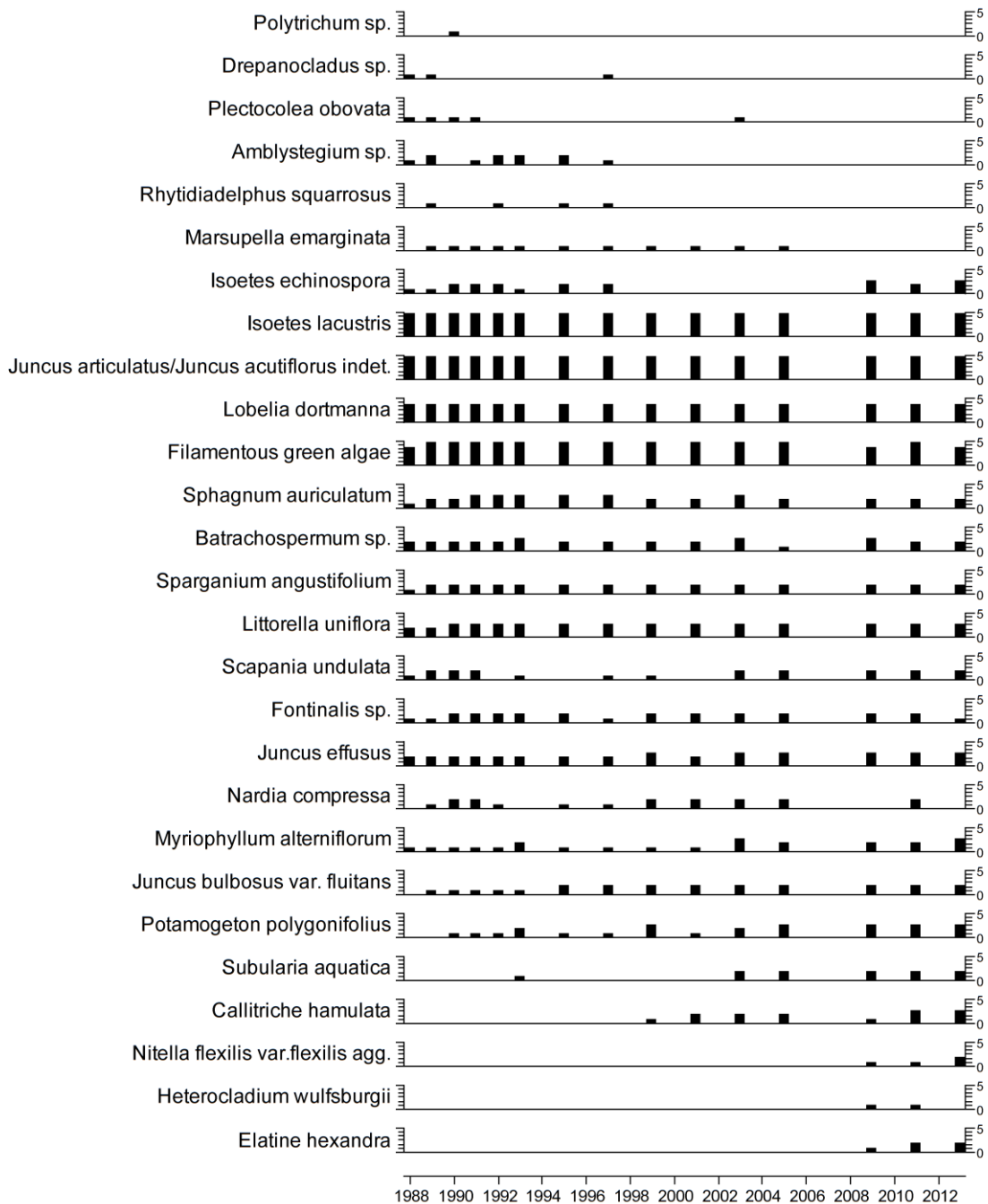


3.11.4.1 Diatom summary statistics, Llyn Llagi



3.11.5 Aquatic macrophyte data, Llyn Llgi

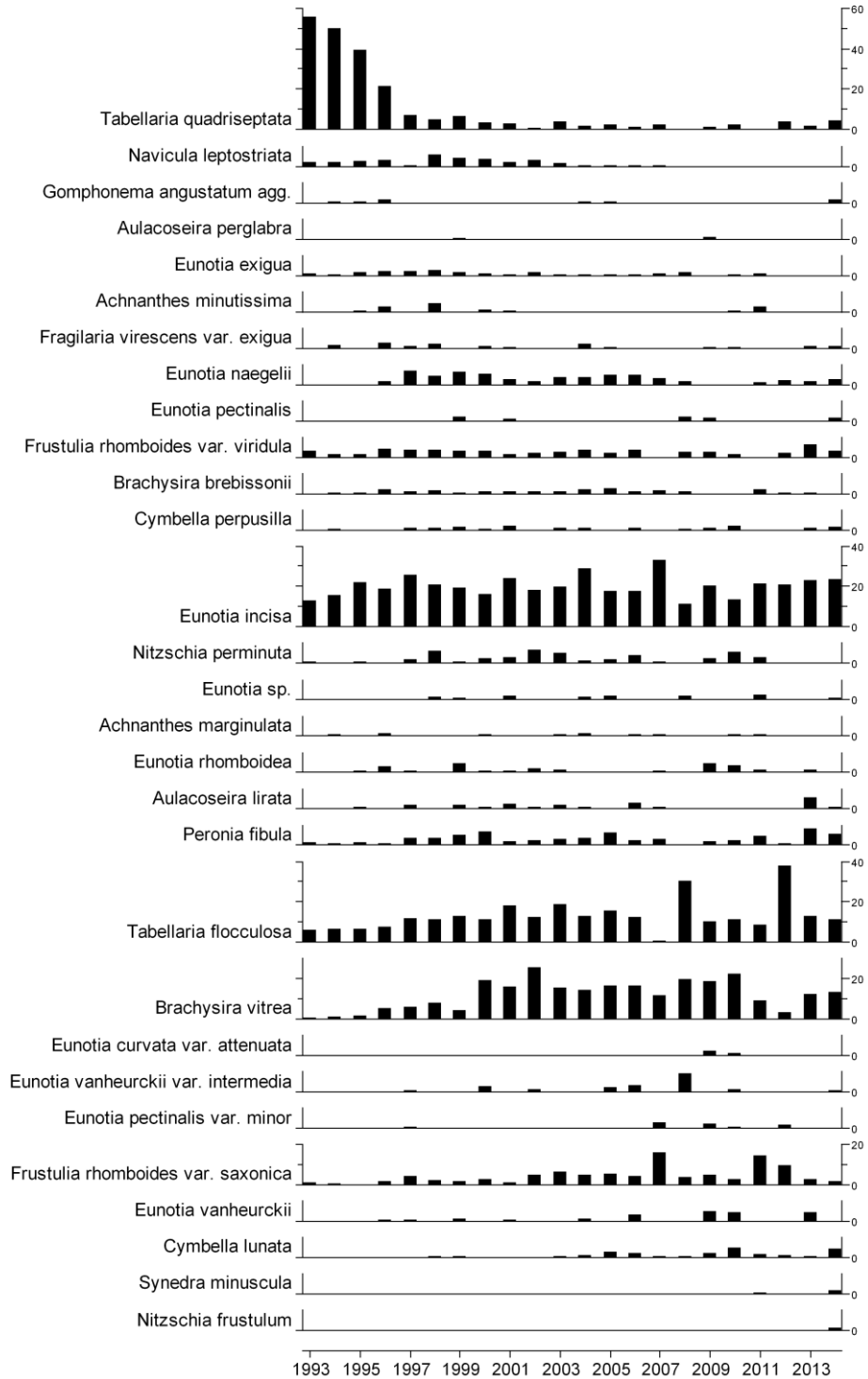
Species Scores (1-5)



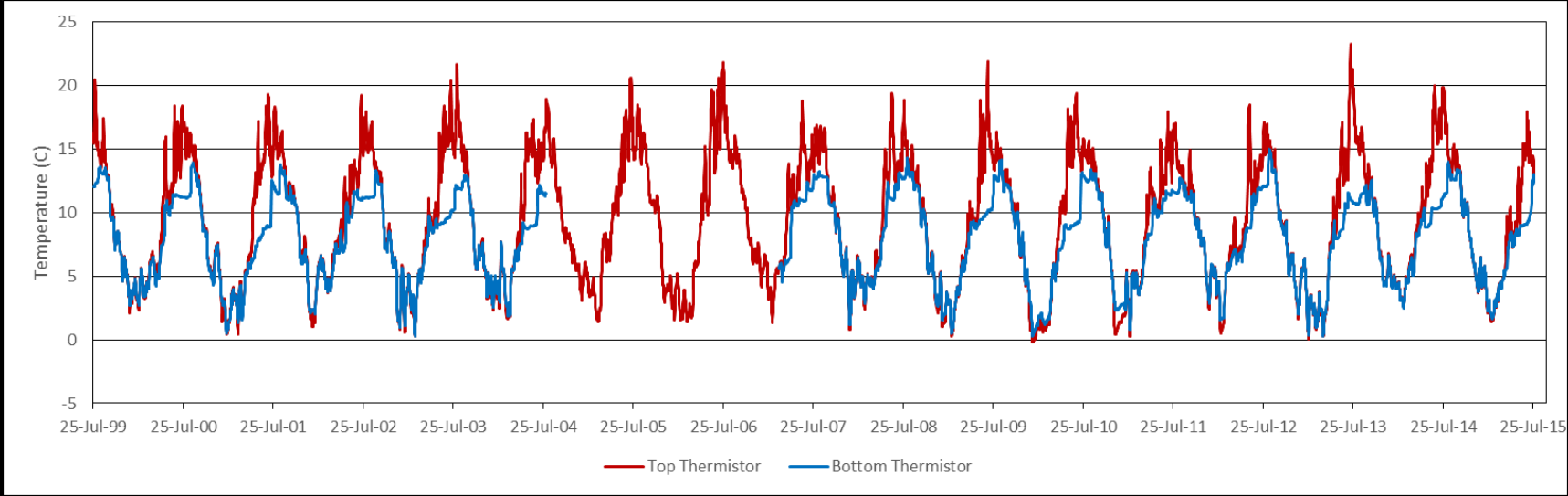
No survey in 2007 due to funding cuts

3.11.6 Sediment trap data, Llyn Llgi

Relative percentage frequency of diatom taxa

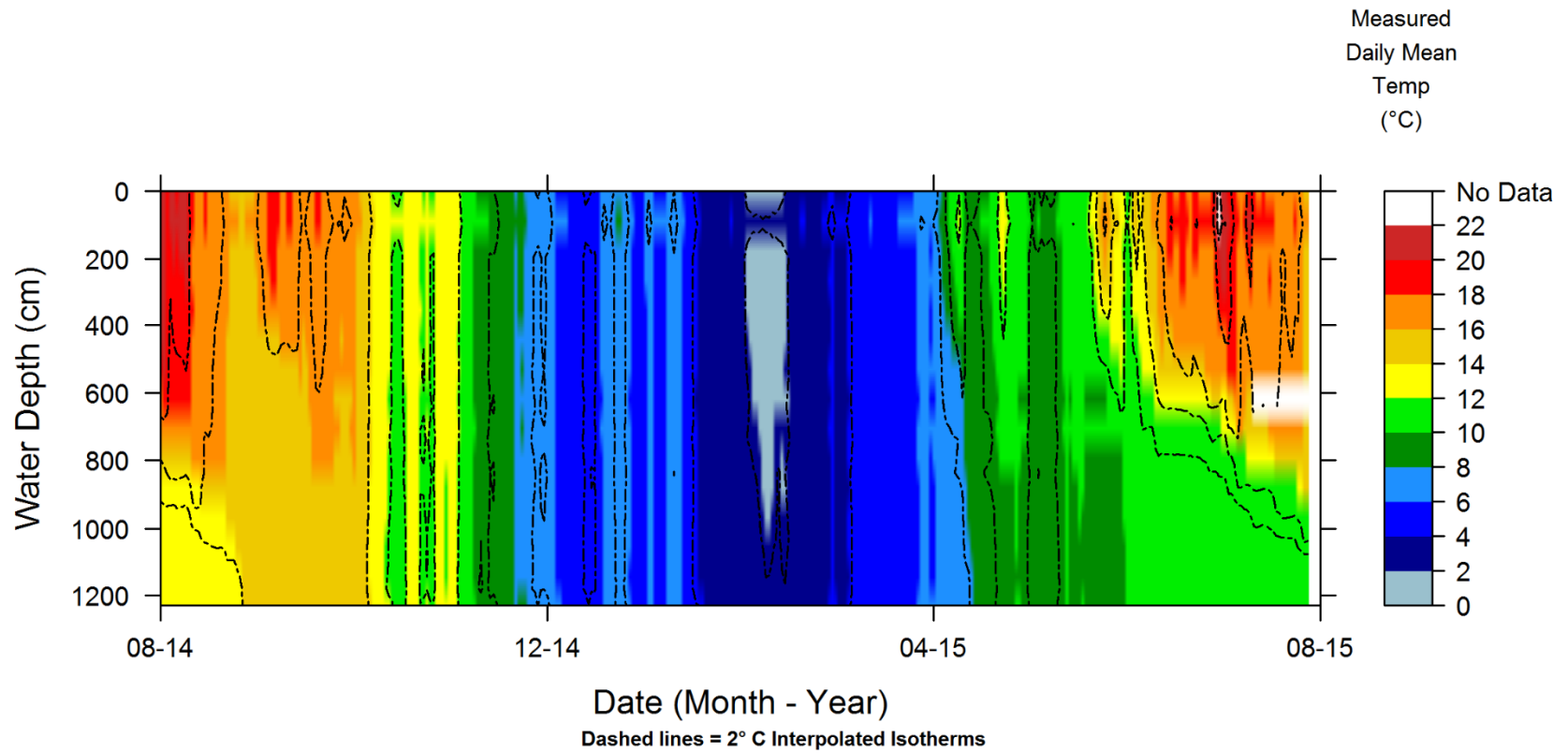


3.11.7 Sediment trap thermistor data, Llyn Llagi

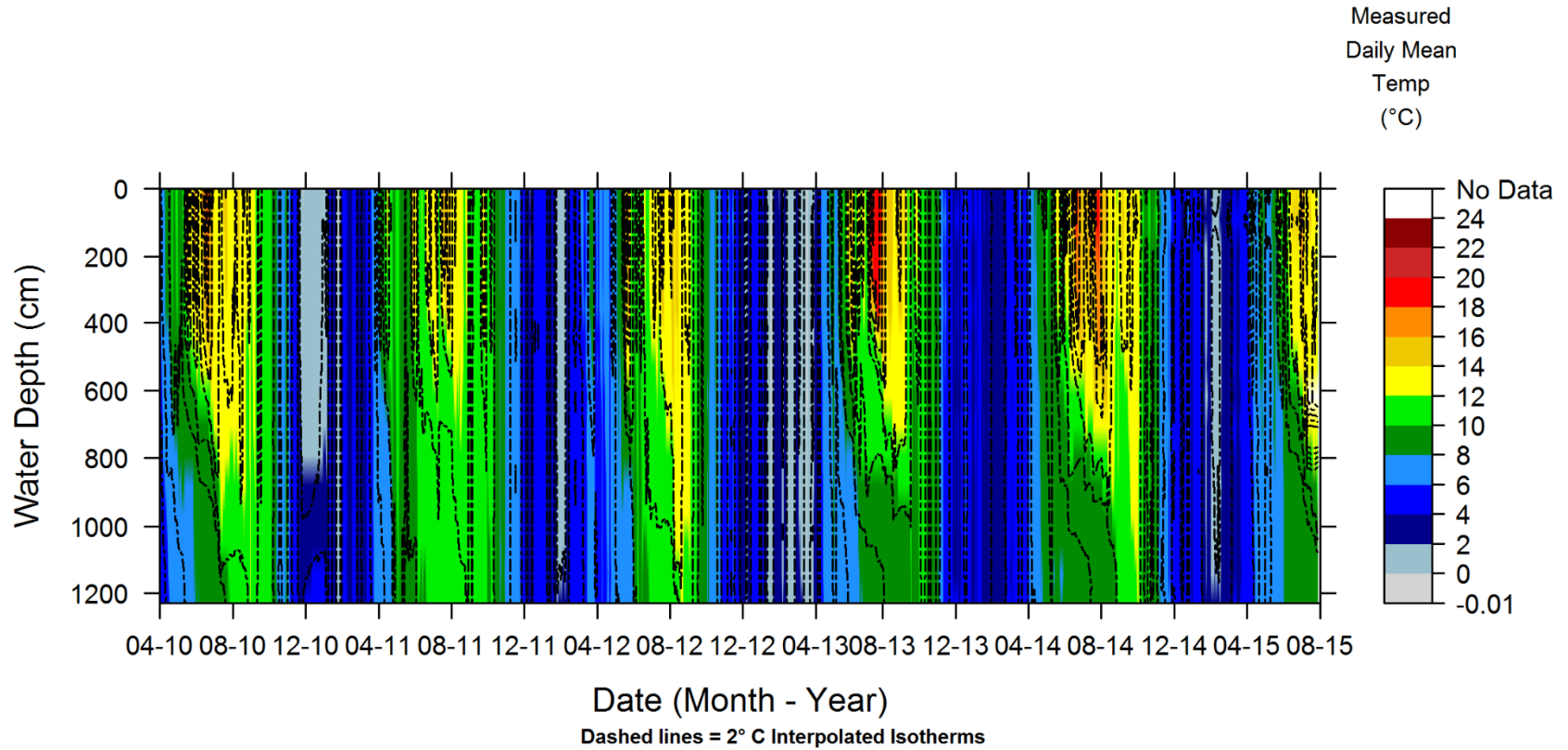


3.11.8 Thermistor chain data, Llyn Llagi

3.11.8.1 Annual detail, Llyn Llagi 2014-2015

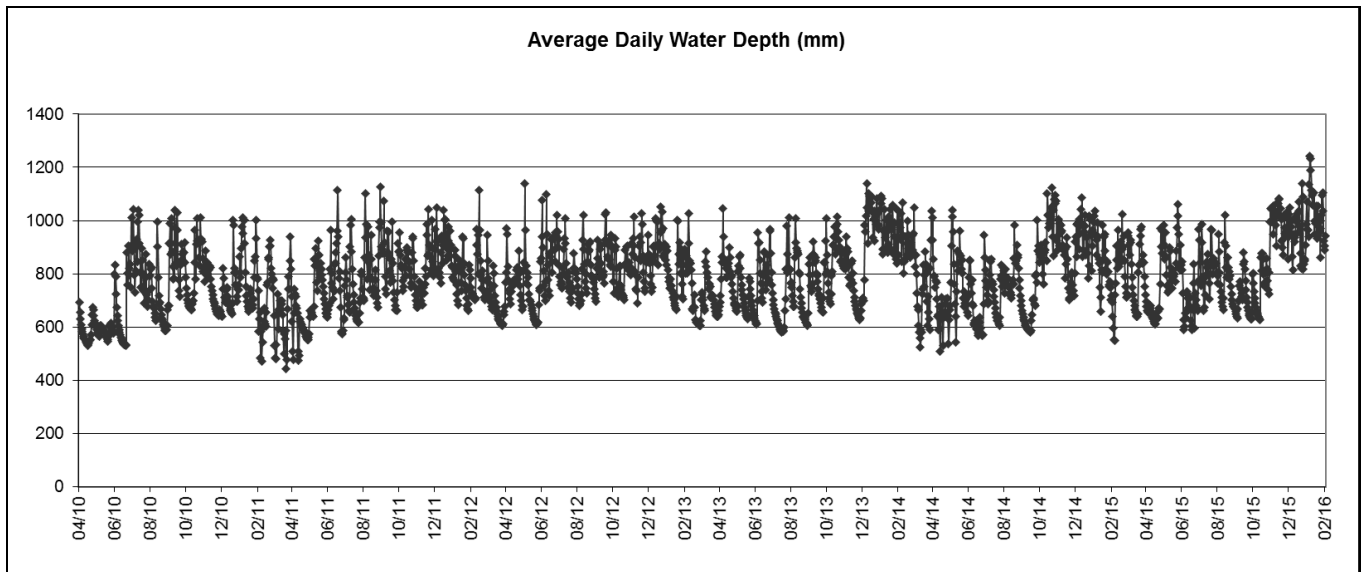
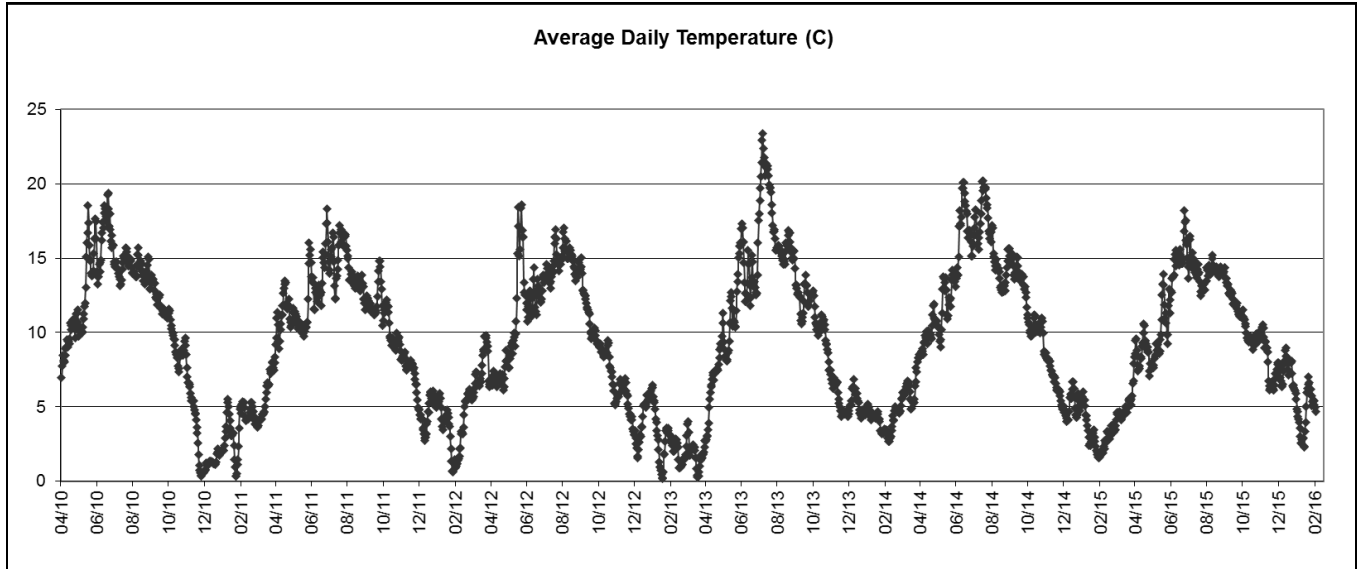


3.11.8.2 Llyn Llagi 2010-2015

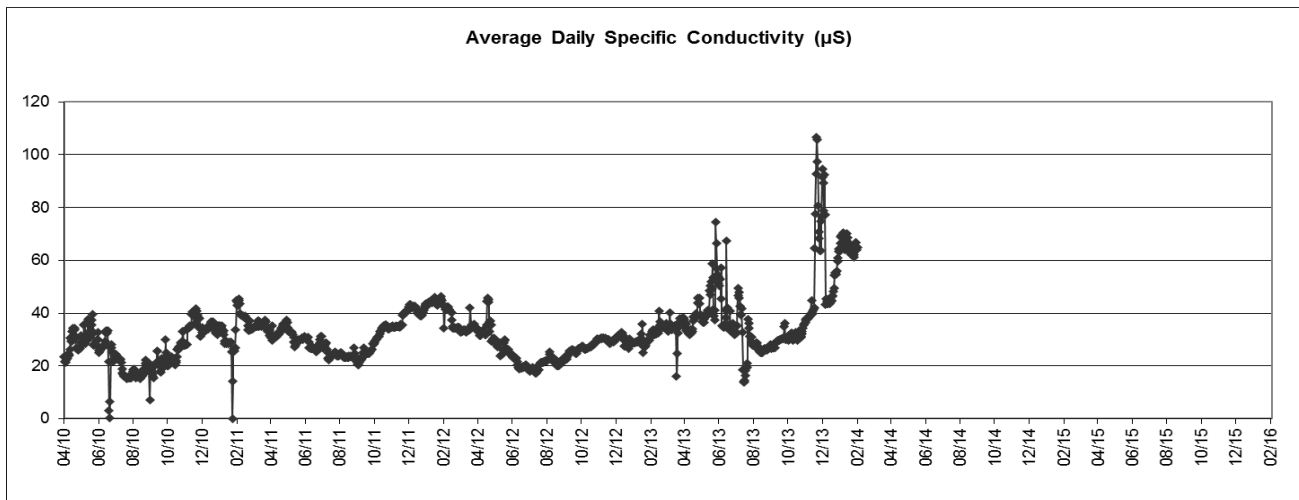
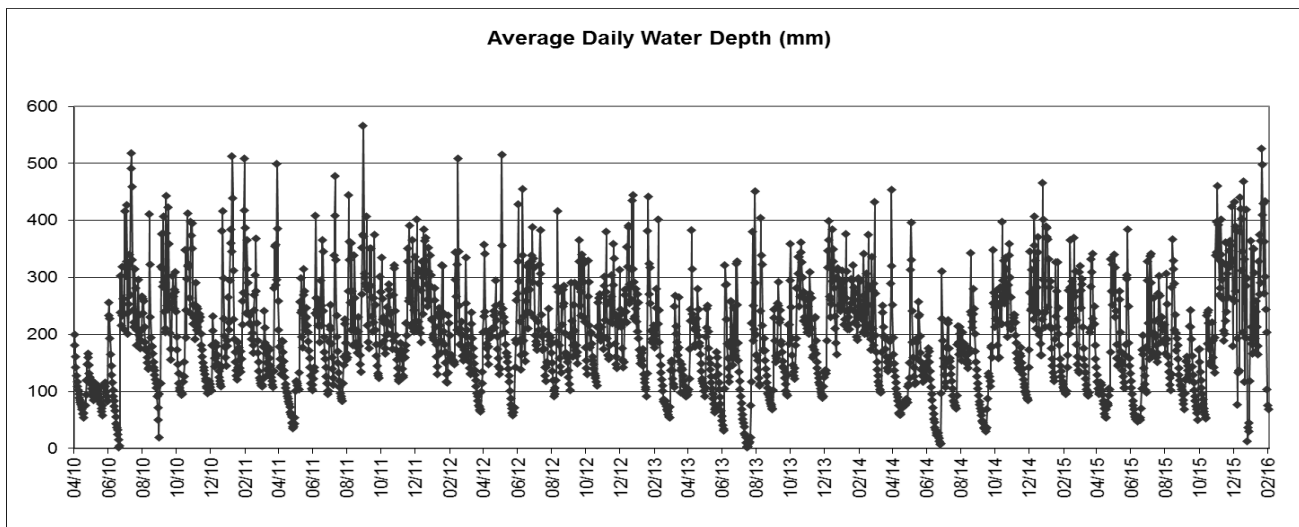
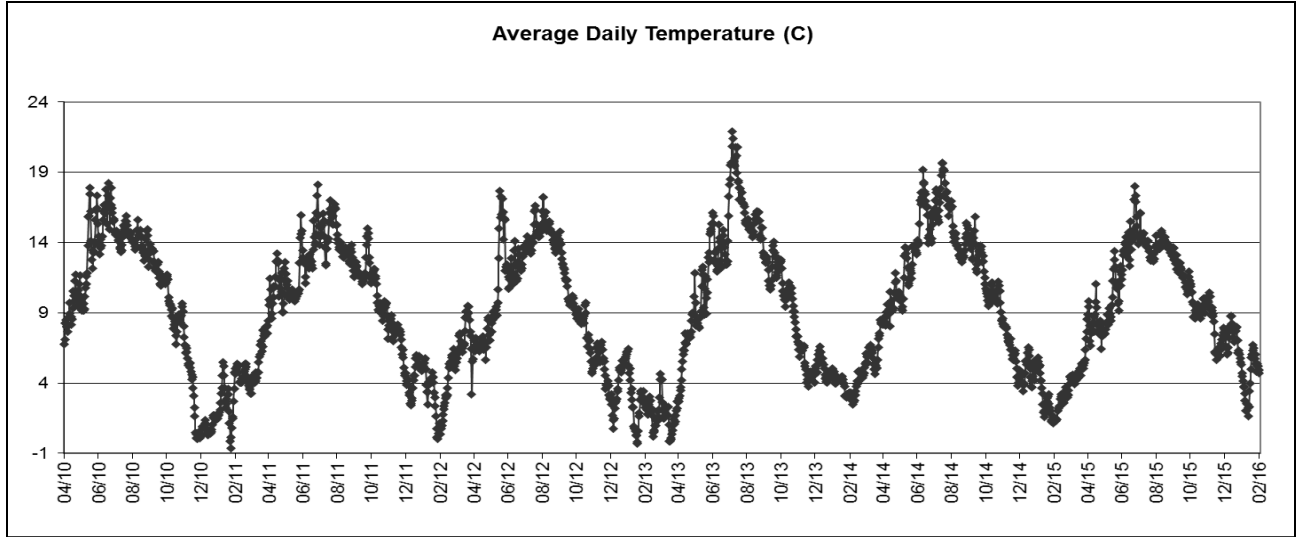


3.11.9 Automatic sensor data, Llyn Llagi

3.11.9.1 Lake sensor data, Llyn Llagi



3.11.9.2 Outflow sensor data, Llyn Llago



4 Llyn Cwm Mynach



Figure 2 Llyn Cwm Mynach. Looking southeast from the North West end of the lake, 28th July 2015.

4.1 Summary Overview

Chemical and biological sample collection, analysis and data collation, quality control and archiving proceeded without any problems at Llyn Cwm Mynach during the period from April 2015 to March 2016.

A supplementary CEH and Woodland Trust project continues to look at the effects of differing forestry practices in the catchment, with water samples being analysed at CEH Bangor.

4.2 Water Chemistry

Samples were collected by CEH in early June, September and December 2015, delivered to the analytical laboratories on schedule and have been analysed, quality controlled and archived in the UKUWMN central chemistry database at CEH Lancaster. March 2016 samples have been collected and are in the process of being analysed.

4.3 Sediment Traps

Sediment traps were recovered and replaced on the 28th of July 2015 by a team from ENSIS. Spheroidal Carbonaceous Particles in the sediment retrieved from the traps are currently being analysed. The sediment trap diatoms have been made into slides and await funding for analysis.

4.4 Thermistors

Lake top and bottom thermistors and the thermistor chain were removed and replaced on the 28th of July 2015 by a team from ENSIS. All had functioned well during the previous year and the data were added to the ENSIS and MS thermistor water temperature database.

4.5 Epilithic Diatoms

Epilithic diatoms were retrieved by a team from ENSIS from three sampling points around the lake on the 28th of July 2015. The samples have been made into slides.

4.6 Macroinvertebrates

Aquatic macroinvertebrates were sampled on the 15th April 2015 by a team from QMuL. Five 1 minute kick samples were performed. The samples were counted and the data sent to ENSIS Ltd. The data is in the process of being quality screened before being added to the UKUWMN biological database at ENSIS.

4.7 Fish

Due to resourcing cuts, fish surveying was not performed in Autumn 2015.

4.8 Aquatic Macrophytes

Aquatic macrophytes were not surveyed at Llyn Cwm Mynach in 2015.

4.9 Data Management and Reporting

No problems or hiatus occurred with the collation and transfer of data within methodological programmes, or to the UKUWMN databases, during the reporting period.

The 2014-2015 annual report has been uploaded to the UKUWMN web page. The section on Llyn Cwm Mynach appears in section 4.11 below.

The UKUWMN website page detailing Llyn Cwm Mynach is here:

http://awmn.defra.gov.uk/sites/site_16.php

Further publications from the contract period utilizing UKUWMN data from Llyn Cwm Mynach are detailed in section 4.10 below.

4.10 Llyn Cwm Mynach Recent UKUWMN Output

Oosthoek, S. (2016) Global browning: Why the world's fresh water is getting murkier. *New Scientist* (3055), 34-35. Reed Business Information, London.

Battarbee, R. W. (2015) Remote lakes: pristine or polluted. UK and Ireland Lakes Network annual conference, Abergavenny. 4th March 2015.

Evans, C. D., Monteith, D. T., Shilland, E. M., Battarbee, R. W., Patrick, S. T. & Malcolm, I. A. (2015) 35 years of upland water quality monitoring in the UK: Foreseen events, unforeseen events, non-events and extreme events. 9th International Conference on Acid Deposition, Rochester, New York. October 19-23, 2015.

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Monteith, D. T., Battarbee, R. W., Hildrew, A. G., Malcolm, I. A., Shilland, E. M., Evans, C. D. & Kernan, M. (2015) Hindered, stubborn or confused? Explaining the patchiness of biological responses to the declining acidity of surface waters. 9th International Conference on Acid Deposition, Rochester, New York. October 19-23, 2015.

Pearce-Higgins, J. W., BREWER, M. J., Elston, D. A., Martay, B., Powney, G. D., Isaac, N. J. B., Monteith, D. T., Henrys, P. A., Vaughan, I. P., Ormerod, S. J., Green, S., Edwards, F. K., Johnston, A., Bell, J. R., Harrington, R., Brereton, T. M., Barlow, K. E., Battarbee, R. W. & Shilland, E. M. (2015) BICCO-Net II. Final report to the Biological Impacts of Climate Change Observation Network (BICCO-Net) Steering Group. 1-69. Defra, London.

Shilland, E. M., Woolway, R. I., Monteith, D. T., Rose, N. L., Yang, H., Malcolm, I. A., Millidine, K. J., Hildrew, A. G., Evans, C. D., Sime, I., Hatton-Ellis, T., Kernan, M., Patrick, S. T., Turner, S. D. & Battarbee, R. W. (2015) Tracking the impact of climate change on UK surface waters recovering from acidification. Poster. 9th International Conference on Acid Deposition, Rochester, New York. October 19-23, 2015.

Shilland, E. M., Monteith, D. T., Millidine, K., Malcolm, I. A. & Norris, D. A. (2015) UK Upland Waters Monitoring Network (UKUWMN) - Contract 22 01 249 Llyn Llagi, Llyn Cwm Mynach, Afon Hafren and Afon Gwy Annual Summary Progress Report April 2014 - March 2015. Report to the Welsh Government and Natural Resources Wales. 1-71. ENSIS Ltd, Environmental Change Research Centre, University College London, London.

Winterbottom, J. H. & Orton, S. E. (2015) United Kingdom Acid Waters Monitoring Network Invertebrate Survey. Twenty Seventh Year: 2014. Summary of species identification and

abundance. 1-13. School of Biological Sciences, Queen Mary University of London, London.

Woolway, R. I. (2015) Drivers, associations and consequences of the diel variability in high-resolution lake surface water temperature measurements. 1-351. Doctoral thesis, UCL (University College London).

Battarbee, R. W. (2014) SWAP: the aftermath. University of Bergen, April 25th 2014.

Battarbee, R. W. (2014) Upland waters in the UK: from acid rain to climate change. Seminar, University of St Andrews, March 26th 2014.

Battarbee, R. W. (2014) The UK Upland Waters Monitoring Network: from acid rain to climate change. Scottish Freshwater Group, Stirling, March 27th, 2014.

Battarbee, R. W., Shilland, E. M., Kernan, M., Monteith, D. T. & Curtis, C. J. (2014) Recovery of acidified surface waters from acidification in the United Kingdom after twenty years of chemical and biological monitoring (1988-2008). *Ecological Indicators*, **37, Part B**, 267-273.

Battarbee, R. W., Simpson, G. L., Shilland, E. M., Flower, R. J., Kreiser, A., Yang, H. & Clarke, G. (2014) Recovery of UK lakes from acidification: An assessment using combined palaeoecological and contemporary diatom assemblage data. *Ecological Indicators*, **37, Part B**, 365-380.

Curtis, C. J. & Simpson, G. L. (2014) Trends in bulk deposition of acidity in the UK, 1988-2007, assessed using additive models. *Ecological Indicators*, **37, Part B**, 274-286.

Curtis, C. J., Battarbee, R. W., Monteith, D. T. & Shilland, E. M. (2014) The future of upland water ecosystems of the UK in the 21st century: A synthesis. *Ecological Indicators*, **37, Part B**, 412-430.

Escudero-Onate, C. (2014) International Cooperative Programme on Assessment and Monitoring of Acidification of Rivers and Lakes. Intercomparison 1428:pH, Conductivity, Alkalinity, NO₃-N, Cl, SO₄,Ca, Mg, Na, K, TOC, Al, Fe, Mn, Cd, Pb, Cu, Ni and Zn. 1-88. NIVA, Oslo, Norway.

Fjellheim, A., Johannessen, A. & Svanevik Landes, T. (2014) International Cooperative Programme on Assessment and Monitoring of Acidification of Rivers and Lakes. Biological intercalibration: Invertebrates 1713. ICP Waters Report 118/2014, 1-25. NIVA, Oslo, Norway.

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the United Kingdom: Prospects for the future under current deposition and land use protocols. *Ecological Indicators*, **37, Part B**, 381-395.

Malcolm, I. A., Bacon, P. J., Middlemas, S. J., Fryer, R. J., Shilland, E. M. & Collen, P. (2014) Relationships between hydrochemistry and the presence of juvenile brown trout (*Salmo trutta*) in headwater streams recovering from acidification. *Ecological Indicators*, **37, Part B**, 351-364.

Monteith, D. T., Shilland, E. M., Battarbee, R. W., Evans, C. D., Hildrew, A. G. & Malcolm, I. A. (2014) Recovery of water chemistry and biology in the UK: latest status and emerging issues. Proceedings of the 26th Meeting of the ICP Waters Task Force in Grimstad, Norway October 8-10 2014.

Monteith, D. T., Evans, C. D., Henrys, P. A., Simpson, G. L. & Malcolm, I. A. (2014) Trends in the hydrochemistry of acid-sensitive surface waters in the UK 1988-2008. *Ecological Indicators*, **37, Part B**, 287-303.

Murphy, J. F., Winterbottom, J. H., Orton, S., Simpson, G. L., Shilland, E. M. & Hildrew, A. G. (2014) Evidence of recovery from acidification in the macroinvertebrate assemblages of UK fresh waters: A 20-year time series. *Ecological Indicators*, **37, Part B**, 330-340.

Rowe, E. C., Tipping, E., Posch, M., Oulehle, F., Cooper, D. M., Jones, T. G., Burden, A., Hall, J. & Evans, C. D. (2014) Predicting nitrogen and acidity effects on long-term dynamics of dissolved organic matter. *Environmental Pollution*, **184**, 271-282.

Shilland, E. M., Monteith, D. T., Millidine, K. & Malcolm, I. A. (2014) The United Kingdom Upland Waters Monitoring Network Data Report for 2012-2013 (year 25). Report to the Department for Environment, Food and Rural Affairs (Contract EPG 1/3/160). 1-259. ENSIS Ltd. Environmental Change Research Centre, University College London, London.

Shilland, E. M., Monteith, D. T., Millidine, K. & Malcolm, I. A. (2014) The United Kingdom Upland Waters Monitoring Network Data Report for 2013-2014 (year 26). Report to the Department for Environment, Food and Rural Affairs (Contract EPG 1/3/160). 1-282. ENSIS Ltd. Environmental Change Research Centre, University College London, London.

Shilland, E. M., Irvine, L., Millidine, K. & Malcolm, I. A. (2014) UK Upland Waters Monitoring Network (UKUWMN) - Contract 22 01 249 Llyn Llgi, Llyn Cwm Mynach, Afon Hafren and Afon Gwy Annual Summary Progress Report April 2013 - March 2014. Report to the Welsh Government and Natural Resources Wales. 1-64. ENSIS Ltd, Environmental Change Research Centre, University College London, London.

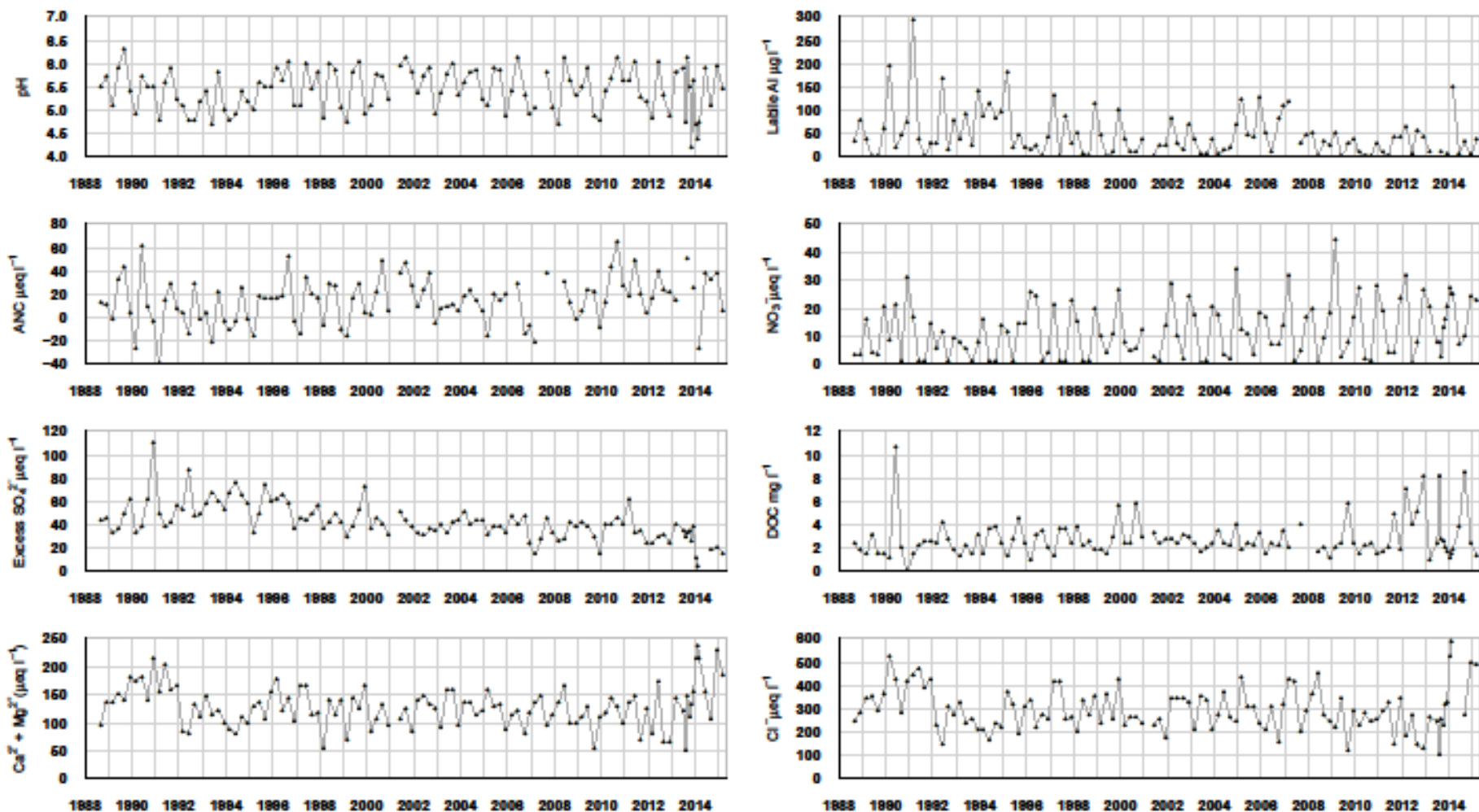
Stockdale, A., Tipping, E., Fjellheim, A., Garmo, O. A., Hildrew, A. G., Lofts, S., Monteith, D. T., Ormerod, S. J. & Shilland, E. M. (2014) Recovery of macroinvertebrate species richness in acidified upland waters assessed with a field toxicity model. *Ecological Indicators*, **37, Part B**, 341-350.

Winterbottom, J. H. & Orton, S. E. (2014) United Kingdom Acid Waters Monitoring Network Invertebrate Survey. Twenty Seventh Year: 2014. Summary of species identification and

abundance. 1-10. School of Biological Sciences, Queen Mary University of London, London.

4.11 Llyn Cwm Mynach Summary Data to March 2015

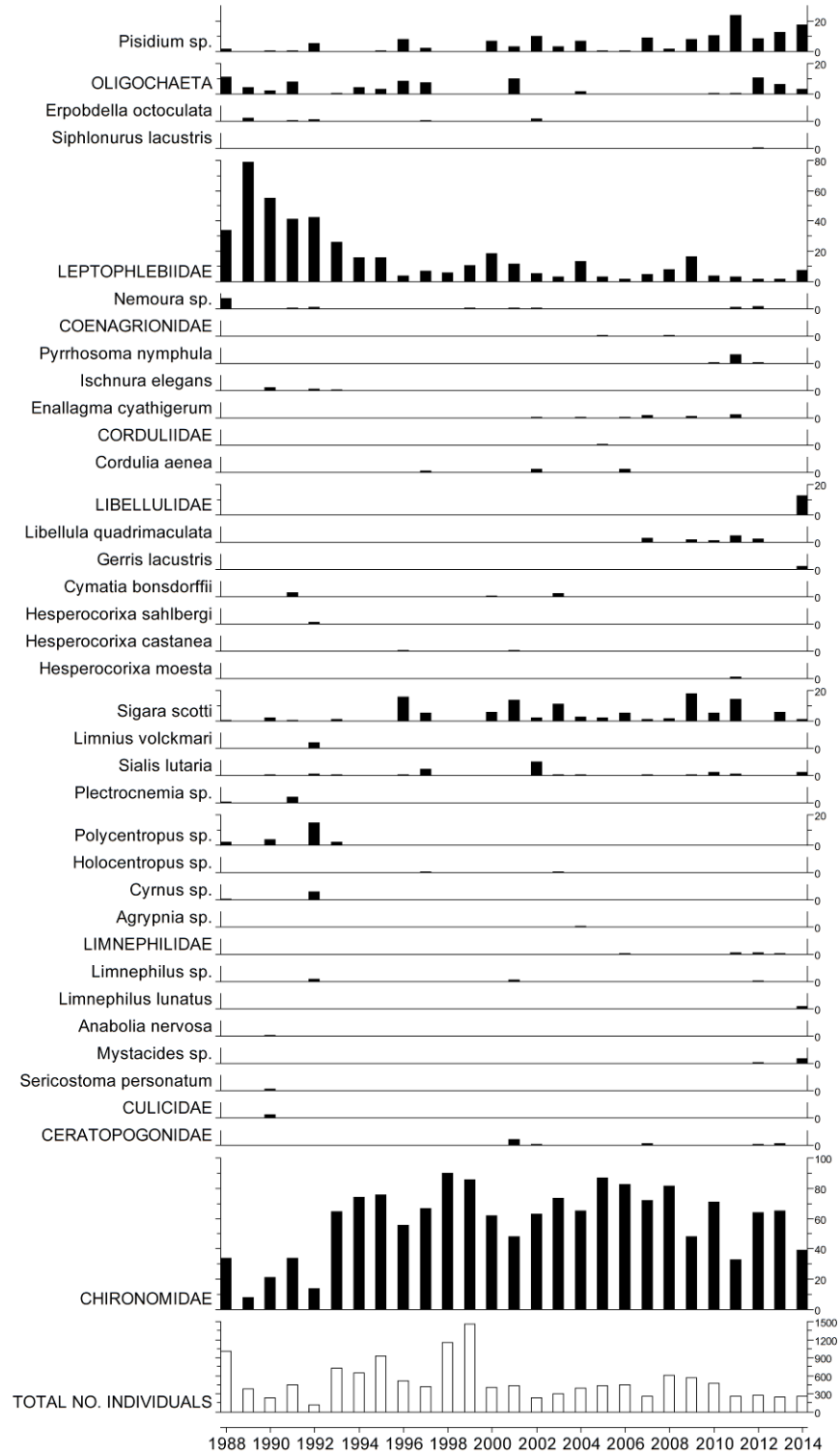
4.11.1 Spot sampled chemistry data



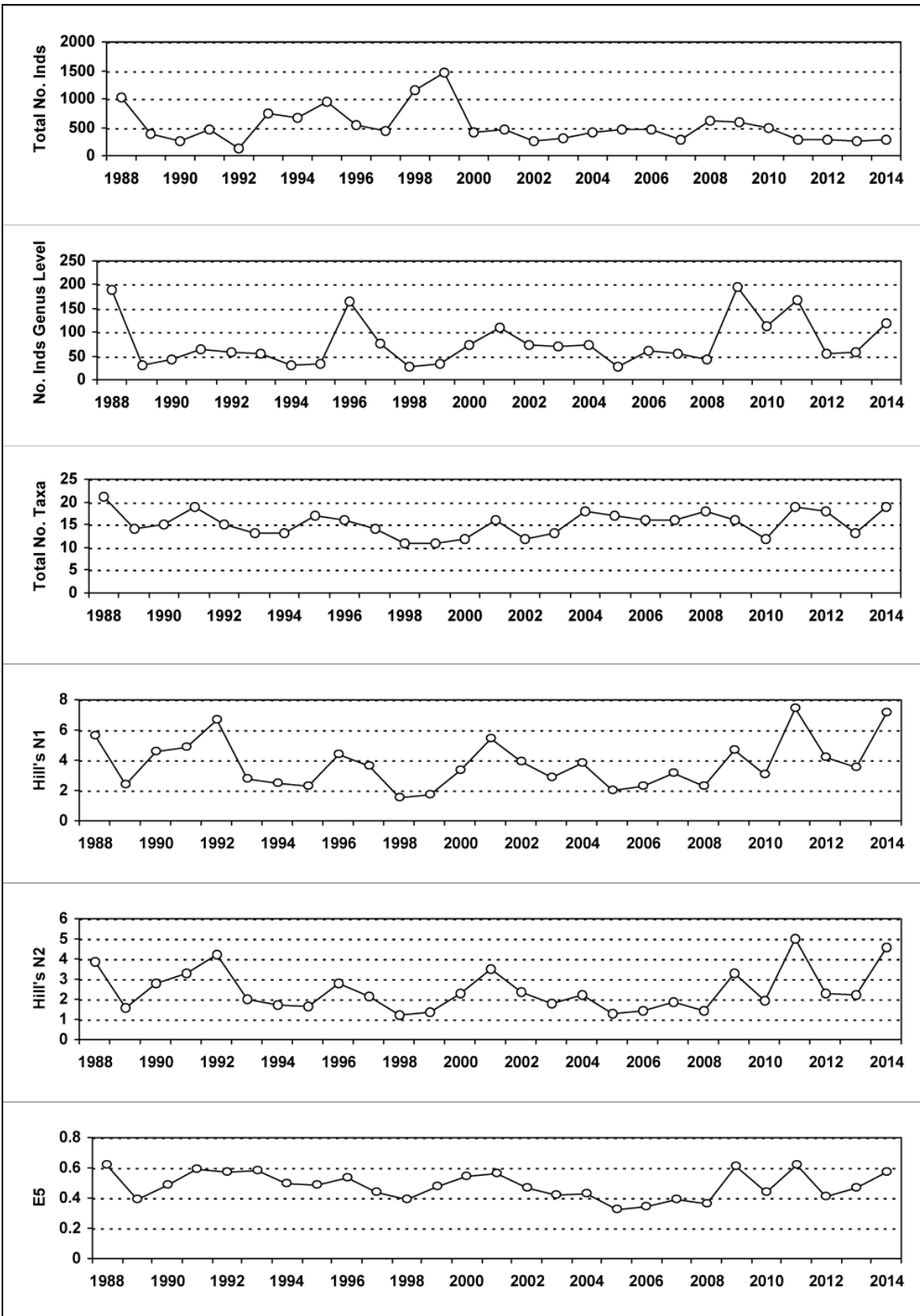
$\mu\text{eq l}^{-1}$, $^*\mu\text{g l}^{-1}$, $^{**}\text{mg l}^{-1}$	pH	ANC	Ca ²⁺	Mg ²⁺	Na ⁺	K ⁺	*Soluble Al	*Labile Al	Cl ⁻	*SO ₄ ²⁻	xSO ₄ ²⁻	NO ₃ ⁻	**DOC
Mean 1 st 5 yrs	5.35	7.68	77.79	67.45	291.02	3.36	110.75	66.58	337.67	88.32	52.91	9.40	2.50
14-15 mean	5.59	28.20	83.21	85.10	377.47	5.98	77.50	20.75	419.11	61.41	18.05	15.95	4.06
14-15 std dev	0.40	15.34	28.23	24.17	87.39	1.22	76.53	16.58	124.40	10.29	2.37	8.83	3.14

4.11.2 Macroinvertebrate data

4.11.2.1 Percentage abundance summary, Llyn Cwm Mynach

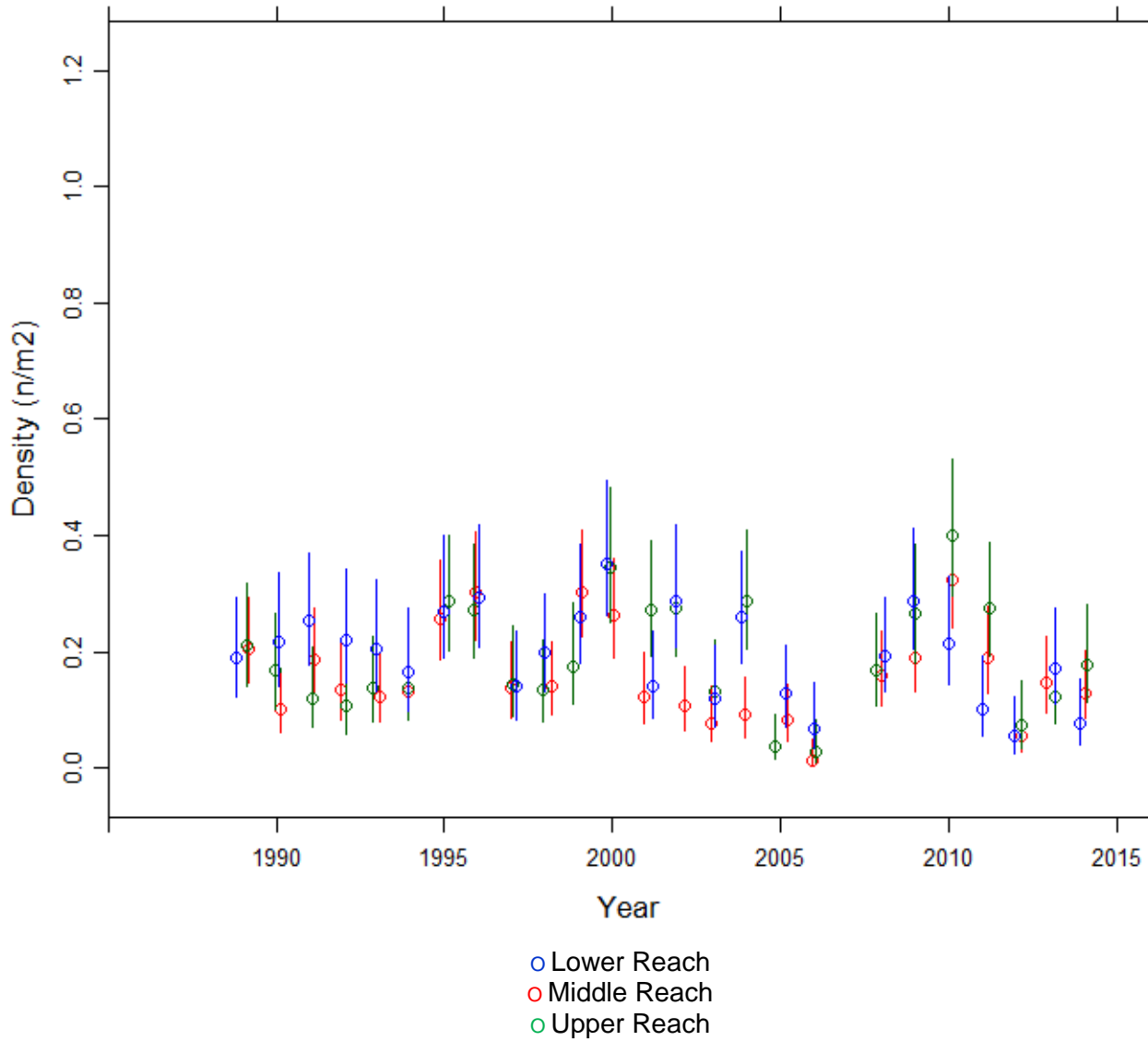


4.11.2.1 Macroinvertebrate summary statistics, Llyn Cwm Mynach



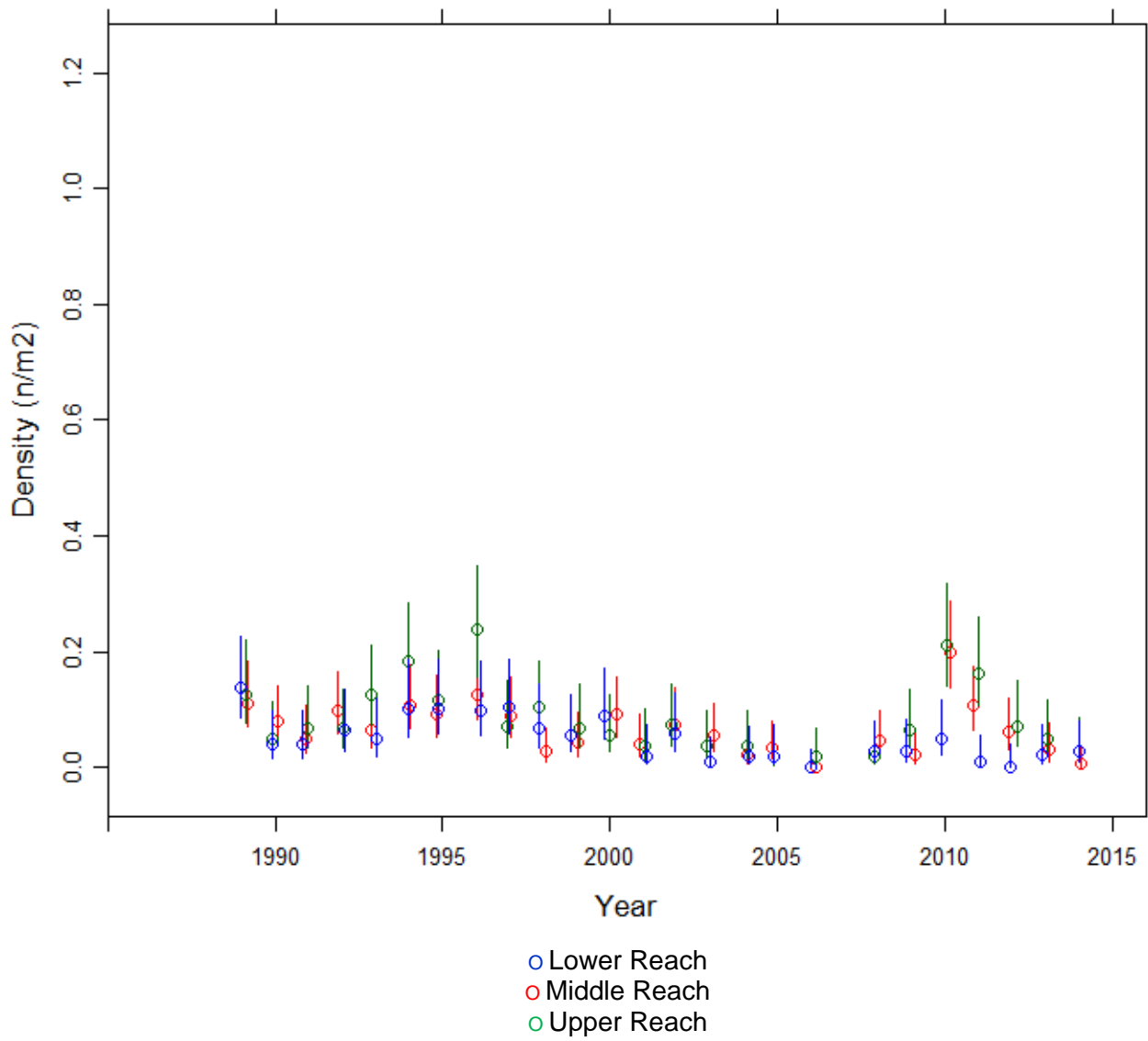
4.11.3 Fish data (for outflow stream)

4.11.3.1 Summary of Trout fry density (numbers m^{-2}), Llyn Cwm Mynach



Fishing no longer funded after 2014.

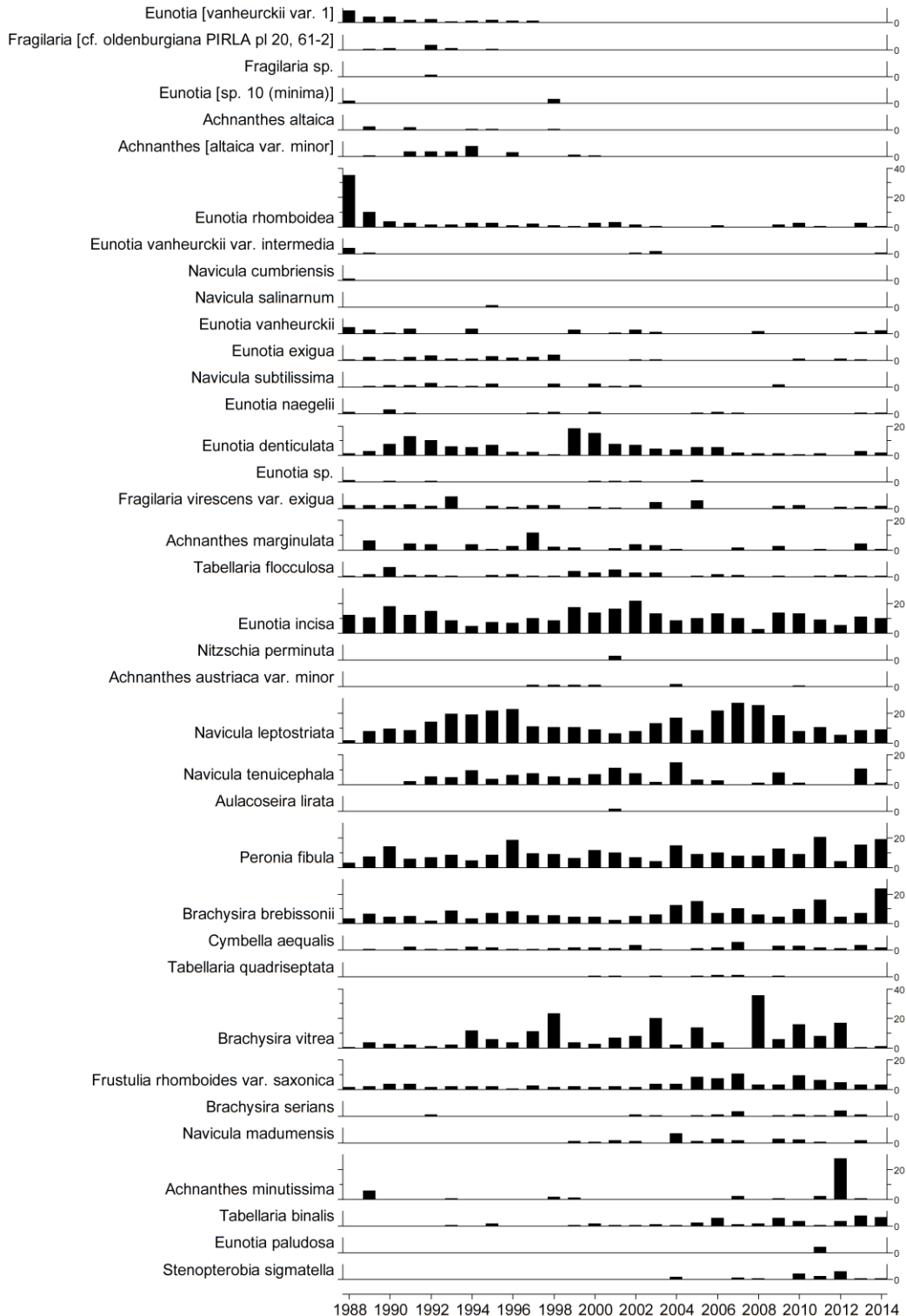
4.11.3.2 Summary of Trout parr density (numbers m⁻²), Llyn Cwm Mynach



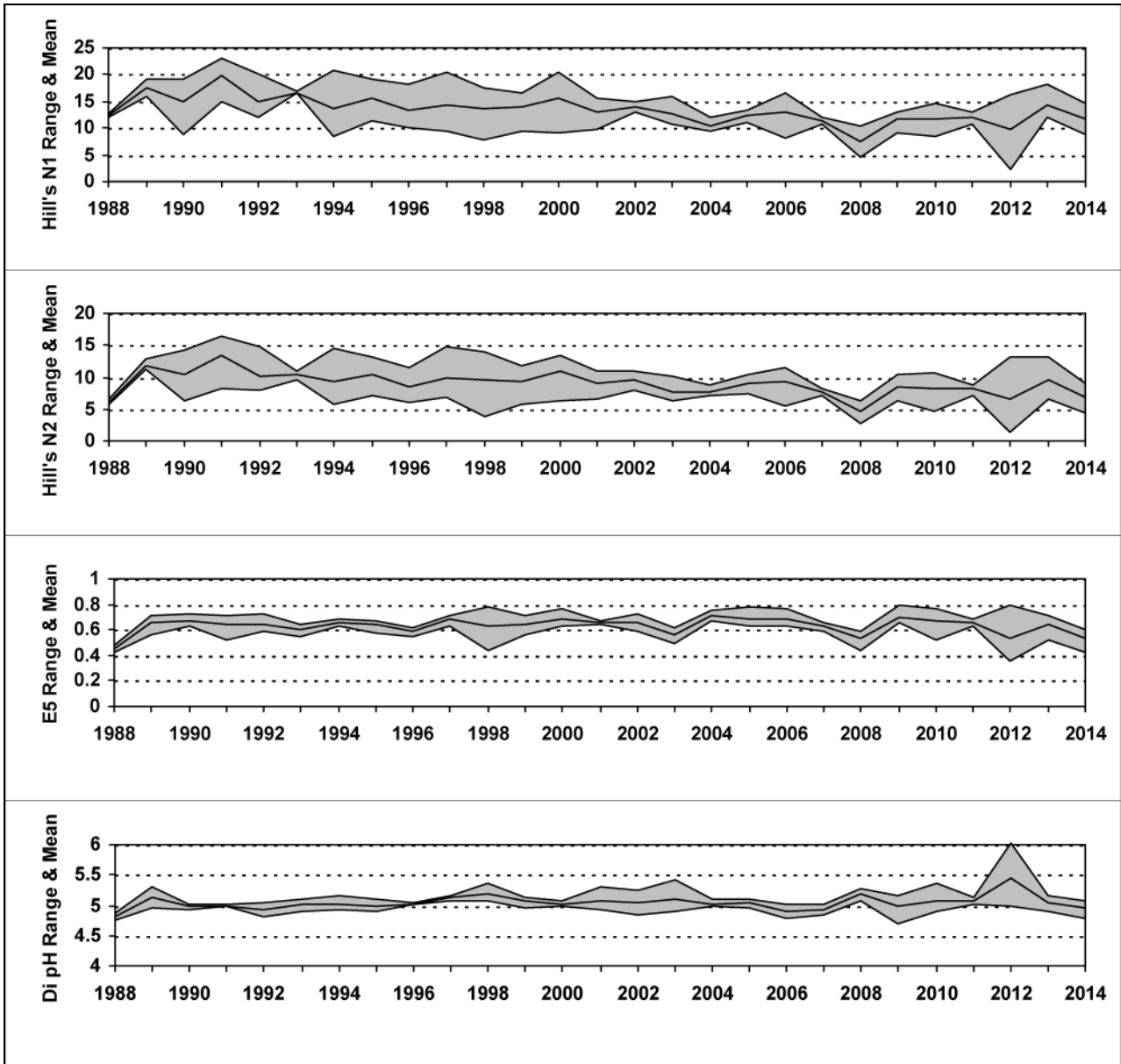
Fishing no longer funded after 2014.

4.11.4 Epilithic diatom data

4.11.4.1 Percentage abundance summary, Llyn Cwm Mynach

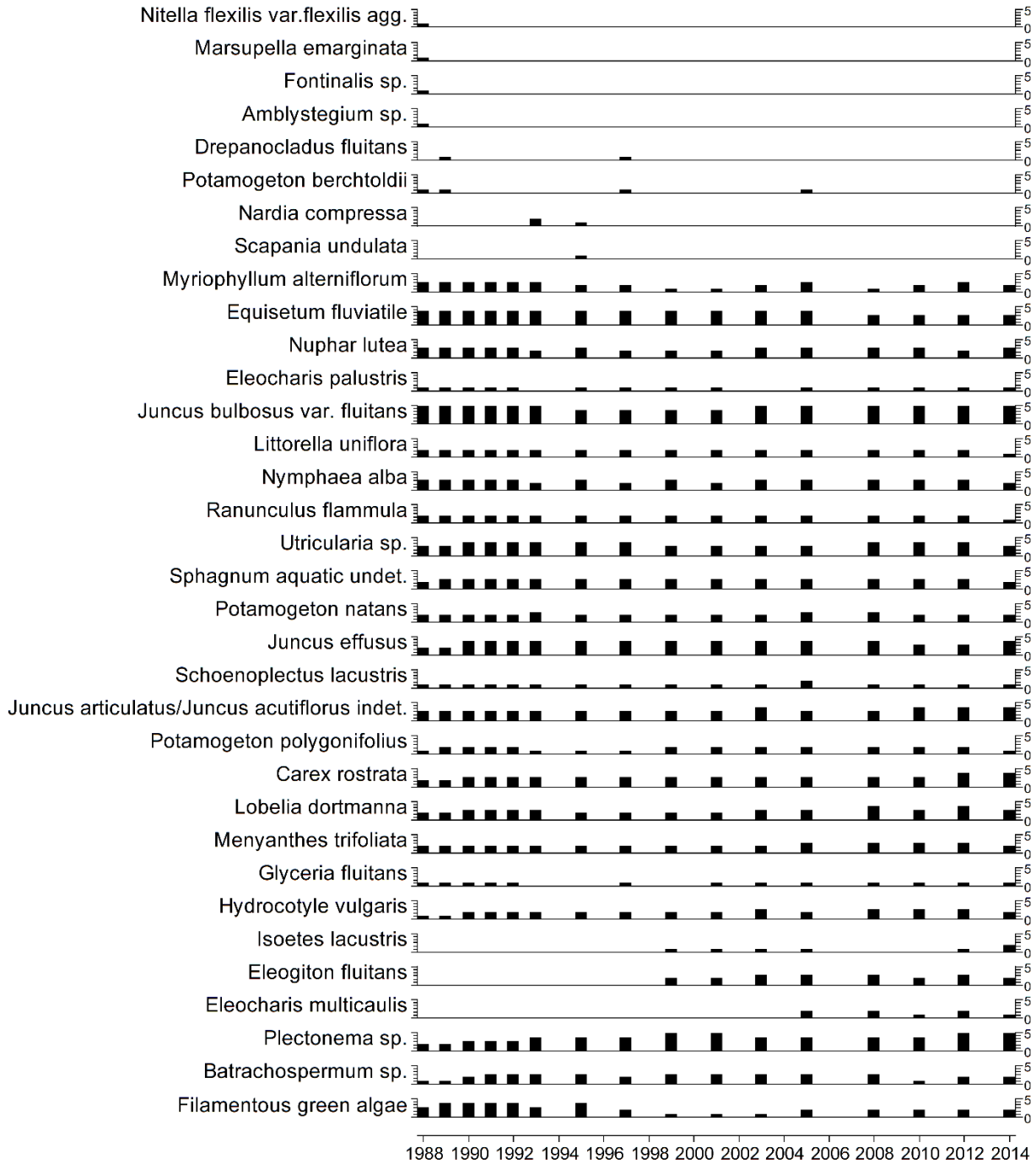


4.11.4.2 Diatom summary statistics, Llyn Cwm Mynach



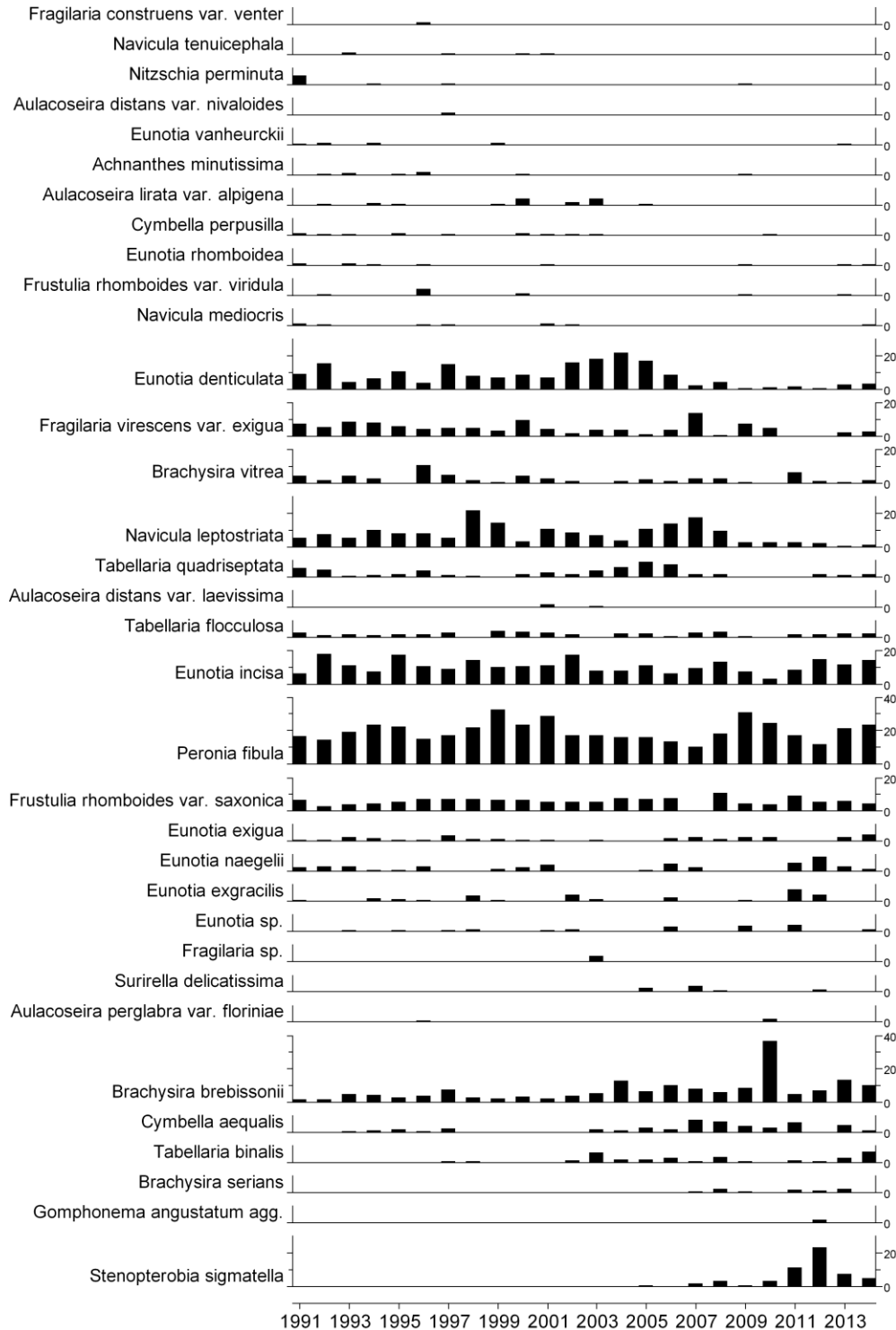
4.11.5 Aquatic macrophyte data, Llyn Cwm Mynach

Species Scores (1-5)

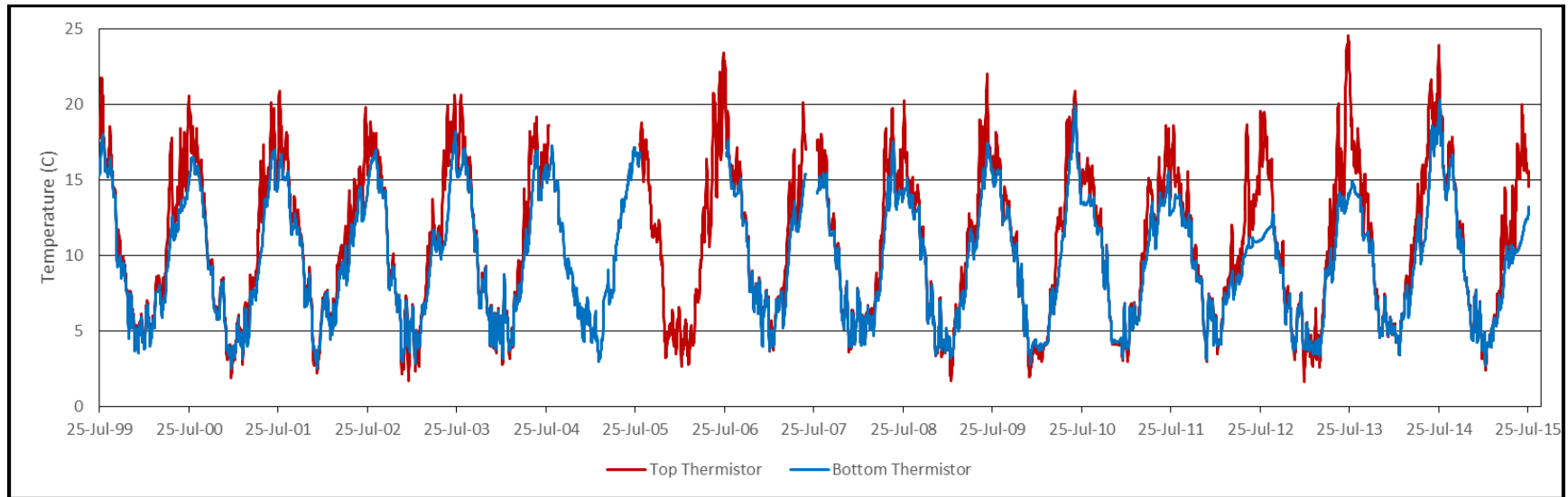


4.11.6 Sediment trap data, Llyn Cwm Mynach

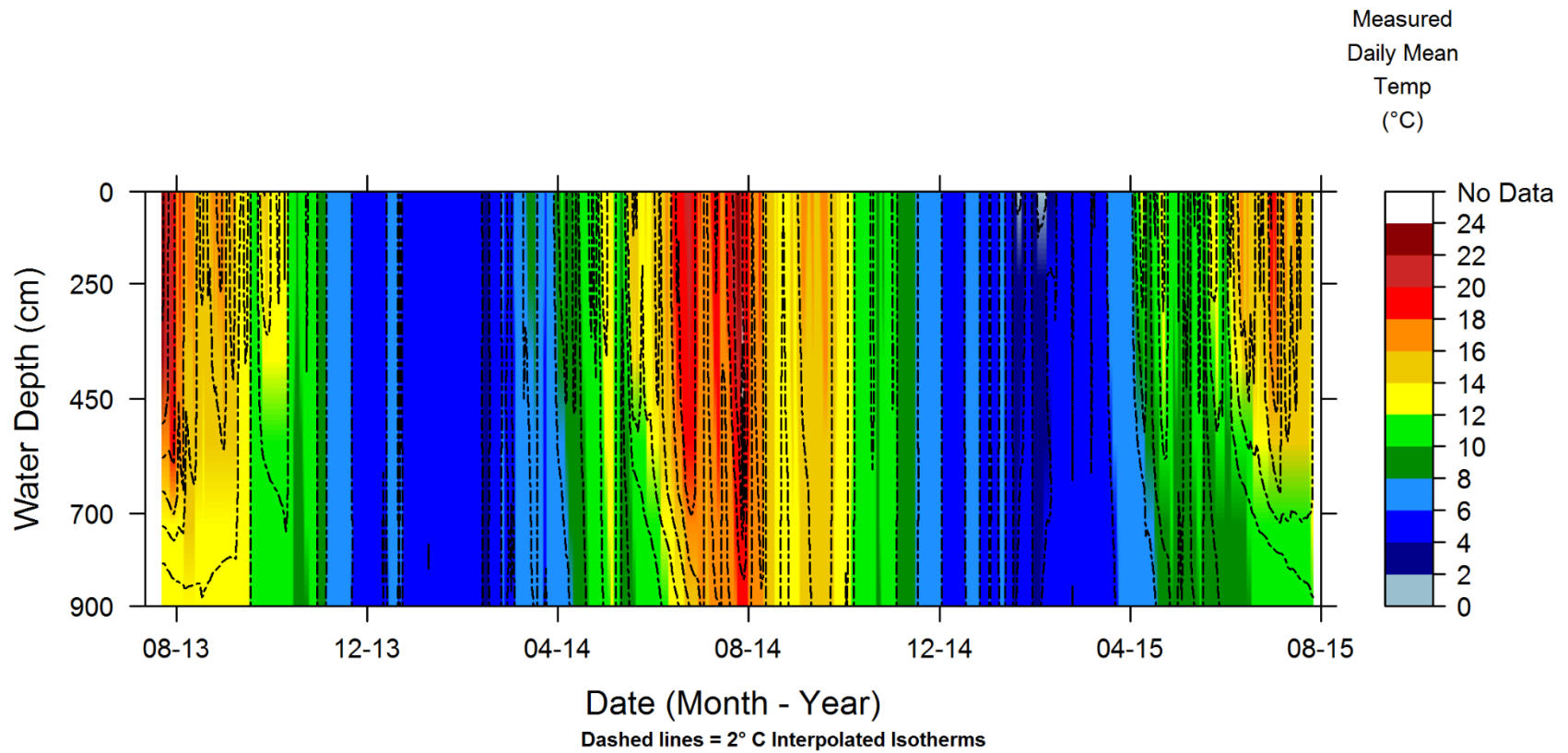
Relative percentage frequency of diatom taxa



4.11.7 Sediment trap thermistor data, Llyn Cwm Mynach



4.11.8 Thermistor chain data, Llyn Cwm Mynach



5 Afon Hafren



Figure 3 Afon Hafren biological survey section 18th September 2015

5.1 Summary Overview

Chemical and biological sample collection, analysis and data collation, quality control and archiving proceeded without any problems at Afon Hafren during the period from April 2015 to March 2016.

5.2 Water Chemistry

Samples were collected by CEH early every month throughout the period April 2015 to March 2016, delivered to the analytical laboratories on schedule and are in the process of being analysed, quality controlled and archived in the UKUWMN central chemistry database at CEH Lancaster.

5.3 Thermistors

The MS thermistor at Afon Hafren functioned well throughout the period April 2015 to September 2015 when, unfortunately, the thermistor fixtures failed and the thermistor had to be removed from the site. High flows on subsequent site visits have delayed reinstallation. Data up to September 2015 have been downloaded, checked and archived in the central ENSIS and MS temperature database.

5.4 Epilithic Diatoms

Epilithic diatoms were retrieved by a team from ENSIS from three sampling points in the stream on the 8th of July 2015. The samples have been made into slides.

5.5 Macroinvertebrates

Aquatic macroinvertebrates were sampled on the 15th April 2015 by a team from QMuL. Five 1 minute kick samples were performed. The samples were counted and the data sent to ENSIS Ltd. The data is in the process of being quality screened before being added to the UKUWMN biological database at ENSIS.

5.6 Fish

Due to resourcing cuts, fish surveying was not performed in Autumn 2015.

5.7 Aquatic Macrophytes

Aquatic macrophytes were surveyed by a team from ENSIS on 18th of September 2015. Percentage cover scores were recorded and data will be added to the ENSIS biological database after microscope confirmation of bryophyte identifications.

5.8 Data Management and Reporting

No problems or hiatus occurred with the collation and transfer of data within methodological programmes, or to the UKUWMN databases, during the reporting period.

The 2014-2015 annual report has been uploaded to the UKUWMN web page. The section on Afon Hafren appears in section 5.10 below.

The UKUWMN website page detailing Afon Hafren can be found here:

http://awmn.defra.gov.uk/sites/site_17.php

Further publications from the contract period utilizing UKUWMN data from Afon Hafren are detailed in section 5.9 below.

5.9 Afon Hafren Recent UKUWMN Output

Oosthoek, S. (2016) Global browning: Why the world's fresh water is getting murkier. *New Scientist* (3055), 34-35. Reed Business Information, London.

Battarbee, R. W. (2015) Forestry, 'acid rain', and the acidification of lakes. In: *Nature's Conscience: the life and legacy of Derek Ratcliffe*, 385-400, Langford Press, Peterborough.

Battarbee, R. W. (2015) Remote lakes: pristine or polluted. UK and Ireland Lakes Network annual conference, Abergavenny. 4th March 2015.

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Garmo, O. A., de Wit, H. A., Høgåsen, T., Lund, E., Wright, R. F., Aherne, J., Arle, J., Colombo, L., Fölster, J., Hruška, J., Indriksone, I., Jeffries, D. S., Krám, P., Monteith, D. T., Paterson, A., Rogora, M., Rzychon, D., Steingruber, S., Stoddard, J. L., Talkop, R., Ulanczyk, R. P. & Vuorenmaa, J. (2015) Trends in water chemistry. In: *ICP Waters Report 119/2015. Chemical and biological recovery in acid-sensitive waters: trends and prognosis*, 8-39, NIVA, Oslo, Norway.

Hudson, L. (24-8-2015) Package "cheddar". 1-109. <https://cran.r-project.org/web/packages/cheddar/index.html>.

Laize, C. L. R. & Bruna Meredith, C. (2015) Water temperatures for the period 1984 to 2007 at 35 sites on 21 UK rivers. NERC Environmental Information Data Centre.

Monteith, D. T., Battarbee, R. W., Hildrew, A. G., Malcolm, I. A., Shilland, E. M., Evans, C. D. & Kernan, M. (2015) Hindered, stubborn or confused? Explaining the patchiness of biological responses to the declining acidity of surface waters. 9th International Conference on Acid Deposition, Rochester, New York. October 19-23, 2015.

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Escudero-Onate, C. (2014) International Cooperative Programme on Assessment and Monitoring of Acidification of Rivers and Lakes. Intercomparison 1428:pH, Conductivity,

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Rowe, E. C., Tipping, E., Posch, M., Oulehle, F., Cooper, D. M., Jones, T. G., Burden, A., Hall, J. & Evans, C. D. (2014) Predicting nitrogen and acidity effects on long-term dynamics of dissolved organic matter. *Environmental Pollution*, **184**, 271-282.

Shilland, E. M., Monteith, D. T., Millidine, K. & Malcolm, I. A. (2014) The United Kingdom Upland Waters Monitoring Network Data Report for 2012-2013 (year 25). Report to the Department for Environment, Food and Rural Affairs (Contract EPG 1/3/160). 1-259. ENSIS Ltd. Environmental Change Research Centre, University College London, London.

Shilland, E. M., Irvine, L., Millidine, K. & Malcolm, I. A. (2014) UK Upland Waters Monitoring Network (UKUWMN) - Contract 22 01 249 Llyn Llagi, Llyn Cwm Mynach,

Afon Hafren and Afon Gwy Annual Summary Progress Report April 2013 - March 2014. Report to the Welsh Government and Natural Resources Wales. 1-64. ENSIS Ltd, Environmental Change Research Centre, University College London, London.

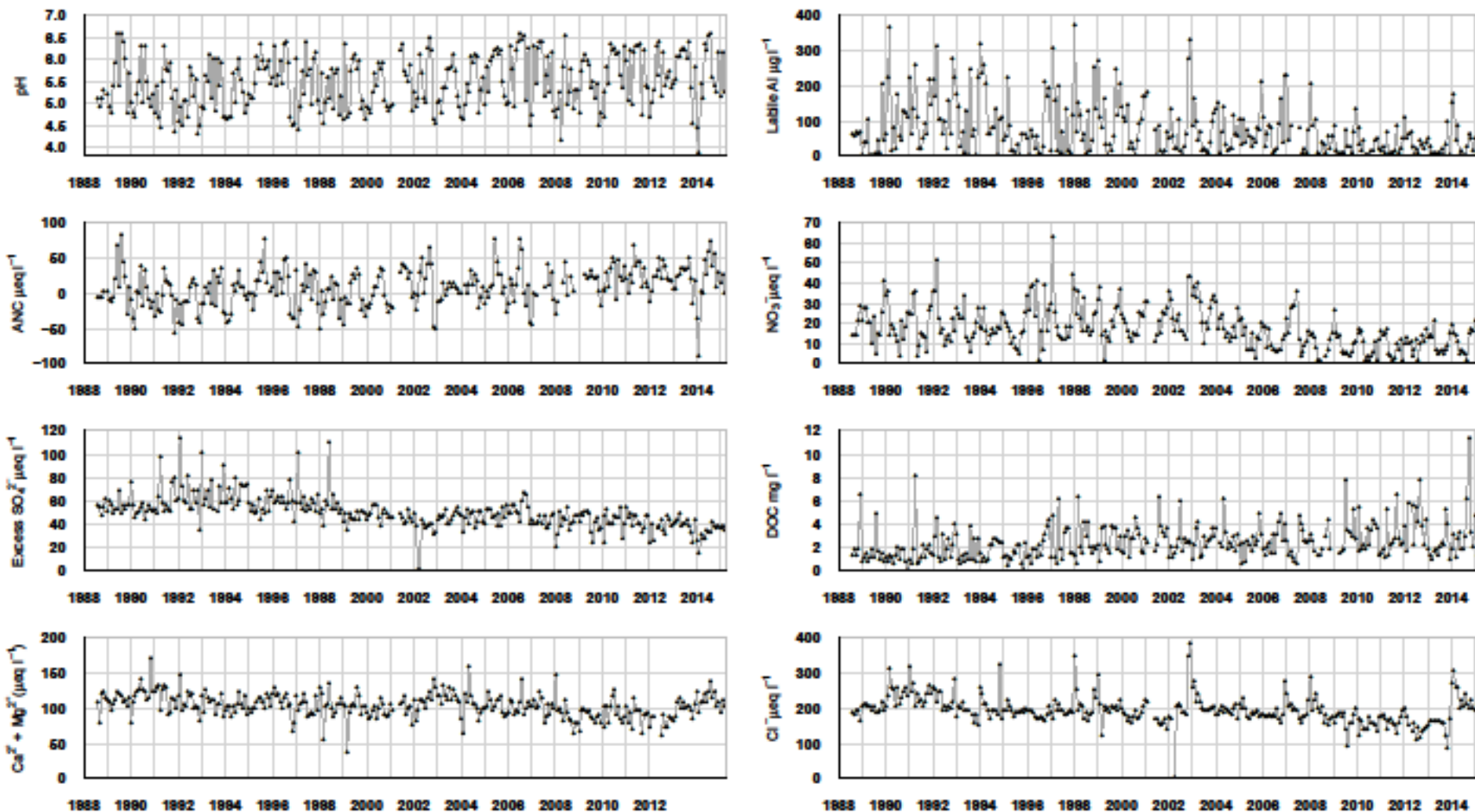
Shilland, E. M., Monteith, D. T., Millidine, K. & Malcolm, I. A. (2014) The United Kingdom Upland Waters Monitoring Network Data Report for 2013-2014 (year 26). Report to the Department for Environment, Food and Rural Affairs (Contract EPG 1/3/160). 1-282. ENSIS Ltd. Environmental Change Research Centre, University College London, London.

Stockdale, A., Tipping, E., Fjellheim, A., Garmo, +. A., Hildrew, A. G., Lofts, S., Monteith, D. T., Ormerod, S. J. & Shilland, E. M. (2014) Recovery of macroinvertebrate species richness in acidified upland waters assessed with a field toxicity model. *Ecological Indicators*, **37, Part B**, 341-350.

Winterbottom, J. H. & Orton, S. E. (2014) United Kingdom Acid Waters Monitoring Network Invertebrate Survey. Twenty Seventh Year: 2014. Summary of species identification and abundance. 1-10. School of Biological Sciences, Queen Mary University of London, London.

5.10 Afon Hafren Summary Data to March 2015

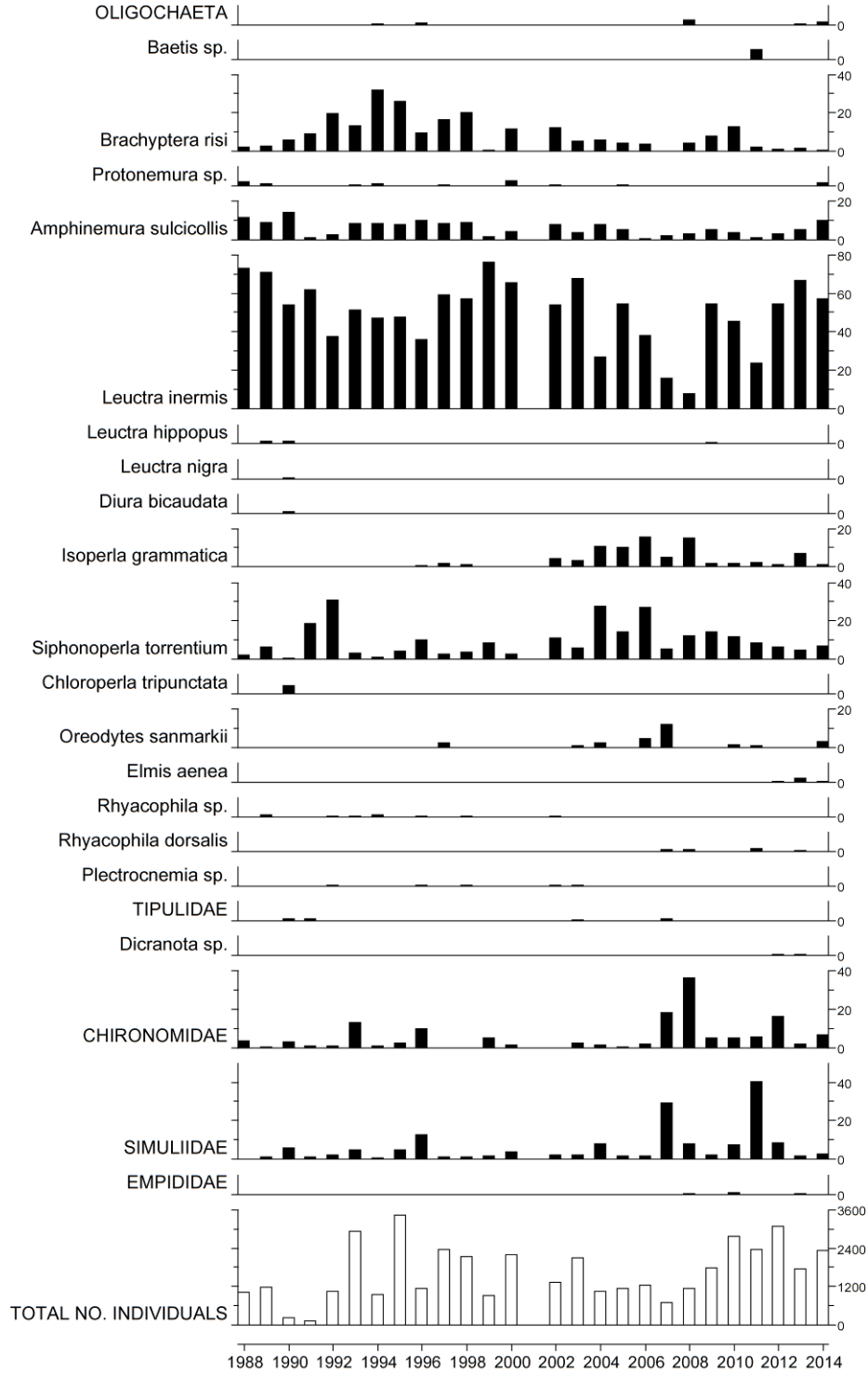
5.10.1 Spot sampled chemistry data



$\mu\text{eq l}^{-1}$, $^*\mu\text{g l}^{-1}$, $^{**}\text{mg l}^{-1}$	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	5.29	-2.40	47.91	66.41	200.39	3.16	170.00	101.71	221.09	82.97	59.79	20.58	1.76
14-15 mean	5.81	31.97	45.09	68.91	199.48	4.45	92.33	32.83	217.10	58.04	35.27	11.66	3.67
14-15 std dev	0.57	24.35	7.70	4.86	8.08	1.93	70.53	30.60	20.10	3.71	4.16	6.57	2.80

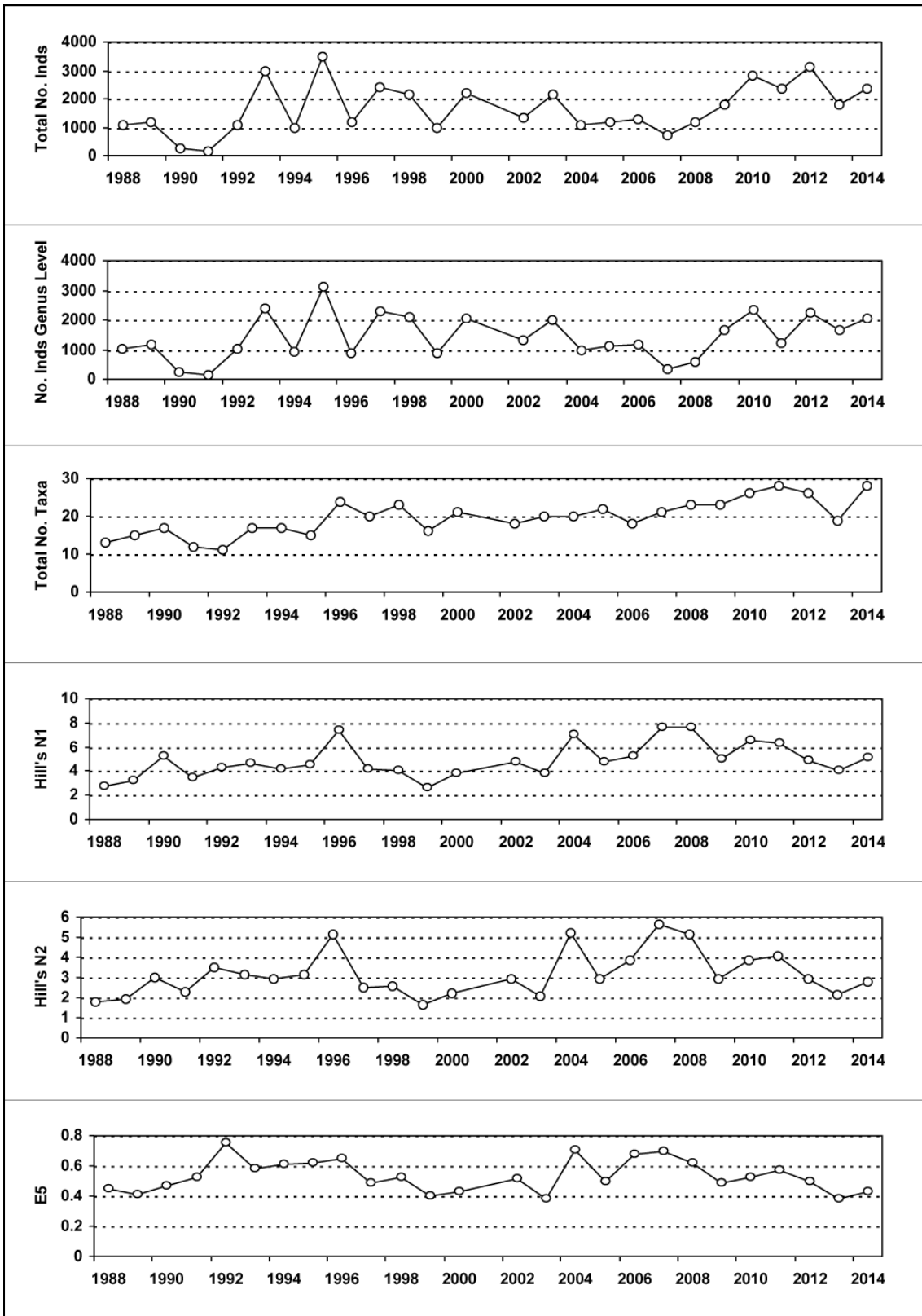
5.10.2 Macroinvertebrate data

5.10.2.1 Percentage abundance summary, Afon Hafren



No sampling in 2001 due to Foot and Mouth restrictions.

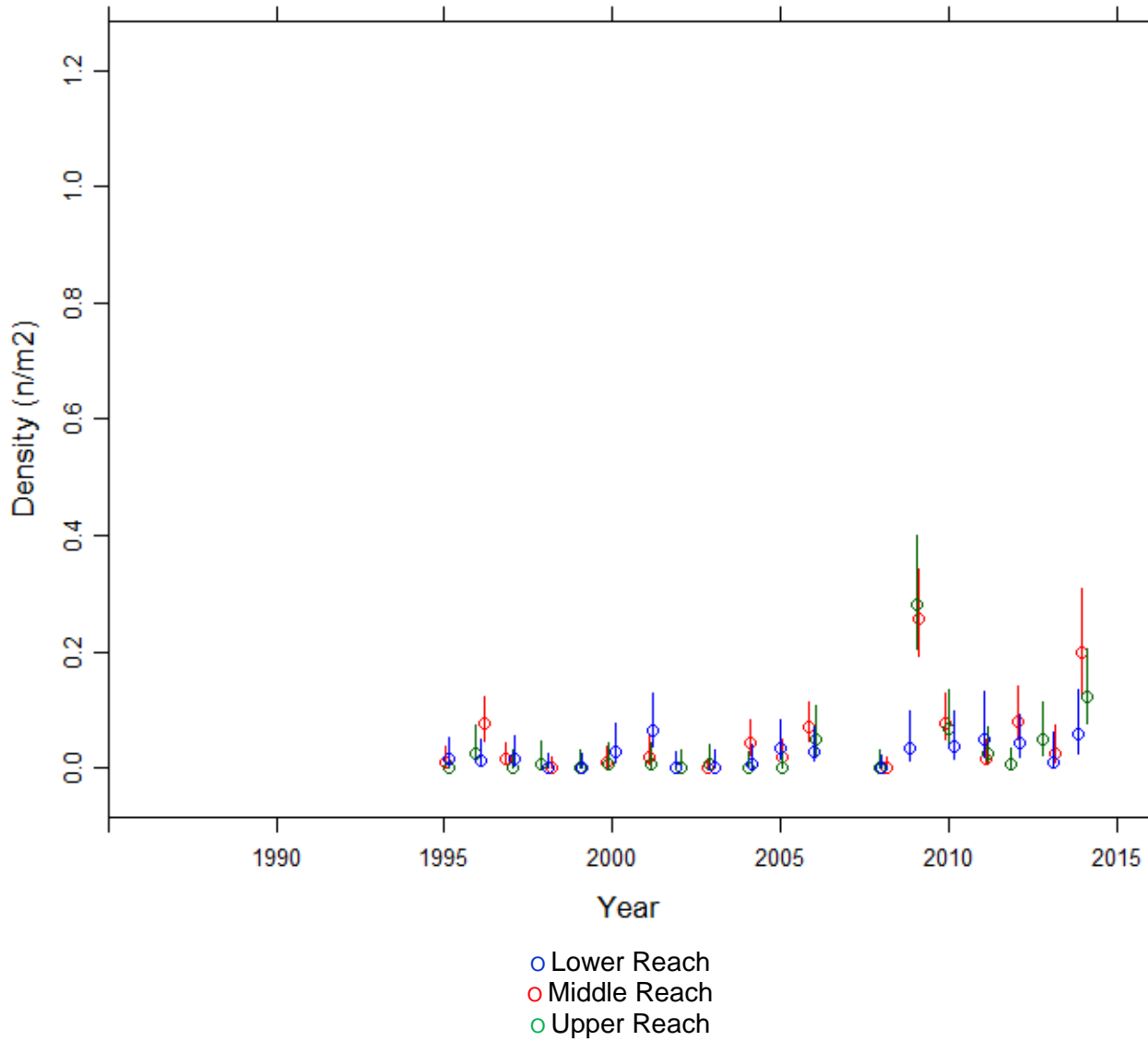
5.10.2.1 Macroinvertebrate summary statistics, Afon Hafren



No sampling in 2001 due to Foot and Mouth restrictions.

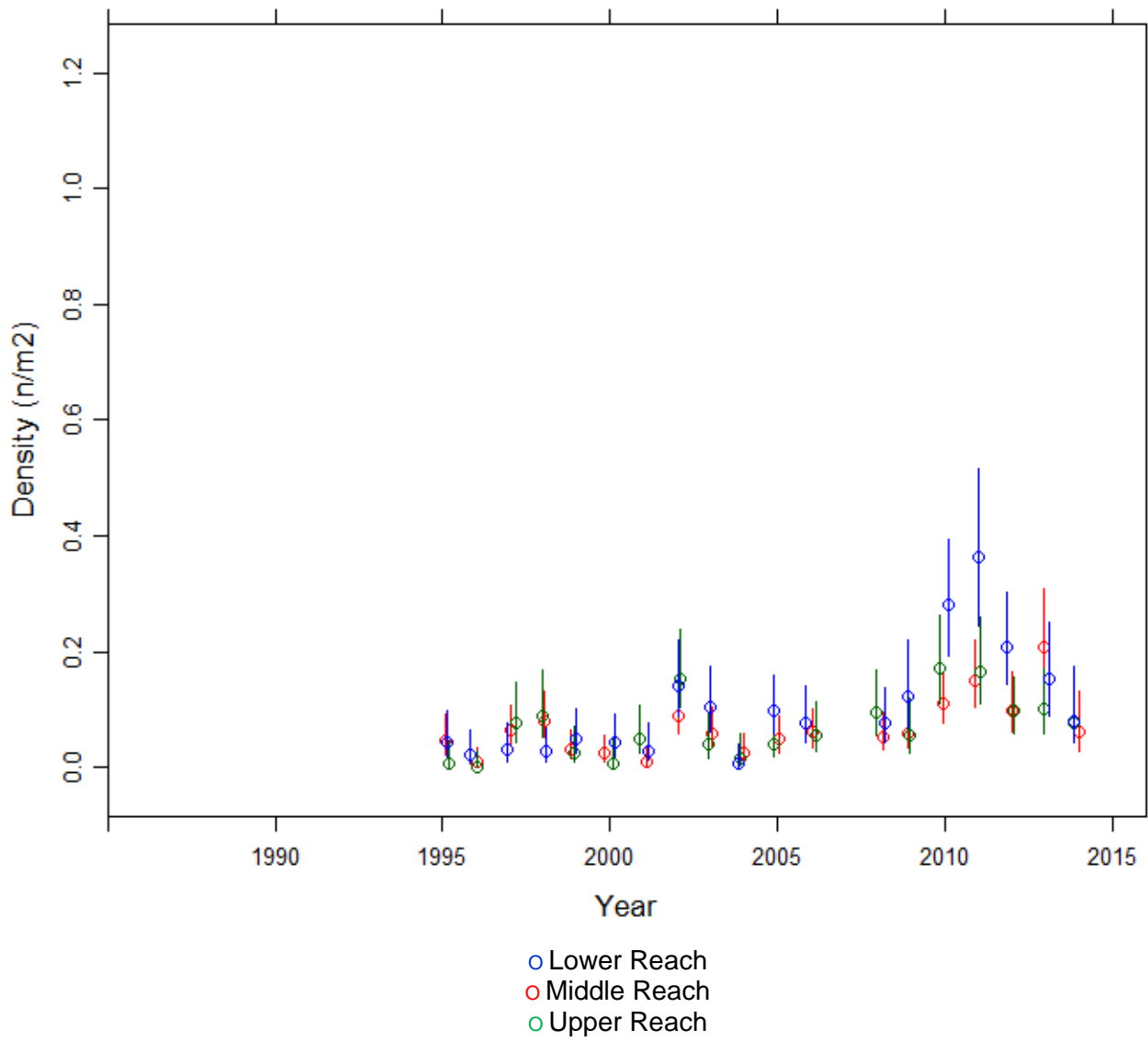
5.10.3 Fish data

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



Fishing no longer funded after 2014.

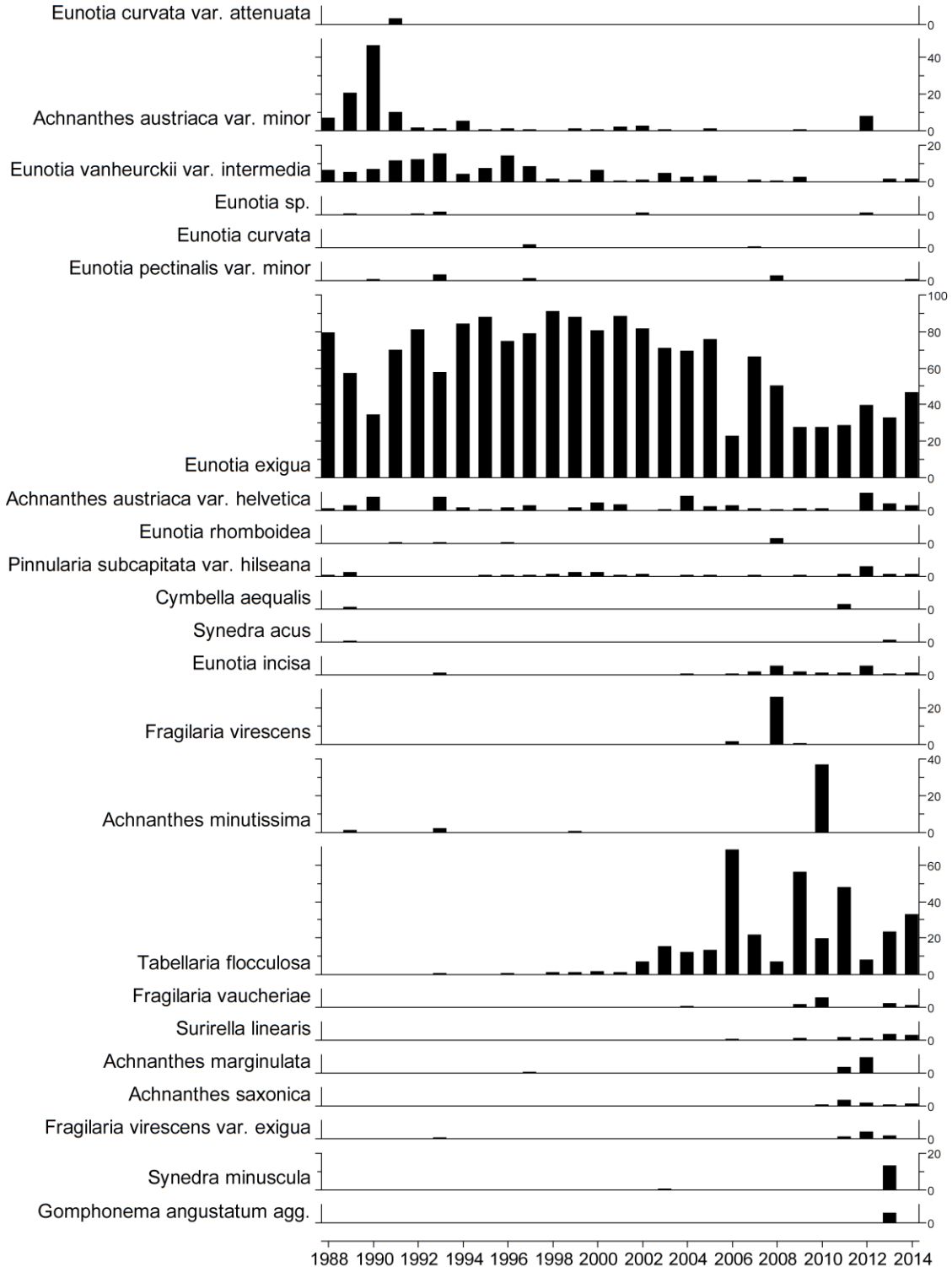
5.10.3.2 Summary of Trout parr density (numbers m⁻²), Afon Hafren



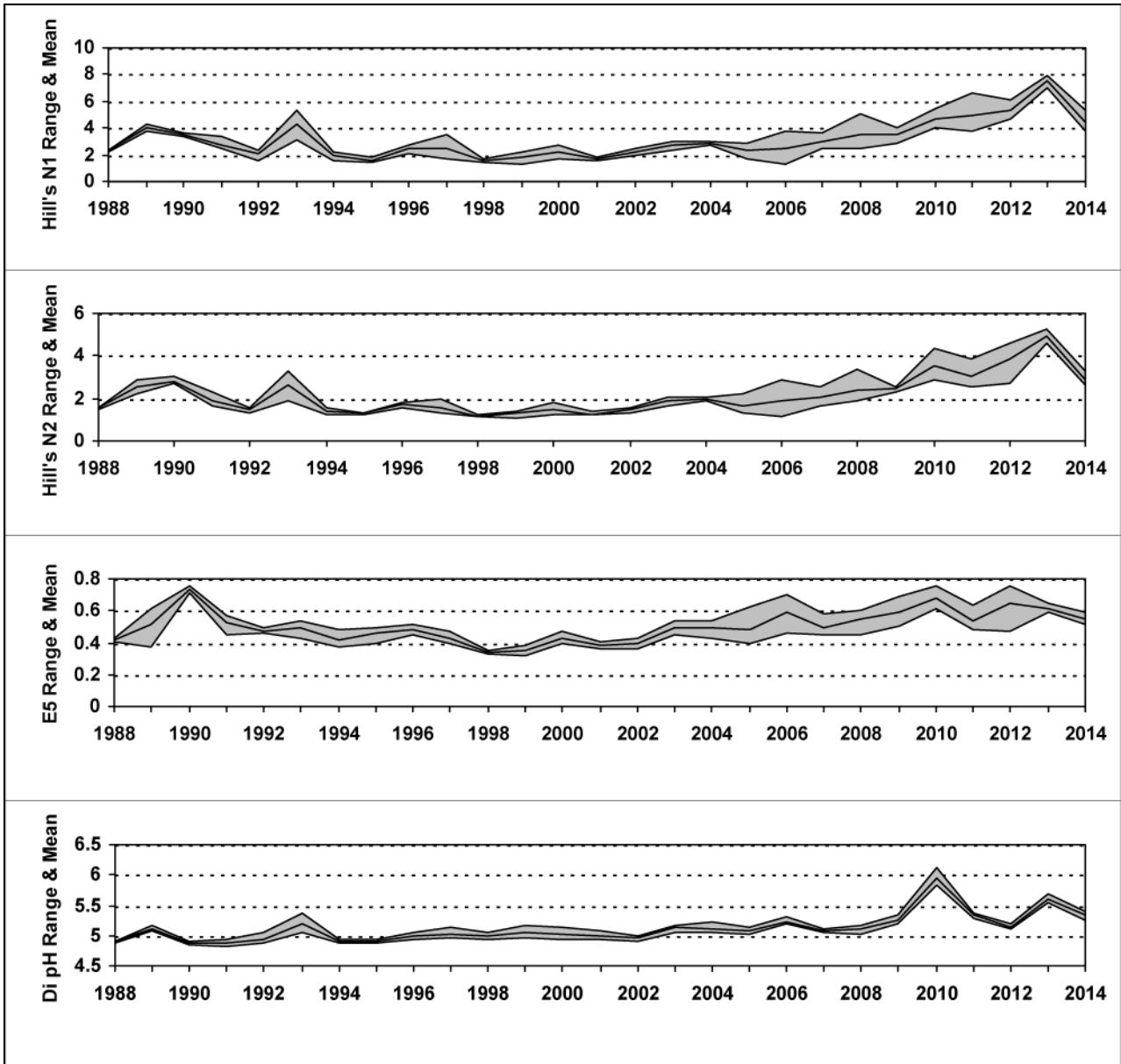
Fishing no longer funded after 2014.

5.10.4 Epilithic diatom data

5.10.4.1 Percentage abundance summary, Afon Hafren

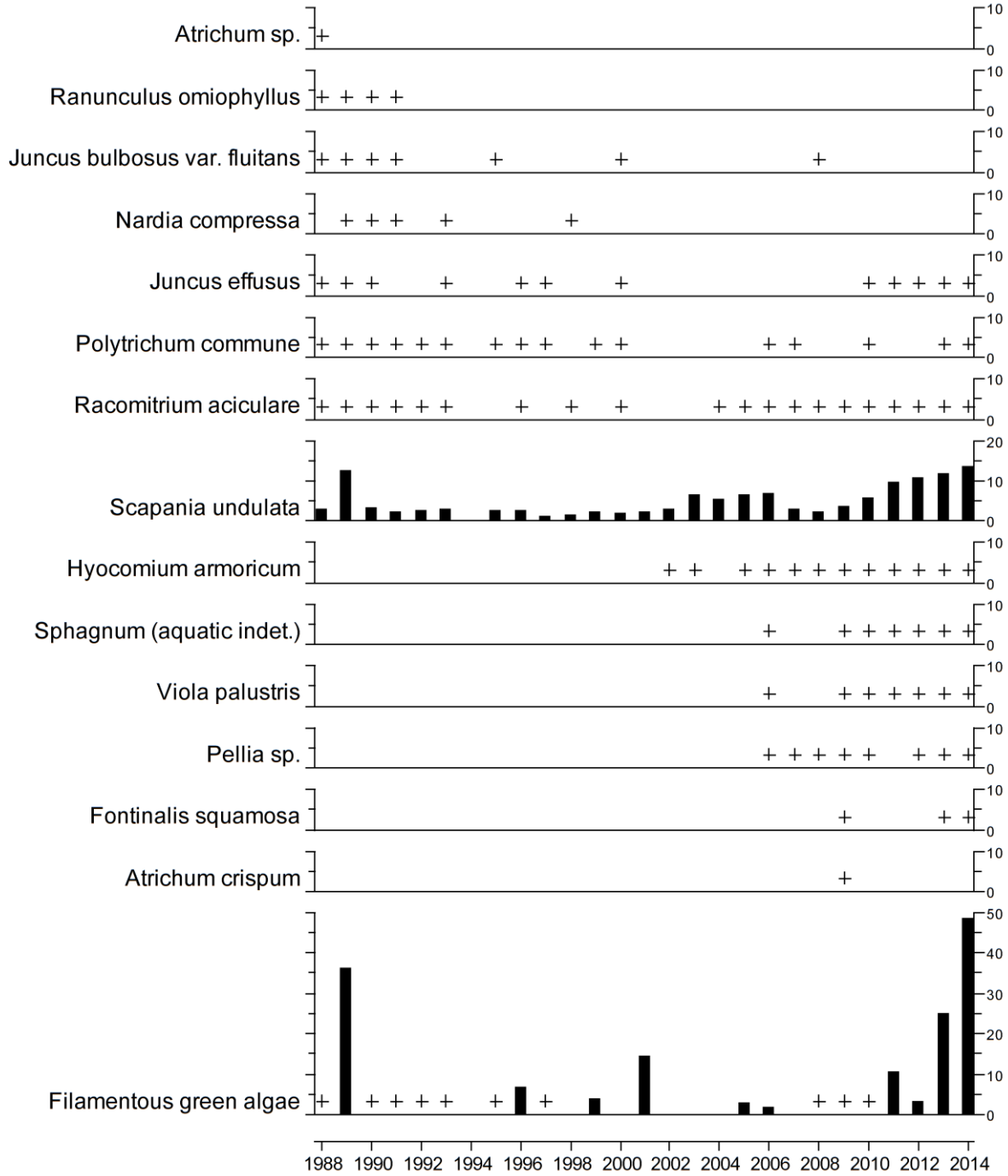


5.10.4.1 Diatom summary statistics, Afon Hafren



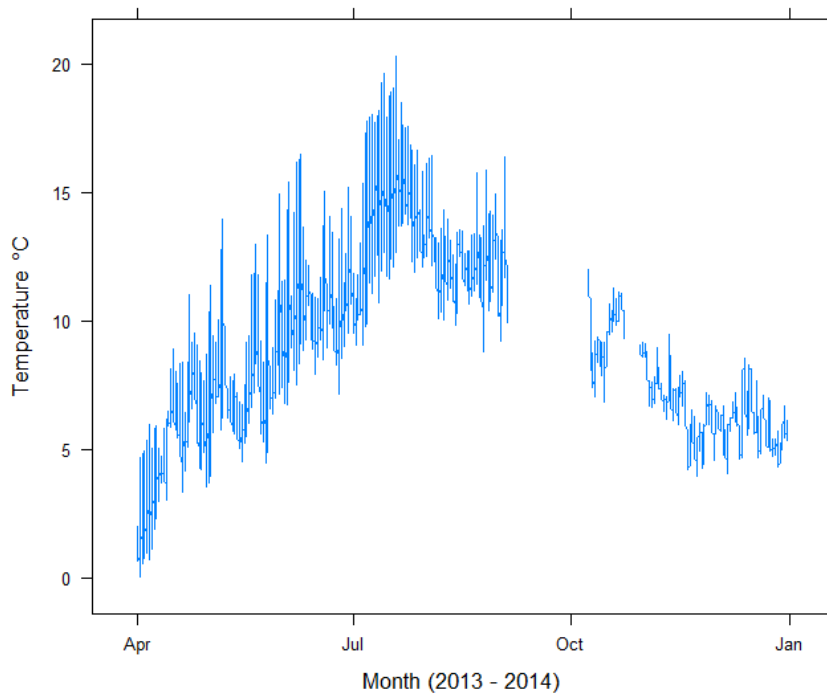
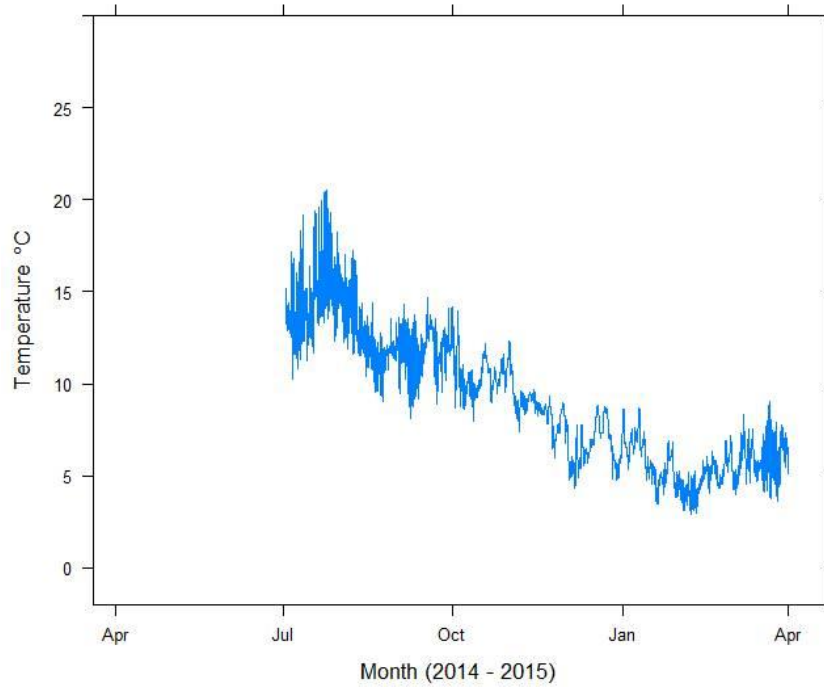
5.10.5 Aquatic macrophyte data, Afon Hafren

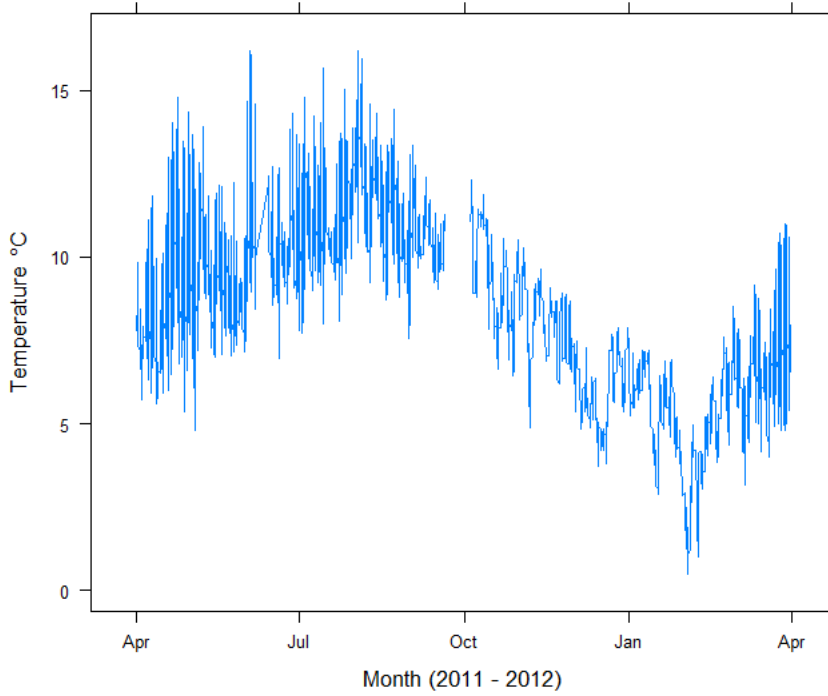
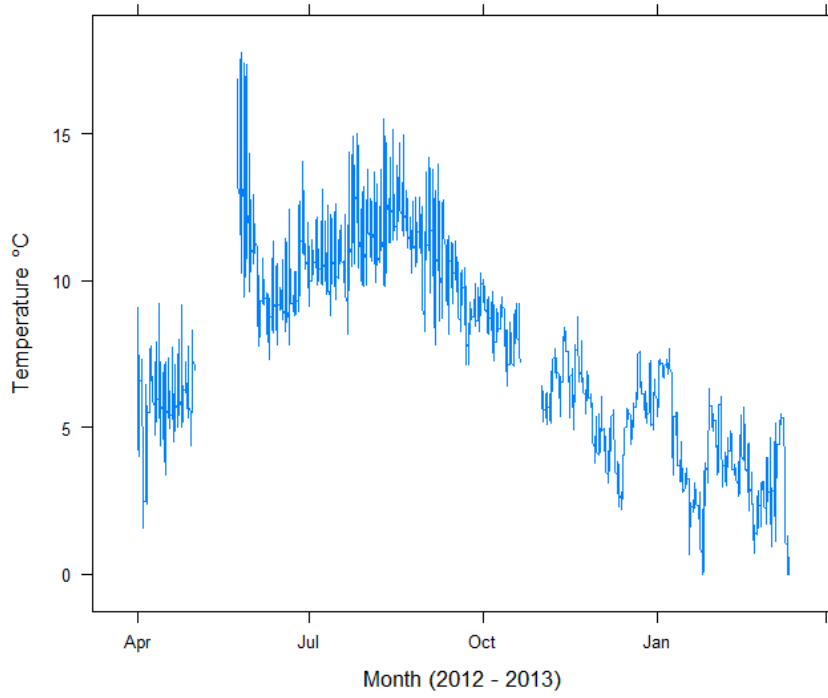
Percentage Species Cover



+ Represents <0.5% abundance

5.10.6 Thermistor data, Afon Hafren





Gaps due to thermistor malfunction

6 Afon Gwy



Figure 4 Afon Gwy biological survey section 18th September 2015

6.1 Summary Overview

Chemical and biological sample collection, analysis and data collation, quality control and archiving proceeded without any problems at Afon Gwy during the period from April 2015 to March 2016.

6.2 Water Chemistry

Samples were collected by CEH early every month throughout the period April 2015 to March 2016, delivered to the analytical laboratories on schedule and are in the process of being analysed, quality controlled and archived in the UKUWMN central chemistry database at CEH Lancaster.

6.3 Thermistors

A thermistor, supplied by Marine Scotland, was downloaded and replaced on 18th of September 2015 by a team from ENSIS Ltd. It had functioned well during the previous year and the data were added to the ENSIS and MS thermistor water temperature database.

6.4 Epilithic Diatoms

Epilithic diatoms were retrieved by a team from ENSIS from three sampling points in the stream on the 8th of July 2015. The samples have been made into slides and await funding for analysis.

6.5 Macroinvertebrates

Aquatic macroinvertebrates were sampled on the 15th April 2015 by a team from QMuL. Five 1 minute kick samples were performed. The samples were counted and the data sent to ENSIS Ltd. The data is in the process of being quality screened before being added to the UKUWMN biological database at ENSIS.

6.6 Fish

Due to resourcing cuts, fish surveying was not performed in Autumn 2015.

6.7 Aquatic Macrophytes

Aquatic macrophytes were surveyed by a team from ENSIS on 18th of September 2015. Percentage cover scores were recorded and data will be added to the ENSIS biological database after microscope confirmation of bryophyte identifications.

6.8 Data Management and Reporting

No problems or hiatus occurred with the collation and transfer of data within methodological programmes, or to the UKUWMN databases, during the reporting period.

The 2014-2015 annual report has been uploaded to the UKUWMN web page. The section on Afon Gwy appears in section 6.10 below.

The UKUWMN website page detailing Afon Gwy can be found here:
http://awmn.defra.gov.uk/sites/site_18.php

Further publications from the contract period utilizing UKUWMN data from Afon Gwy are detailed in section 6.9 below.

6.9 Afon Gwy Recent UKUWMN Output

Oosthoek, S. (2016) Global browning: Why the world's fresh water is getting murkier. *New Scientist* (3055), 34-35. Reed Business Information, London.

Battarbee, R. W. (2015) Forestry, 'acid rain', and the acidification of lakes. In: *Nature's Conscience: the life and legacy of Derek Ratcliffe*, 385-400, Langford Press, Peterborough.

Battarbee, R. W. (2015) Remote lakes: pristine or polluted. UK and Ireland Lakes Network annual conference, Abergavenny. 4th March 2015.

Evans, C. D., Monteith, D. T., Shilland, E. M., Battarbee, R. W., Patrick, S. T. & Malcolm, I. A. (2015) 35 years of upland water quality monitoring in the UK: Foreseen events, unforeseen events, non-events and extreme events. 9th International Conference on Acid Deposition, Rochester, New York. October 19-23, 2015.

Evans, C. D. (2015) UK and international freshwater monitoring. Swedish Agricultural University, Uppsala. 11th May 2015, Invited keynote. Meeting to mark 50 years of freshwater monitoring in Sweden, attended by the King and Crown Princess.

Laize, C. L. R. & Bruna Meredith, C. (2015) Water temperatures for the period 1984 to 2007 at 35 sites on 21 UK rivers. NERC Environmental Information Data Centre.

Monteith, D. T., Battarbee, R. W., Hildrew, A. G., Malcolm, I. A., Shilland, E. M., Evans, C. D. & Kernan, M. (2015) Hindered, stubborn or confused? Explaining the patchiness of biological responses to the declining acidity of surface waters. 9th International Conference on Acid Deposition, Rochester, New York. October 19-23, 2015.

Monteith, D. T., Henrys, P. A., Evans, C. D., Malcolm, I. A., Shilland, E. M. & Pereira, M. G. (2015) Spatial controls on dissolved organic carbon in upland waters inferred from a simple statistical model. *Biogeochemistry* 1-15.

Oulehle, F., Cosby, B. J., Austnes, K., Evans, C. D., Hrušić, J., Koprić, J., Moldan, F. & Wright, R. F. (2015) Modelling inorganic nitrogen in runoff: Seasonal dynamics at four European catchments as simulated by the MAGIC model. *Science of the Total Environment*, **536**, 1019-1028.

Pearce-Higgins, J. W., BREWER, M. J., Elston, D. A., Martay, B., Powney, G. D., Isaac, N. J. B., Monteith, D. T., Henrys, P. A., Vaughan, I. P., Ormerod, S. J., Green, S., Edwards, F. K., Johnston, A., Bell, J. R., Harrington, R., Brereton, T. M., Barlow, K. E., Battarbee, R. W. & Shilland, E. M. (2015) BICCO-Net II. Final report to the Biological Impacts of Climate Change Observation Network (BICCO-Net) Steering Group. 1-69. Defra, London.

Shilland, E. M., Woolway, R. I., Monteith, D. T., Rose, N. L., Yang, H., Malcolm, I. A., Millidine, K. J., Hildrew, A. G., Evans, C. D., Sime, I., Hatton-Ellis, T., Kernan, M.,

Patrick, S. T., Turner, S. D. & Battarbee, R. W. (2015) Tracking the impact of climate change on UK surface waters recovering from acidification. Poster. 9th International Conference on Acid Deposition, Rochester, New York. October 19-23, 2015.

Shilland, E. M., Monteith, D. T., Millidine, K., Malcolm, I. A. & Norris, D. A. (2015) UK Upland Waters Monitoring Network (UKUWMN) - Contract 22 01 249 Llyn Llagi, Llyn Cwm Mynach, Afon Hafren and Afon Gwy Annual Summary Progress Report April 2014 - March 2015. Report to the Welsh Government and Natural Resources Wales. 1-71. ENSIS Ltd, Environmental Change Research Centre, University College London, London.

Winterbottom, J. H. & Orton, S. E. (2015) United Kingdom Acid Waters Monitoring Network Invertebrate Survey. Twenty Seventh Year: 2014. Summary of species identification and abundance. 1-13. School of Biological Sciences, Queen Mary University of London, London.

Battarbee, R. W. (2014) Upland waters in the UK: from acid rain to climate change. Seminar, University of St Andrews, March 26th 2014.

Battarbee, R. W. (2014) SWAP: the aftermath. University of Bergen, April 25th 2014.

Battarbee, R. W. (2014) The UK Upland Waters Monitoring Network: from acid rain to climate change. Scottish Freshwater Group, Stirling, March 27th, 2014.

Battarbee, R. W., Shilland, E. M., Kernan, M., Monteith, D. T. & Curtis, C. J. (2014) Recovery of acidified surface waters from acidification in the United Kingdom after twenty years of chemical and biological monitoring (1988-2008). *Ecological Indicators*, **37, Part B**, 267-273.

Curtis, C. J., Battarbee, R. W., Monteith, D. T. & Shilland, E. M. (2014) The future of upland water ecosystems of the UK in the 21st century: A synthesis. *Ecological Indicators*, **37, Part B**, 412-430.

Curtis, C. J. & Simpson, G. L. (2014) Trends in bulk deposition of acidity in the UK, 1988-2007, assessed using additive models. *Ecological Indicators*, **37, Part B**, 274-286.

Escudero-Onate, C. (2014) International Cooperative Programme on Assessment and Monitoring of Acidification of Rivers and Lakes. Intercomparison 1428:pH, Conductivity, Alkalinity, NO₃-N, Cl, SO₄,Ca, Mg, Na, K, TOC, Al, Fe, Mn, Cd, Pb, Cu, Ni and Zn. 1-88. NIVA, Oslo, Norway.

Fjellheim, A., Johannessen, A. & Svanevik Landes, T. (2014) International Cooperative Programme on Assessment and Monitoring of Acidification of Rivers and Lakes. Biological intercalibration: Invertebrates 1713. ICP Waters Report 118/2014, 1-25. NIVA, Oslo, Norway.

Gray, C., Woodward, G. & Ma, A. (2014) Conserved substructure in a large collection of freshwater food webs as they recover from acidification. Poster. Joint British Ecological Society and Société d'Ecologie Annual Meeting. 11th December 2014, Lille, France.

Helliwell, R. C., Aherne, J., MacDougall, G., Nisbet, T. R., Lawson, D., Cosby, B. J. & Evans, C. D. (2014) Past acidification and recovery of surface waters, soils and ecology in the United Kingdom: Prospects for the future under current deposition and land use protocols. *Ecological Indicators*, **37, Part B**, 381-395.

Malcolm, I. A., Bacon, P. J., Middlemas, S. J., Fryer, R. J., Shilland, E. M. & Collen, P. (2014) Relationships between hydrochemistry and the presence of juvenile brown trout (*Salmo trutta*) in headwater streams recovering from acidification. *Ecological Indicators*, **37, Part B**, 351-364.

Monteith, D. T., Evans, C. D., Henrys, P. A., Simpson, G. L. & Malcolm, I. A. (2014) Trends in the hydrochemistry of acid-sensitive surface waters in the UK 1988-2008. *Ecological Indicators*, **37, Part B**, 287-303.

Monteith, D. T., Shilland, E. M., Battarbee, R. W., Evans, C. D., Hildrew, A. G. & Malcolm, I. A. (2014) Recovery of water chemistry and biology in the UK: latest status and emerging issues. Proceedings of the 26th Meeting of the ICP Waters Task Force in Grimstad, Norway October 8-10 2014.

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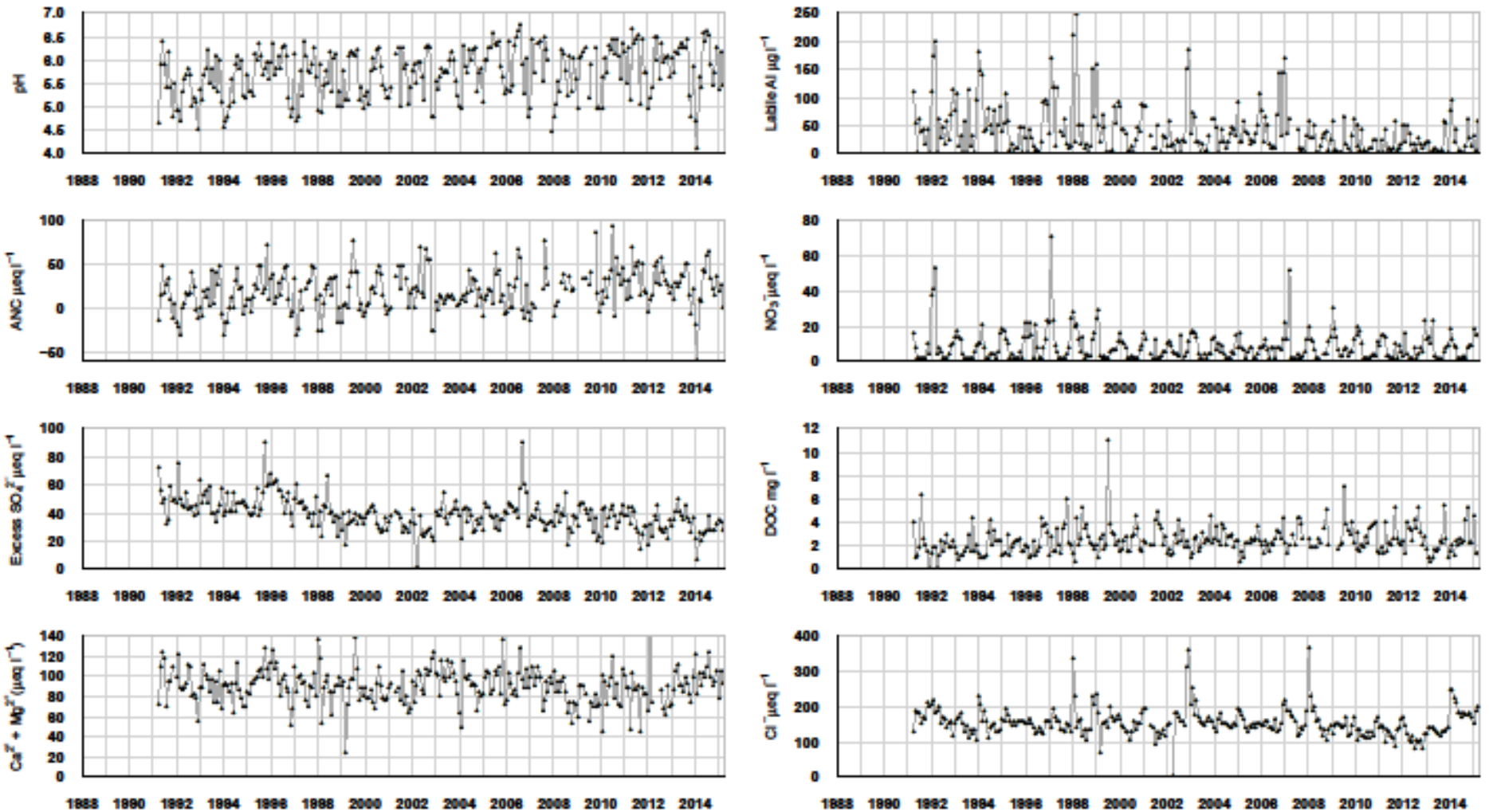
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1/3/160). 1-259. ENSIS Ltd. Environmental Change Research Centre, University College London, London.

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6.10 Afon Gwy Summary Data to March 2015

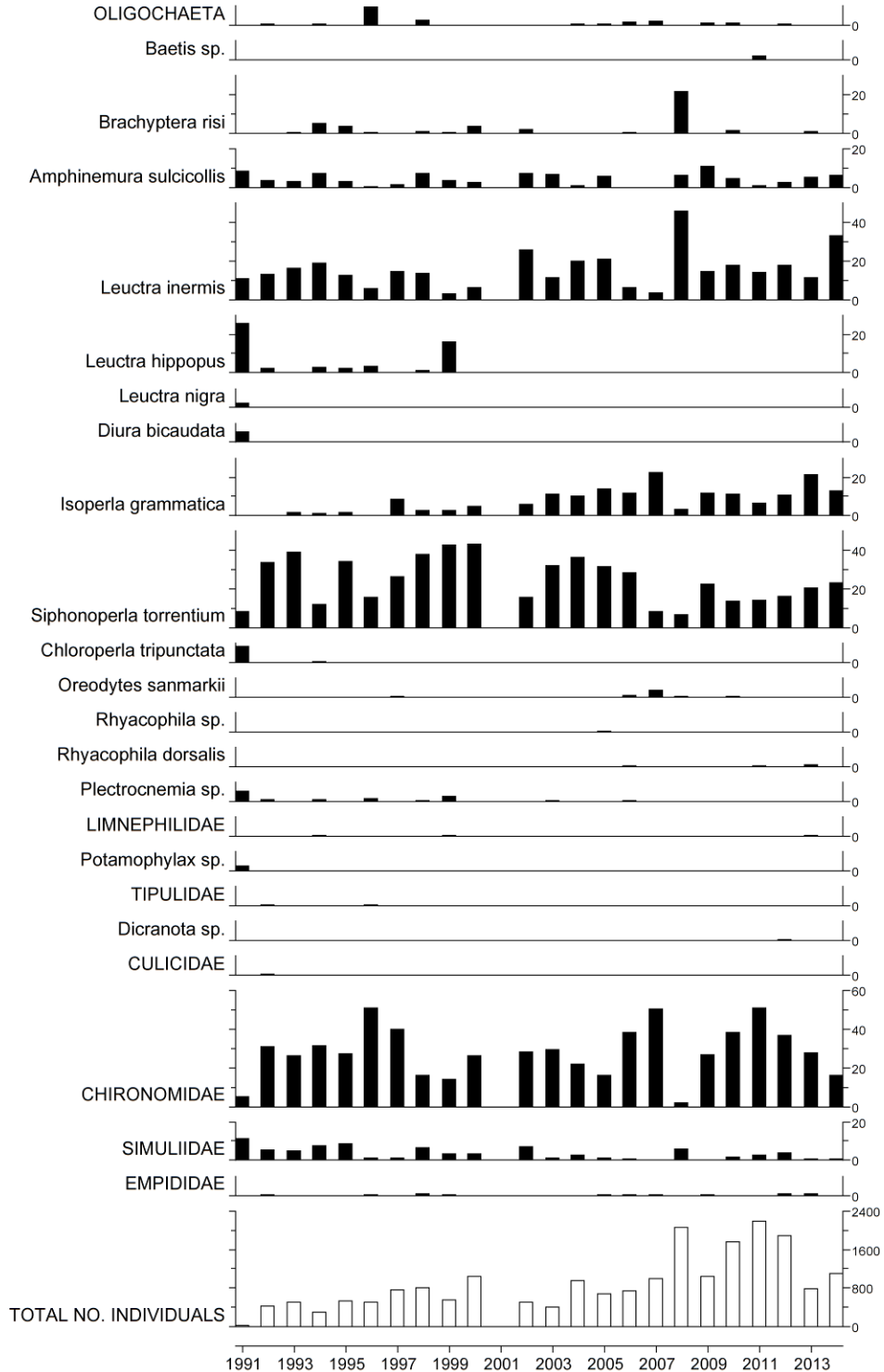
6.10.1 Spot sampled chemistry data



µeq l ⁻¹ , *µg l ⁻¹ , **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
14-15 mean	5.99	31.50	41.15	58.74	162.65	3.06	50.17	21.67	179.91	47.95	29.08	7.62	2.75
14-15 std dev	0.50	19.57	7.66	4.49	11.00	1.41	39.33	22.12	16.24	4.21	4.84	5.87	1.24

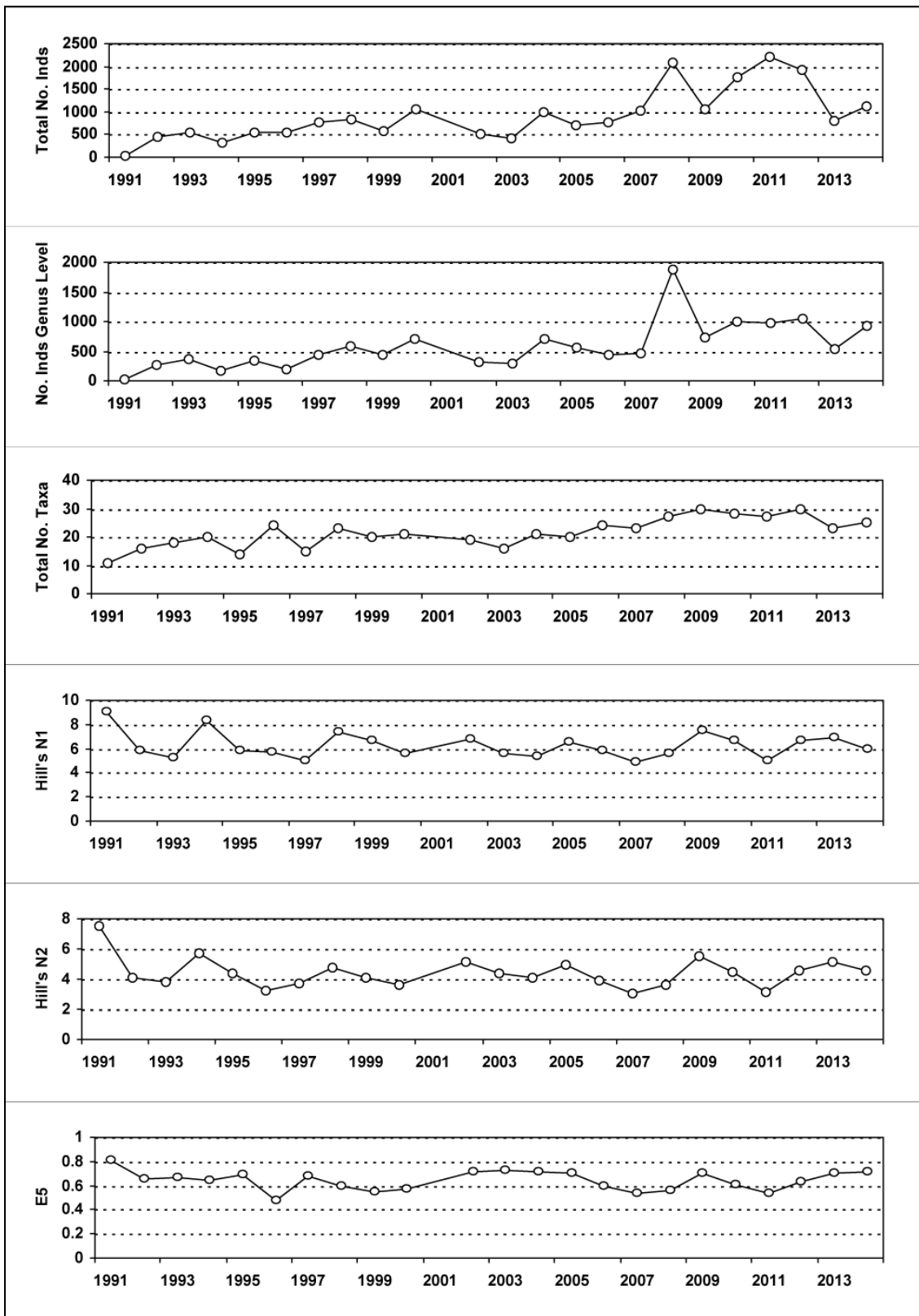
6.10.2 Macroinvertebrate data

6.10.2.1 Percentage abundance summary, Afon Gwy



No sampling in 2001 due to Foot and Mouth restrictions.

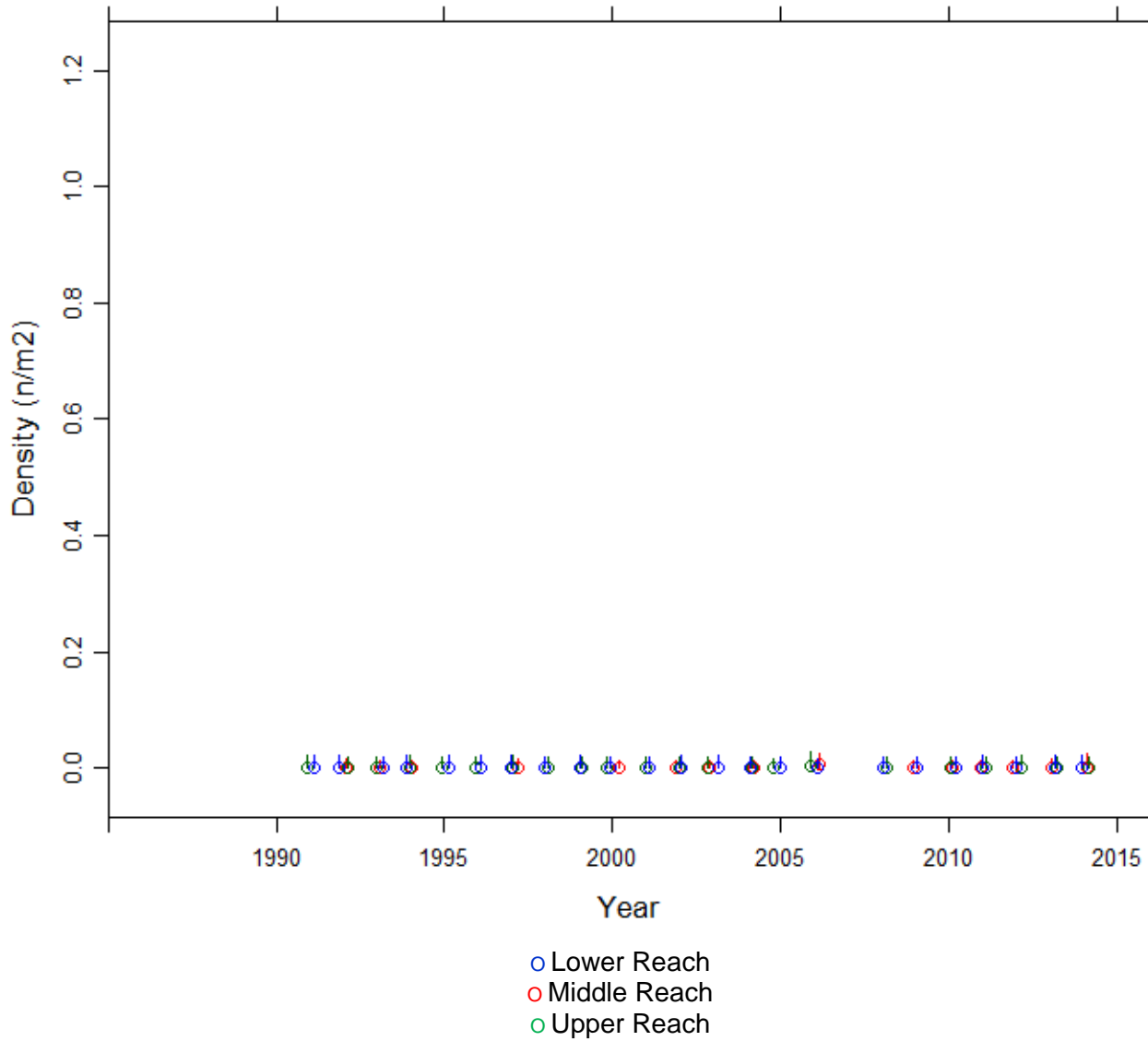
6.10.2.2 Macroinvertebrate summary statistics, Afon Gwy



No sampling in 2001 due to Foot and Mouth restrictions.

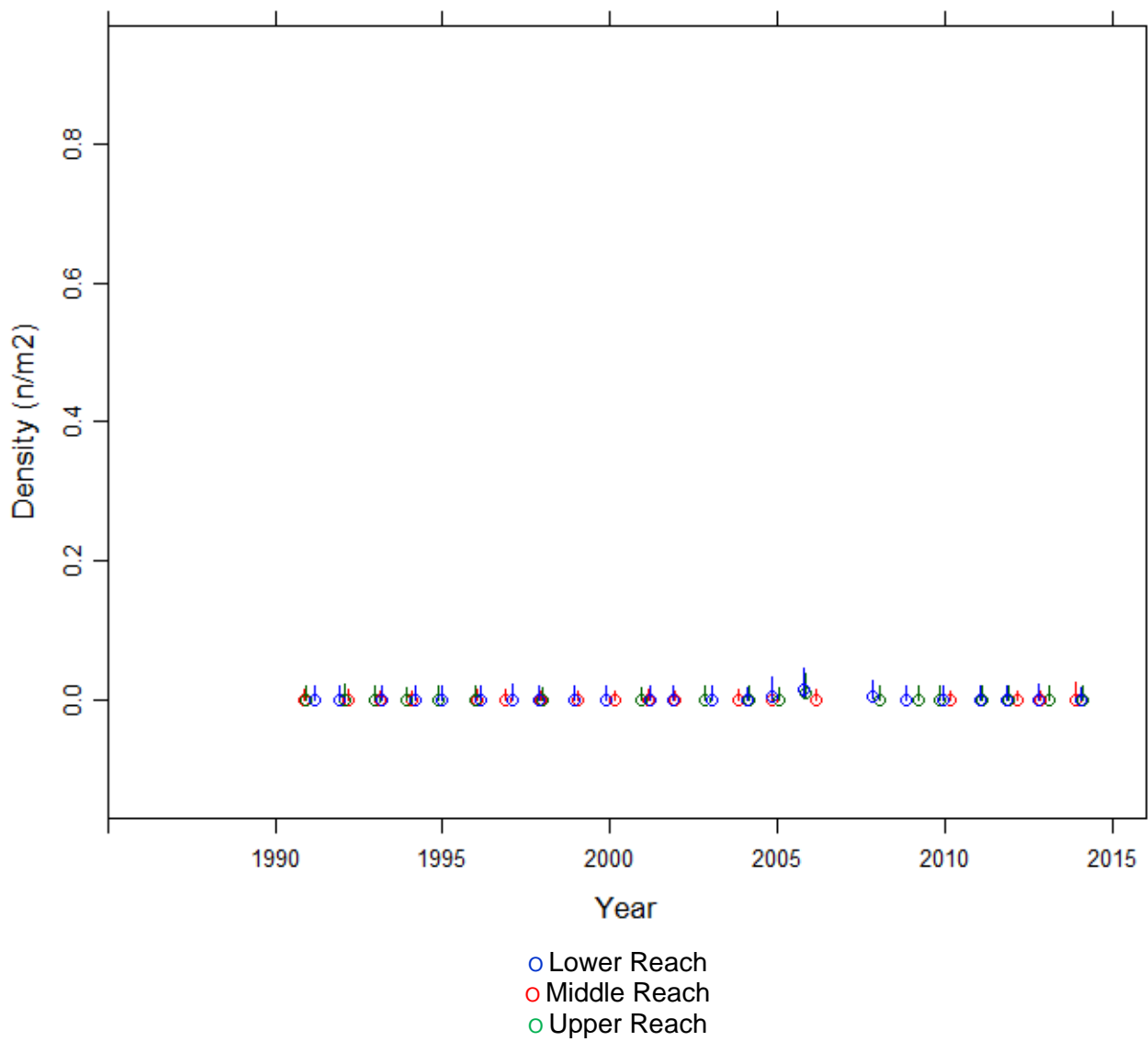
6.10.3 Fish data

6.10.3.1 Summary of Salmon fry densities (numbers m^{-2}), Afon Gwy



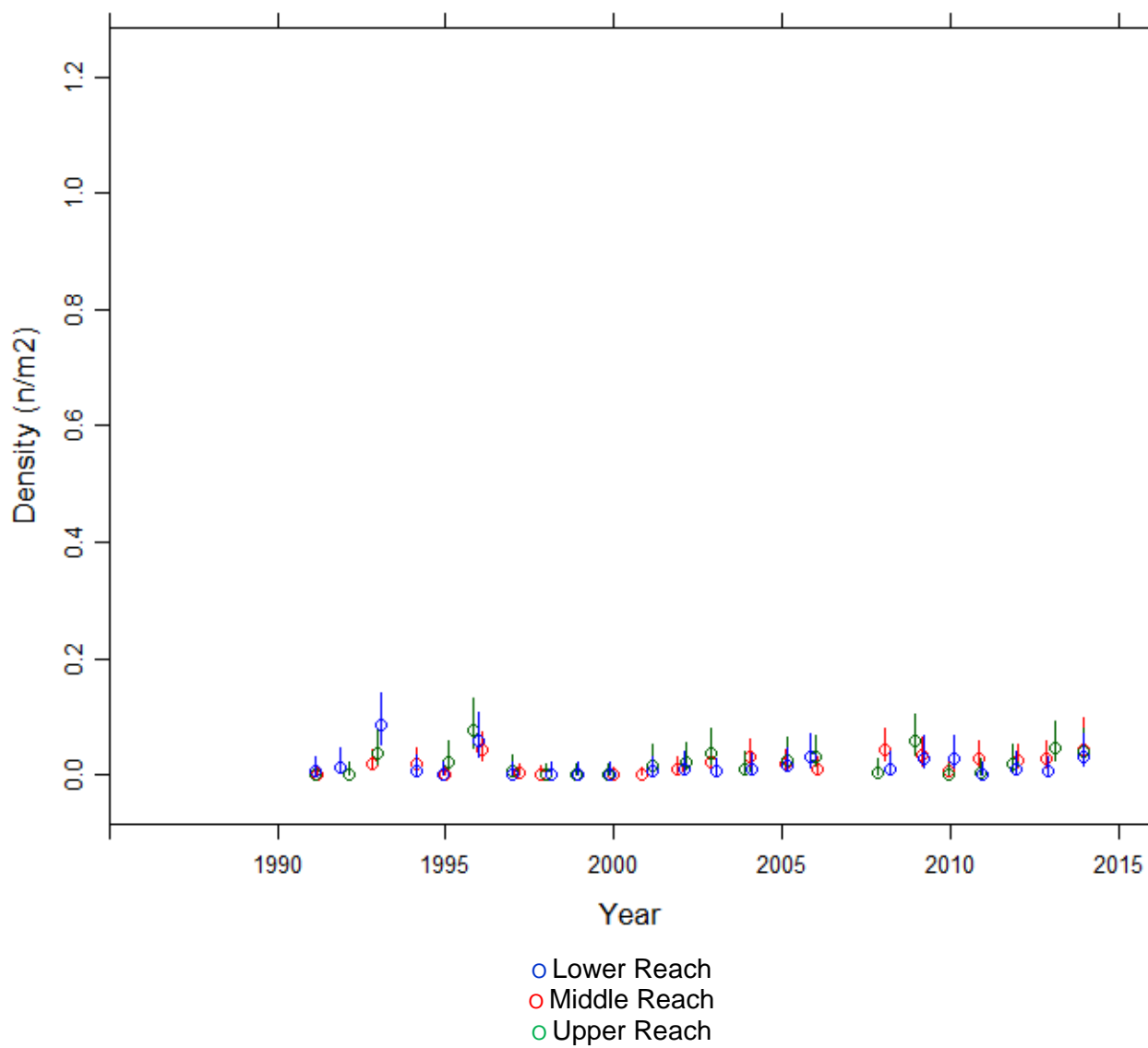
Fishing no longer funded after 2014.

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



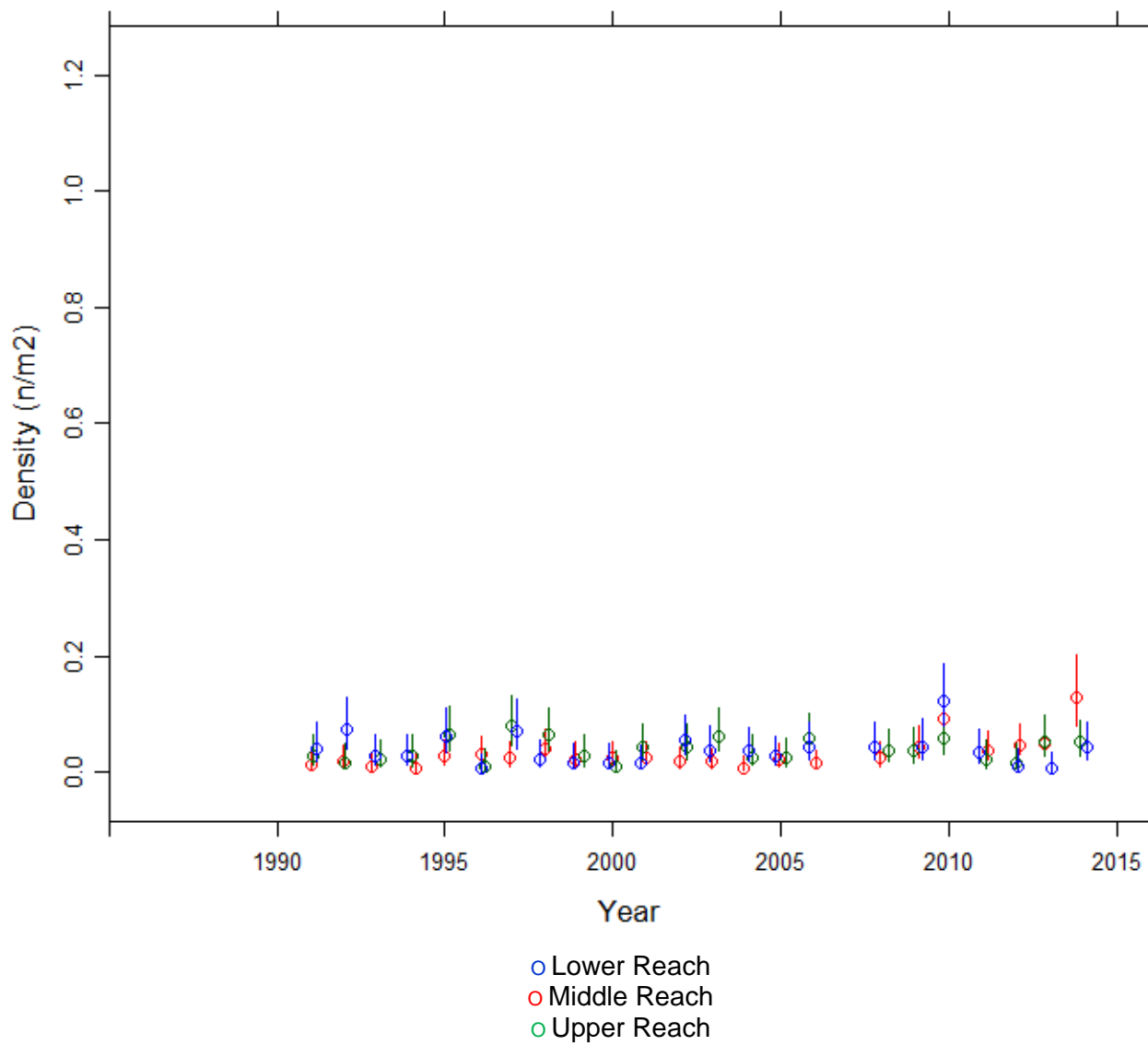
Fishing no longer funded after 2014.

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



Fishing no longer funded after 2014.

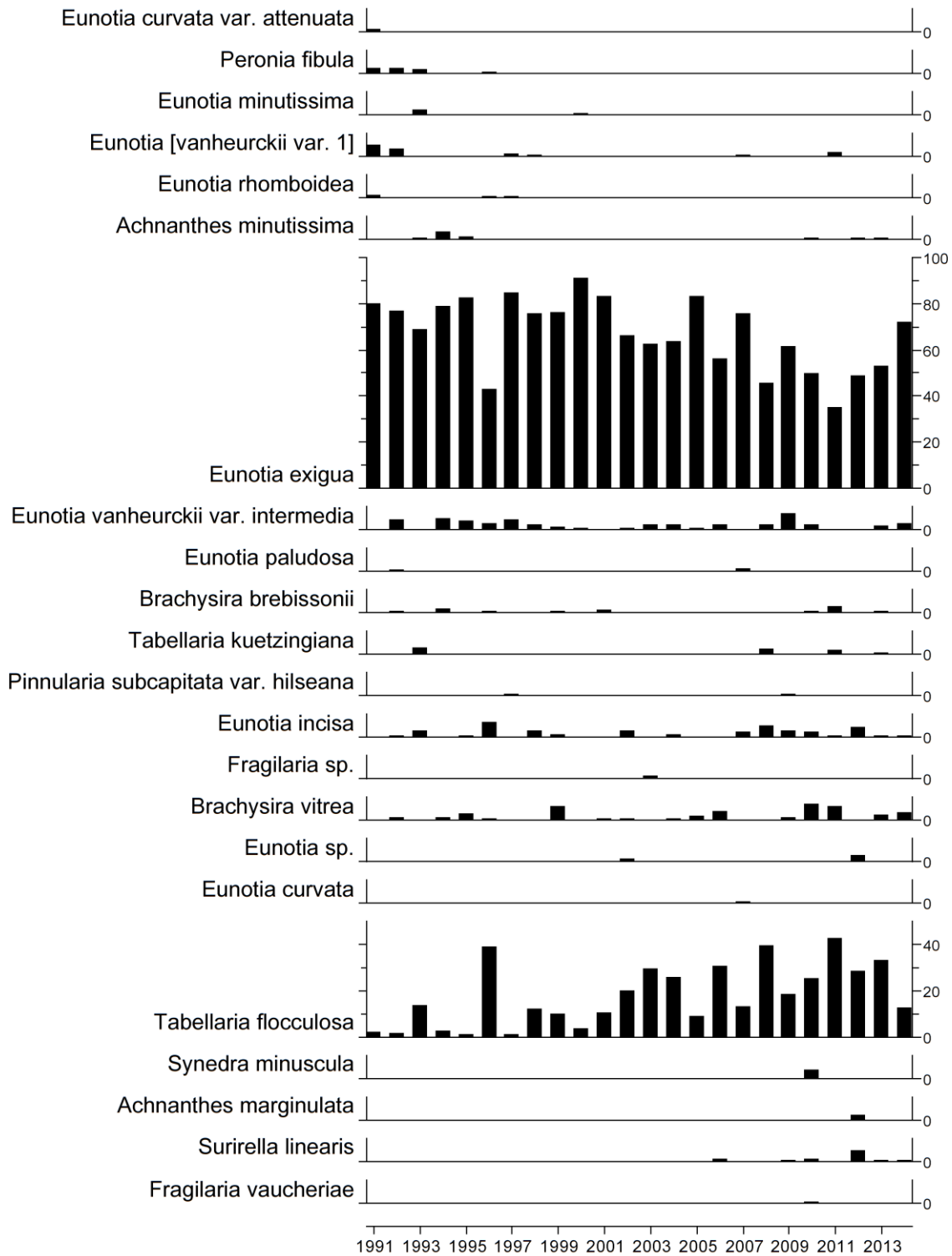
6.10.3.4 Summary of Trout parr density (numbers m⁻²), Afon Gwy



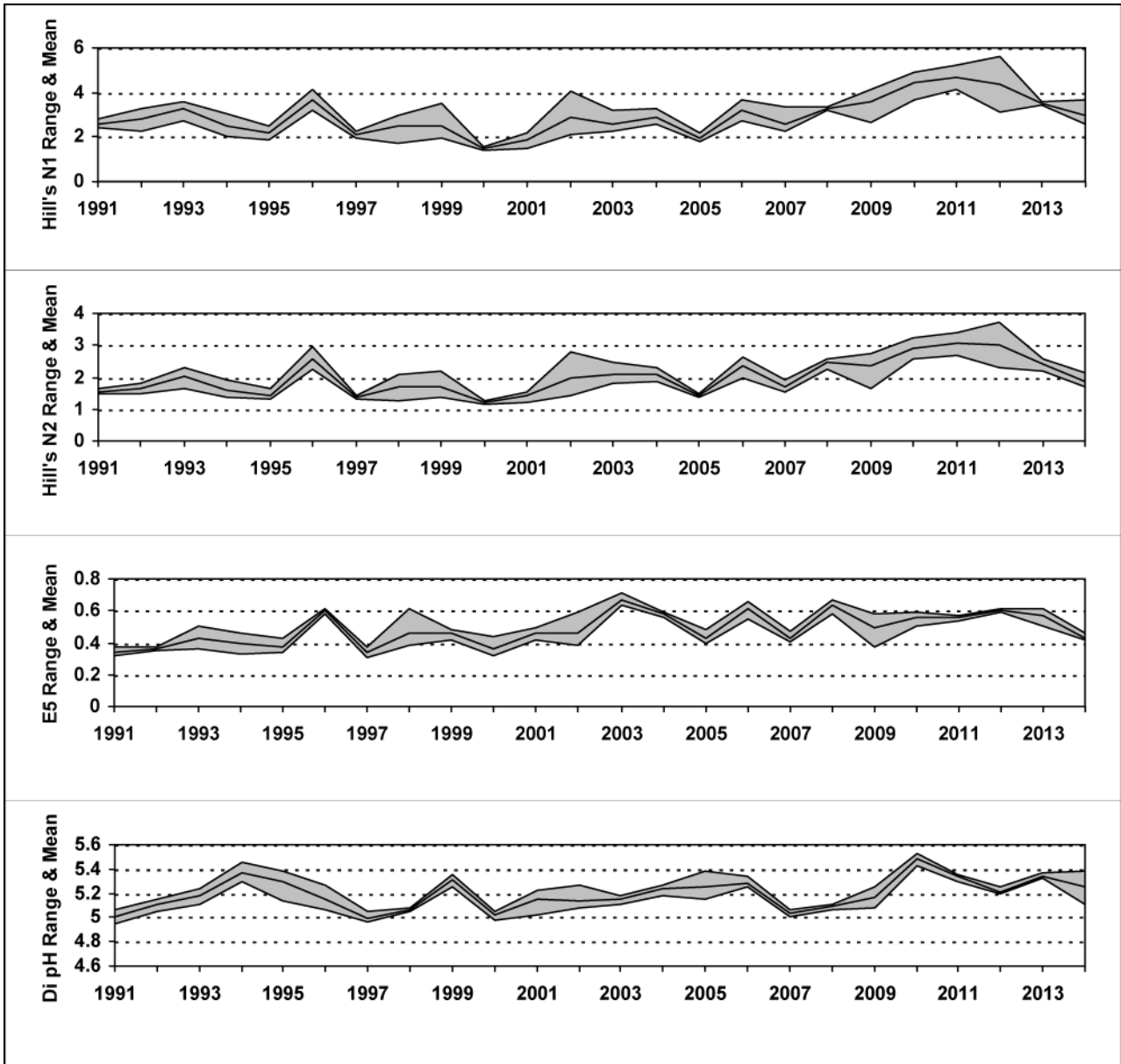
Fishing no longer funded after 2014

6.10.4 Epilithic diatom data

6.10.4.1 Percentage abundance summary, Afon Gwy

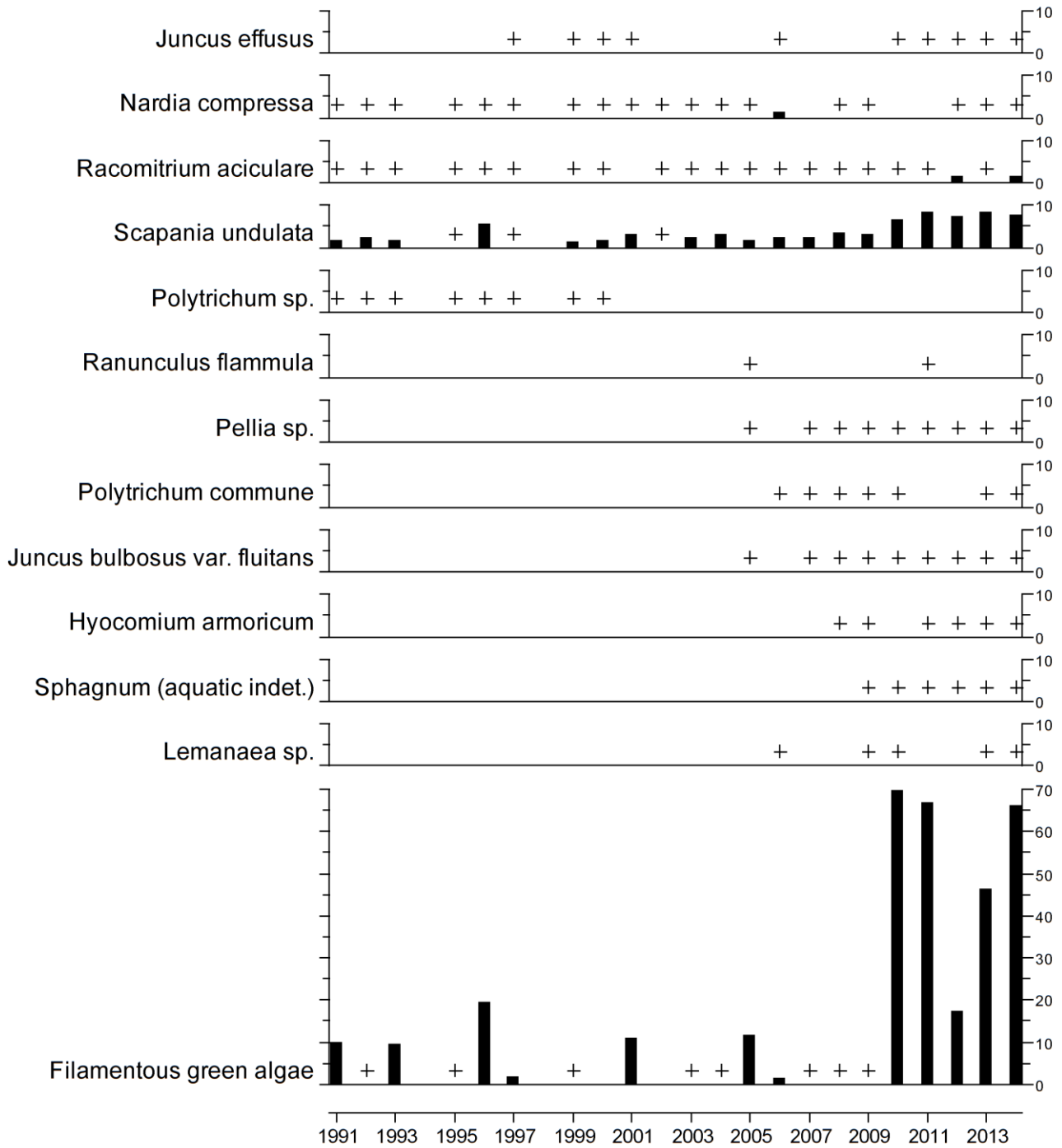


6.10.4.2 Diatom summary statistics, Afon Gwy



6.10.5 Aquatic macrophyte data, Afon Gwy

Percentage Species Cover



+ Represents <0.9% abundance

6.10.6 Thermistor data, Afon Gwy

