UCL ENVIRONMENTAL CHANGE RESEARCH CENTRE

UK Acid Waters Monitoring Network (UKAWMN)

Llyn Llagi

Annual Summary Progress Report to the Countryside Council for Wales April 11 - March 12

E. M. Shilland, L. Irvine, I. A. Malcolm & J. Salgado

2012

UK ACID WATERS MONITORING NETWORK (UKAWMN)

LLYN LLAGI

ANNUAL SUMMARY PROGRESS REPORT TO COUNTRYSIDE COUNCIL FOR WALES. April 2011 - March 2012.

Ewan M. Shilland[1], Lynne Irvine[2] Iain A. Malcolm[3] & J. Salgado[1]

2012

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Cover Photo: Llyn Llagi, 20th July 2011 © Ewan Shilland

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2 INTRODUCTION

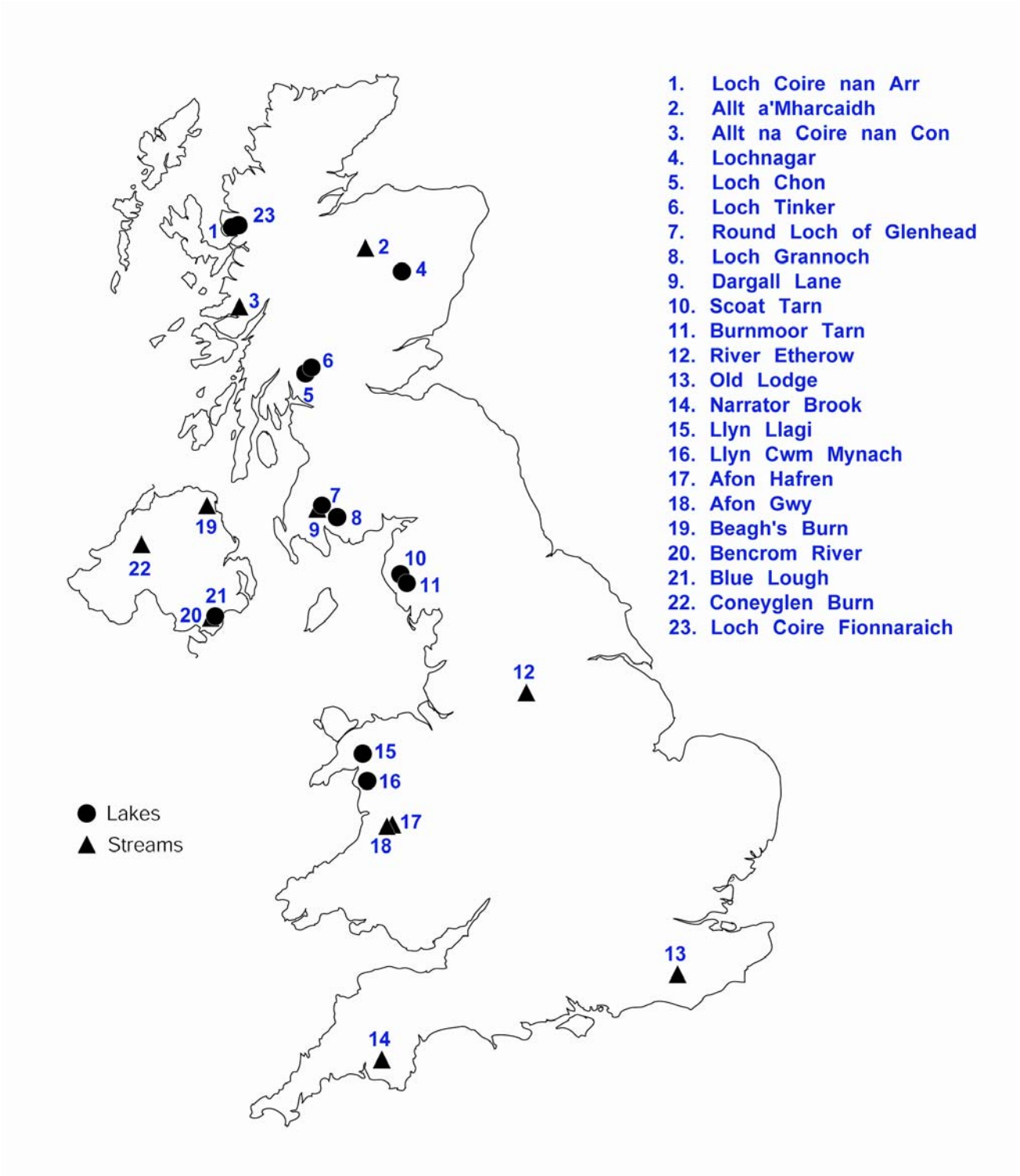
The UK Acid Waters Monitoring Network (UKAWMN) has been operating continuously since 1988. This report presents a summary of work undertaken in the contract year 2011-2012 at Llyn Llagi, partly supported by CCW. The UKAWMN gratefully acknowledges CCW for providing resources that contribute towards the continuation of monitoring at this site. We would also like to thank Marine Scotland, Queen Mary University of London, the NERC Centre for Ecology and Hydrology (CEH) and ENSIS Ltd who all provide support-in-kind for the rest of the UKAWMN programme.

In order to present the CCW funded aspects of the UKAWMN monitoring at Llyn Llagi in context, all sampling performed in 2011-12 is described and time series summary data are presented for the full suite of chemical and biological measurements taken from the start of monitoring up to April 2011.

The 2010-2011 data demonstrate that Llyn Llagi continues to show reductions in both xSO_4 and NO_3 concentration relative to the start of the monitoring period. There was no evidence of additionally acidifying major seasalt events during the reporting period. Lake pH remained higher and labile aluminium concentrations substantially lower than at the onset of study. This has resulted in a major change in diatom species composition through time and can also be linked to major changes in the macroinvertebrate community. Four acid-sensitive aquatic macrophytes, not recorded in early surveys, were found in 2009 and 2011. The brown trout population of the lake outflow provided little indication of acid stress at the outset of monitoring and recent densities show little evidence for any positive response to improving water quality.

Detailed analysis of UKAWMN data has been presented in four interpretative reports, Kernan *et al* (2010), Monteith and Shilland (2007), Monteith (2005) and Monteith and Evans (2000) dealing with 20, 18, 15 and 10 years of accumulated results respectively. All four can be found in the reports section of the UKAWMN web site. A full description of sampling methods and analytical procedures, together with site descriptions, is also presented on the UKAWMN web page.

3 LOCATION OF LLYN LLAGI AND UKAWMN SITES



4 SUMMARY OF WORK UNDERTAKEN 2011-2012

4.1 Summary Overview

During the period from April 2011 to March 2012 physical, chemical and biological sample and data collection, analysis and data collation, quality control and archiving proceeded with few problems at Llyn Llagi. The only exception was the outflow stage board (staff gauge) being washed away during a high flow event. It was successfully replaced.

4.2 Water Chemistry

Samples were collected from the lake in early June, September and December 2011 and March 2012 by staff from CEH Bangor. The June, Sept and Dec samples were delivered to the analytical laboratories at CEH Bangor and CEH Lancaster on schedule and have been analysed and archived in the UKAWMN central chemistry database at CEH Lancaster. Quality control is being performed on the data prior to it being presented in the annual UKAWMN data report and online on the UKAWMN website. The March 2012 samples are in the process of being analysed.

4.3 Sediment Traps

Sediment traps were recovered and replaced on the 20th of July 2011 at Llyn Llagi. Diatoms in the sediment retrieved from the trap are currently being analysed. Sediment trap samples for potential future zooplankton and metals analyses were archived.

4.4 Sediment Trap Thermistors

Sediment trap top and bottom thermistors were removed and replaced on the 20th of July 2011 at Llyn Llagi. Both thermistors had functioned well during the previous year and the data were added to the ENSIS thermistor water temperature database.

4.5 Thermistor Chain

The thermistor chain was downloaded on the 20th of July 2011 and again on the 5th of October 2011 when the batteries in the units were also replaced. All the thermistors had functioned well, and the data were transferred to the ENSIS thermistor water temperature database.

4.6 Automatic Sensors and Stage Boards

The automatic In-Situ Level-TROLL sensors in the lake and outflow were downloaded and the desiccant replaced on the 20th of July 2011. Both had functioned well, and the data were transferred to the ENSIS physical measurements database. Dilution flow

gauging on the outflow was performed on the 20th of July 2011 and again on the 5th of October 2011.

The outflow stage board (staff gauge) was washed away during high flow in early September 2011. A new stage board was purchased and then subsequently installed on the 5th of October 2011.

4.7 Epilithic Diatoms

Epilithic diatoms were retrieved from three sampling points around Llyn Llagi on the 20th of July 2011. All the samples were made into slides and have been analysed by Dr H. Yang. The data are being quality screened and will be added to the UKAWMN biological database at ENSIS.

4.8 Macroinvertebrates

Aquatic macroinvertebrates were sampled at Llyn Llagi by QMuL on the 20th April 2011. Five 1 minute kick samples were performed at the site and the samples were counted at QMuL. The data have been sent to ENSIS Ltd and are being quality screened before being added to the UKAWMN biological database.

4.9 Fish

Fish surveying was performed at Llyn Llagi on the 17th of August 2011 by the Game and Wildlife Conservation Trust. The data has been sent to ENSIS Ltd and is in the process of being quality controlled.

4.10 Aquatic Macrophytes

Aquatic macrophytes were surveyed at Llyn Llagi on the 5th of October 2011. Voucher specimens have been sent for expert verification and on their return the data will be quality controlled and added to the UKAWMN biological database.

4.11 Chironomid Exuviae

Chironomid exuviae were collected using standard techniques from Llyn Llagi on 20th of July 2011 and have been archived at ENSIS Ltd pending future funding for analysis.

4.12 Zooplankton

Two bottom to top hauls of zooplankton were collected from the centre of the lake using a 100 micron net on 20th of July 2011, and alongside the zooplankton sample from the sediment trap have been archived at ENSIS Ltd pending future funding for analysis.

4.13 Data Management and Reporting

No problems or hiatus with the collation and transfer of data within methodological programmes, or to the UKAWMN databases, occurred during the reporting period. UKAWMN data from Llyn Llagi were sent to the Environmental Change Network (ECN) and the UNECE International Cooperative Programme on Assessment and Monitoring Effects of Air Pollution on Rivers and Lakes (ICP Waters).

The 2010-2011 annual report (Shilland *et al*. 2012) has been uploaded to the AWMN web site and the summary data for Llyn Llagi appear in section 7 below.

4.14 Publications

Papers, reports, magazine articles and conference proceedings that include Llyn Llagi and have used UKAWMN data are listed below. The time period reported here spans 2010-2012.

Shilland, E. M., Irvine, L., Malcolm, I. A., Marazzi, L., Panizzo, V. N. & Salgado, J. (2012) The United Kingdom Acid Waters Monitoring Network Data Report for 2010-2011 (year 23). Report to the Department for Environment, Food and Rural Affairs (Contract EPG 1/3/160). 1-239. ENSIS Ltd. Environmental Change Research Centre, University College London, London.

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Tipping, E. & Carter, H. T. (2011) Aluminium speciation in streams and lakes of the UK Acid Waters Monitoring Network, modelled with WHAM. *Science of the Total Environment*, **409**, 1550-1558.

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5 DATA FORMAT

The chemical and biological data are presented in a series of sections, summarised below, on a site-by-site basis.

Section 1:	Time series graphs of key spot sampled chemical determinands for individual samples. Summary table for key chemical determinands including: the mean over the 1988-1993 baseline period; the mean for the current year (2010-2011) and the standard deviation for the current year. The normal number of observations per year is 4 for lakes.
Section 2:	Macroinvertebrates. Time series of macroinvertebrate taxon % abundance in annual aggregated samples (5 kick samples from lake littoral habitats), and annual total number of individual animals. Some species occurring at less than 1% relative abundance are omitted. Macroinvertebrate summary statistic time series: 1) total number of individuals; 2) number of individuals identified at Genus level only (excludes some ubiquitous groups such as the chironomids and oligochaetes); 3) total number of taxa; 4) Diversity Indices: a) Hill's N_1, the exponent of Shannon's Index and a measure of the number of abundant species in a sample (Hill, 1973). b) Hill's N_2, the reciprocal of Simpson's Index and a measure of the number of very abundant species in a sample (Hill, 1973). c) E_5, a measure of evenness based on the ratio $(N_2-1):(N_1-1)$. As a single species becomes more and more dominant, E_5 tends to zero.
Section 3:	Salmonids. Summary histogram of mean density of trout and salmon, if present, in three 50m reaches (number of individuals caught per m^2 survey area) for each year of the monitoring period. (0+ = new recruits, "fry", >0+ = all fish over one year of age, "parr").
Section 4:	Epilithic diatoms. Time series of annual mean percentage frequency (from 3-4 replicate samples) of taxa occurring at greater than 2 % abundance in any one sample. Epilithic diatom summary statistic time series. Mean, maximum and minimum for: a) Hill's N_1 (see above) b) Hill's N_2 (see above) c) E_5 (see above) d) Diatom inferred pH (Di pH), reconstructed from the diatom data using C2 (Juggins, 2007) running the Weighted Averaging Partial Least Squares method and using pH training set data from the SWAP project (Stevenson *et al*. 1991). Bootstrapping was performed to choose the best Component to use for the reconstruction. Component 2 improved the model prediction by over 5% and was therefore chosen, and is shown here alongside the diatom percentage abundance stratigraphy.

	pH reconstructions are intended only for application to sedimentary diatoms but directional trends in inferred pH of epilithic assemblages should provide an indication of the direction of a response to changing acidity.
Section 5:	Aquatic macrophytes. For lakes relative species abundance determined on a five point scale (comparable to the DAFOR scoring system, Palmer *et al*. 1992) following shoreline survey, shore transects and deep water grapnel trawls, as follows: 1. rare/infrequent 2. occasional but not abundant 3. widespread but not abundant 4. locally abundant 5. widespread and abundant
Section 6:	Histogram of diatom species composition from annually retrieved sediment traps. Species occurring at less than 1% abundance in all years are omitted.
Section 7:	Time series graphs of annual data from thermistors attached to the sediment traps. Thermistor pairs are used, one 1.5m from the lake bottom and the other 1m from the water surface.
Section 8:	Time series depth-temperature contour plot of data from a thermistor chain suspended near the deepest part of the site. Thermistors are located at 50 cm intervals to 2m water depth and at 1m intervals thereafter.
Section 9:	Time series graphs of annual data recorded by In-Situ logger devices. One device is situated in the lake and records water temperature and stage height. Another device is positioned in the lake outflow and records temperature, stage height and conductivity.

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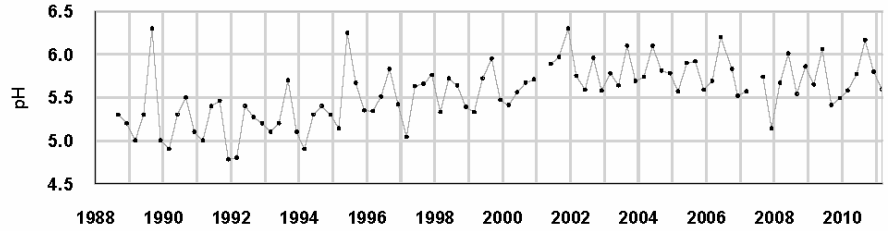
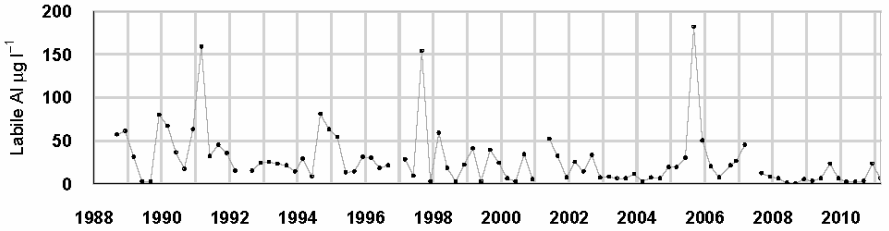
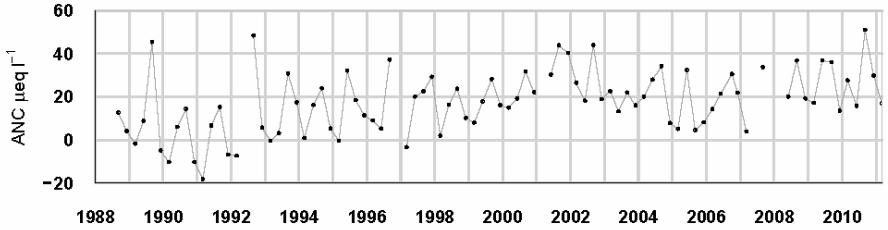
7 SITE DATA

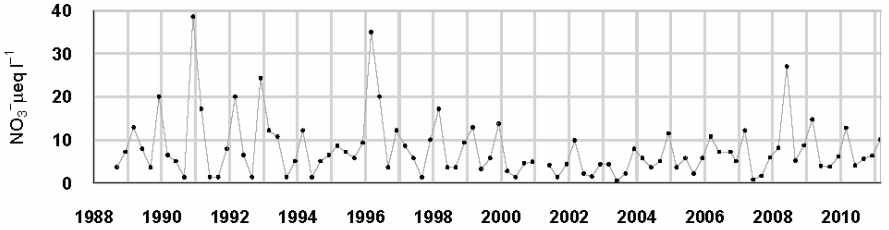
7.1 Llyn Llagi

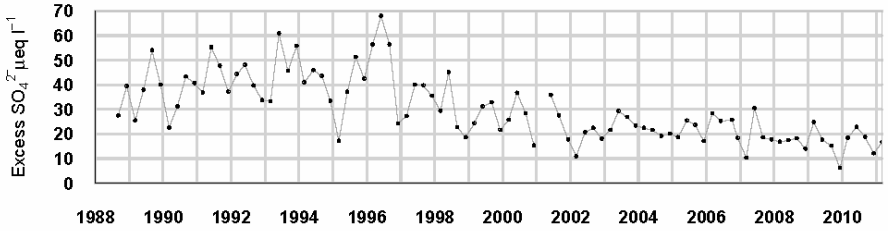
7.1.1 Spot sampled chemistry data

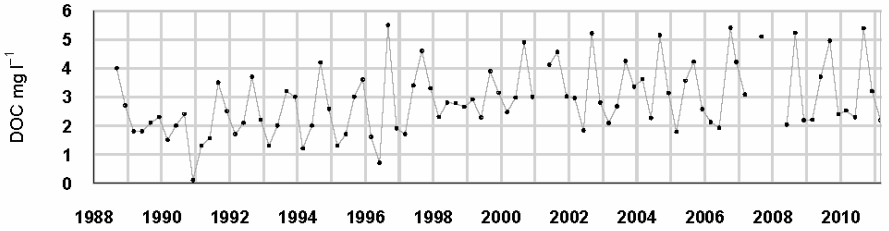


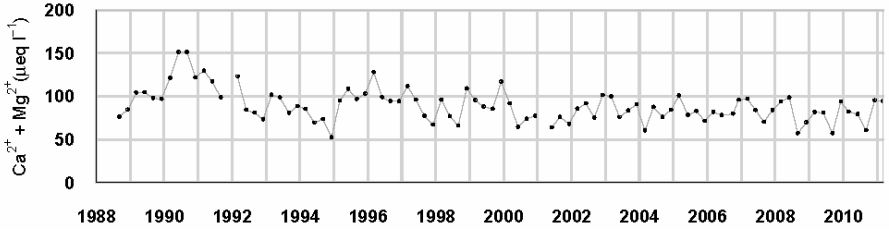


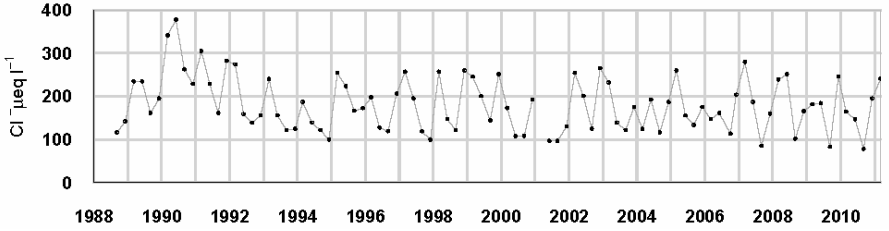








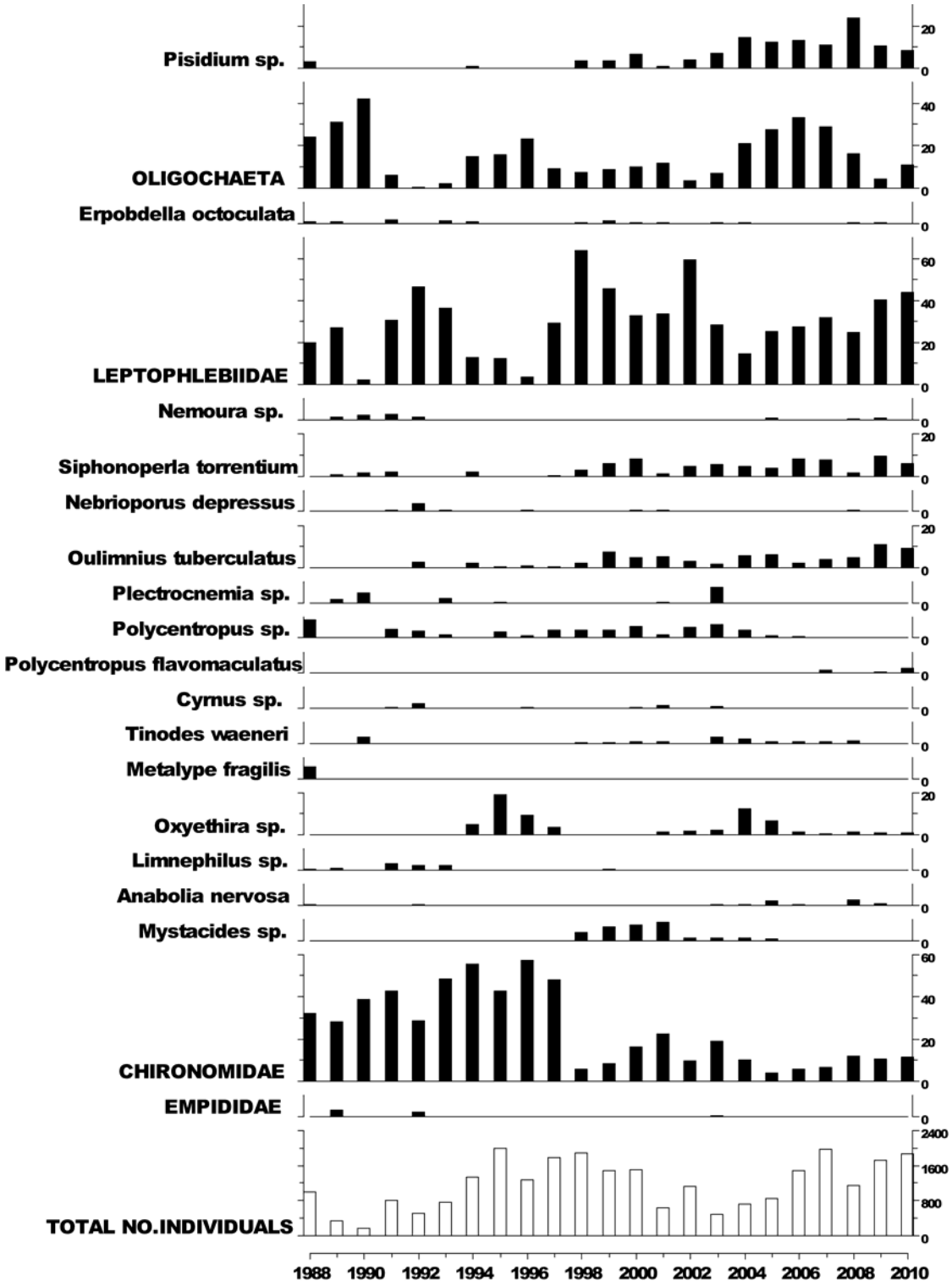




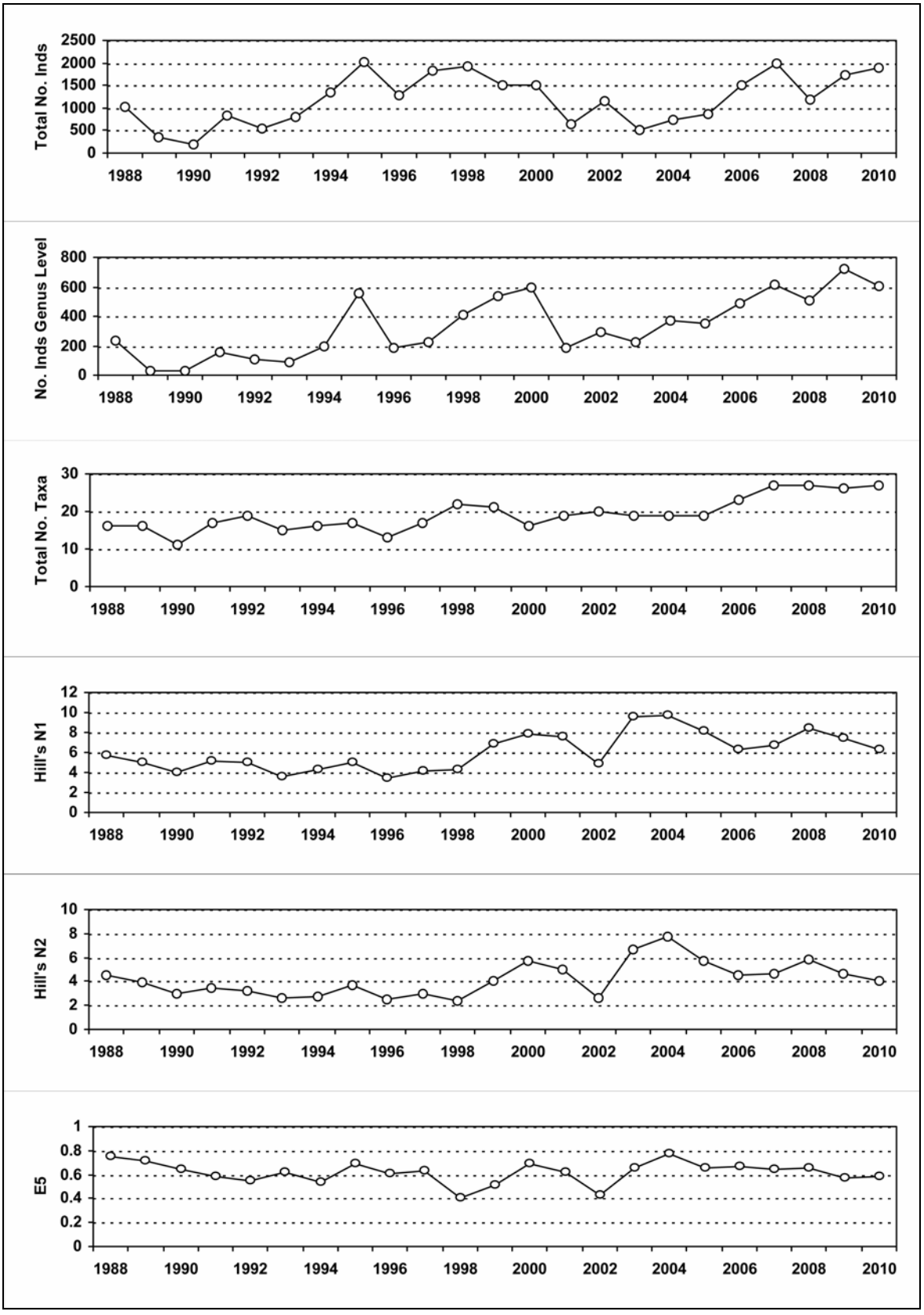
µeq l $^{-1}$, *µg l $^{-1}$, **mg l $^{-1}$	pH	ANC	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	*Soluble Al	*Labile Al	Cl^{-}	$*SO_4^{2-}$	xSO_4^{2-}	NO_3^{-}	**DOC
Mean 1st 5 yrs	5.23	5.71	56.70	49.69	185.75	3.54	75.37	41.61	219.33	62.91	39.91	10.44	2.13
10-11 mean	5.83	28.32	43.28	39.01	144.64	4.44	28.00	8.50	164.68	34.84	17.56	6.48	3.27
10-11 std dev	0.24	16.40	6.34	10.45	45.39	1.02	11.22	9.81	69.87	6.56	4.46	2.58	1.49

7.1.2 Macroinvertebrate data

7.1.2.1 Percentage abundance summary, Llyn Llagi

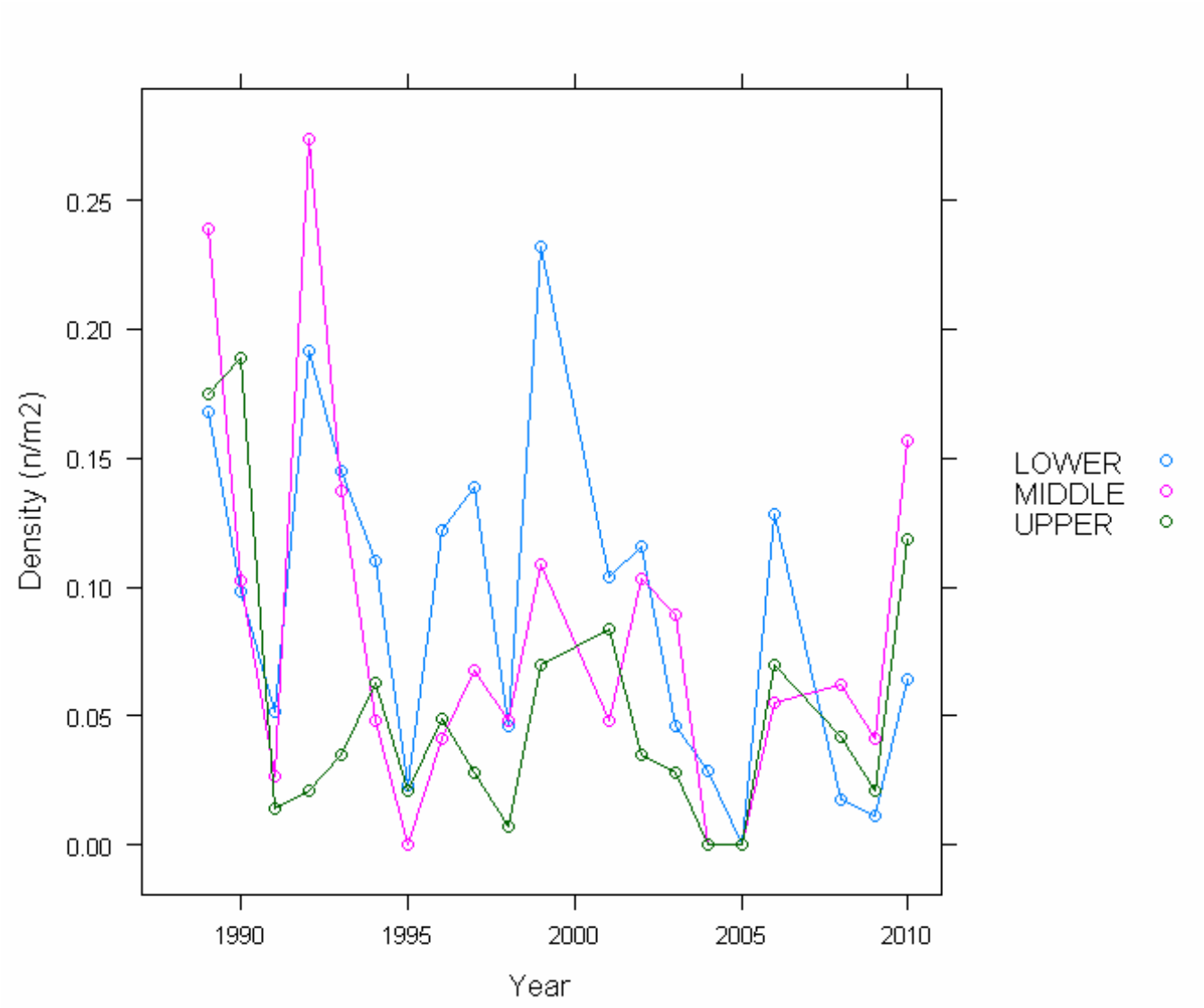


7.1.2.2 Summary statistics, Llyn Llagi



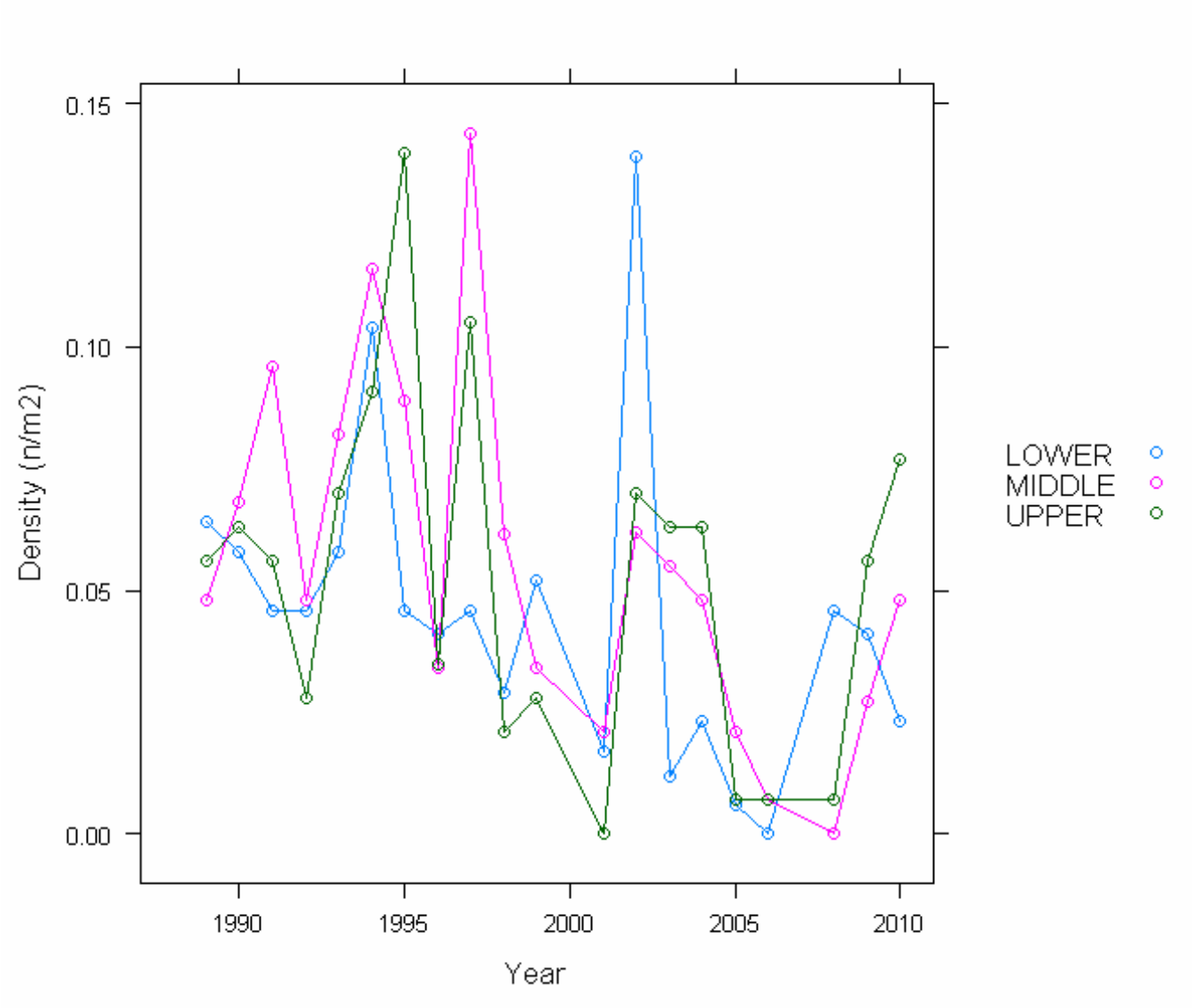
7.1.3 Fish data

7.1.3.1 Summary of Trout fry densities (numbers m^{-2}), Llyn Llagi



Blue series = Reach 1
Pink series = Reach 2
Green series = Reach 3

7.1.3.2 Summary of Trout parr densities (numbers m^{-2}), Llyn Llagi



Blue series = Reach 1
Pink series = Reach 2
Green series = Reach 3

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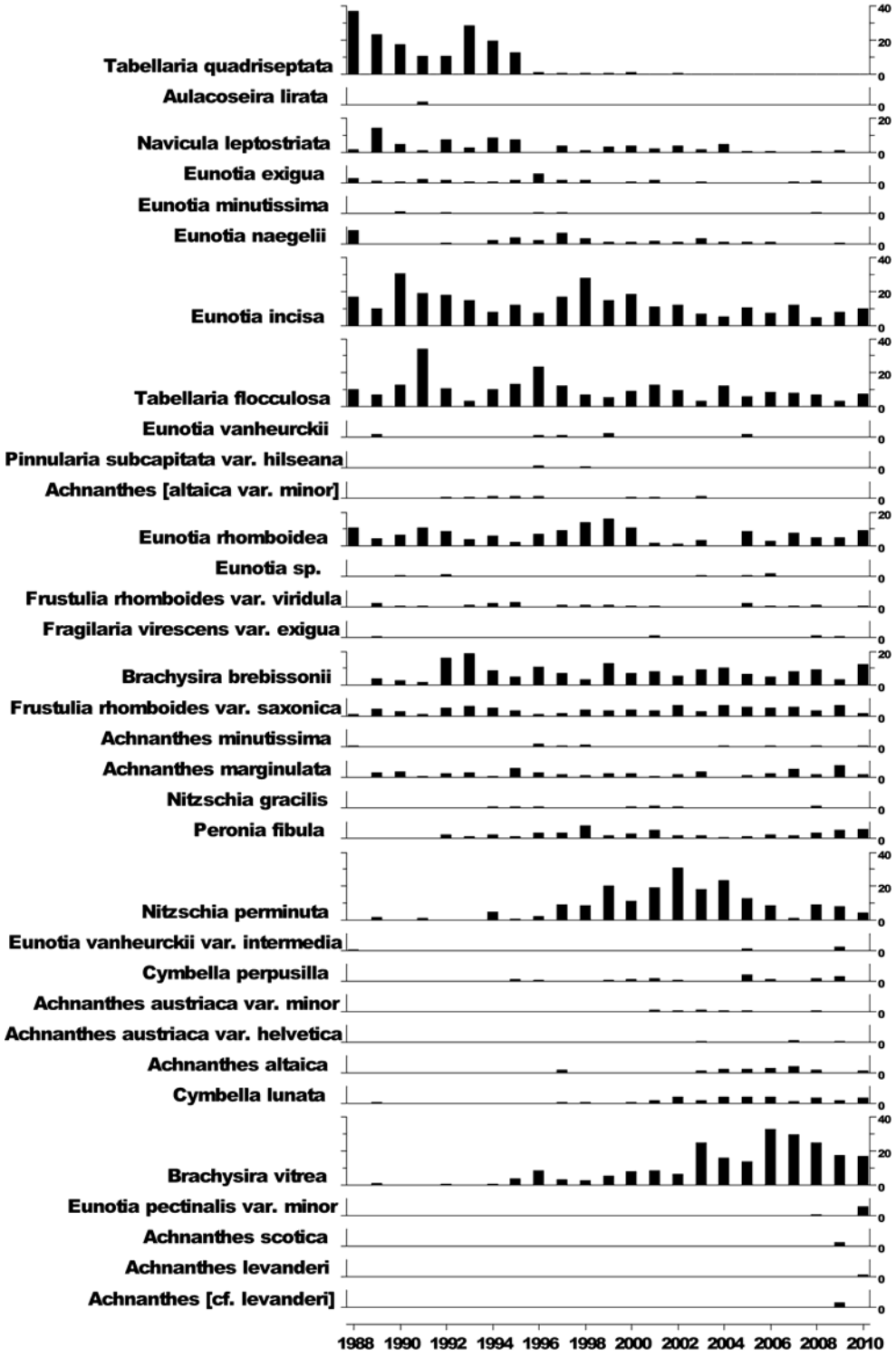
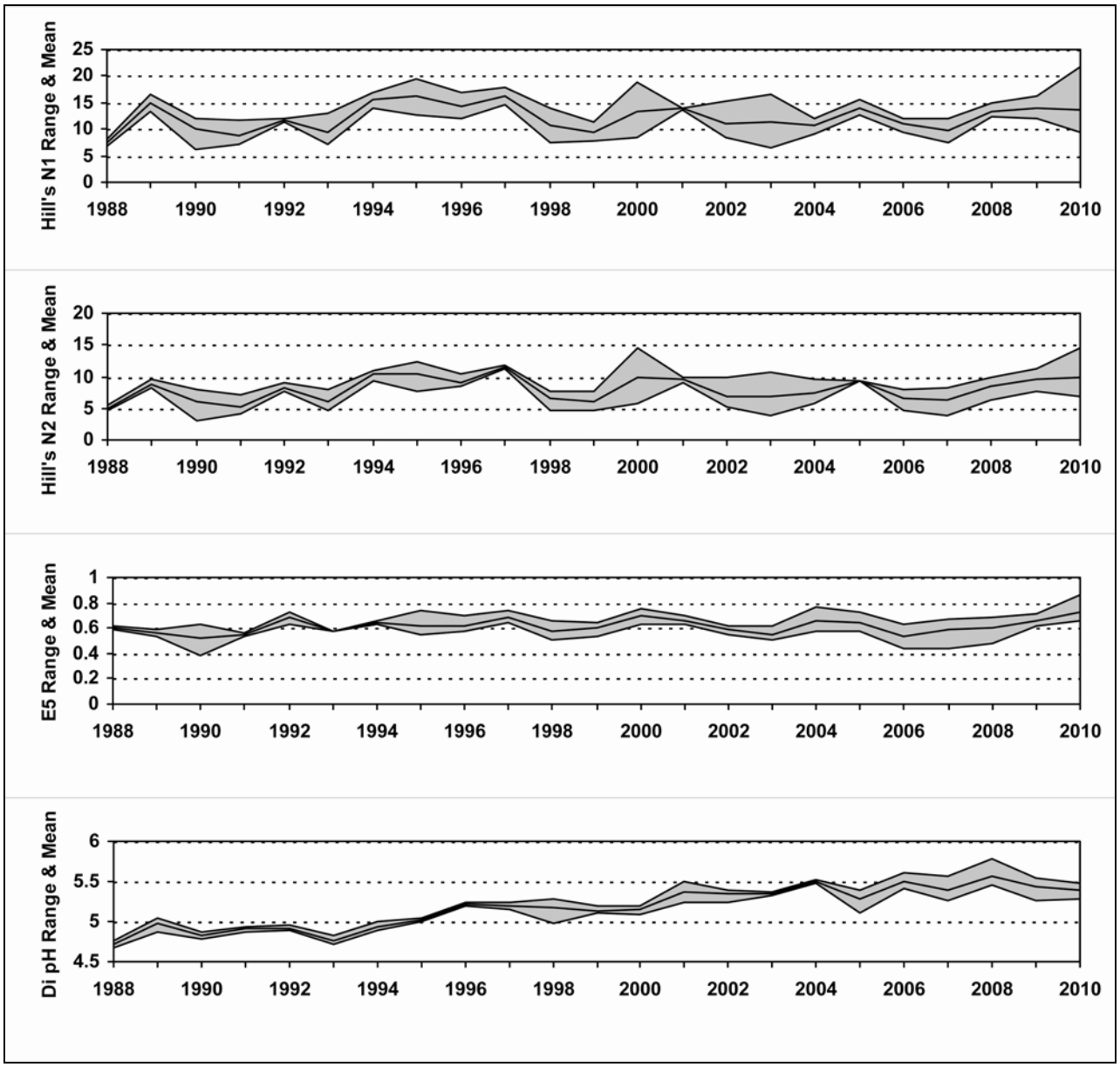
7.1.4 Epilithic diatom data

7.1.4.1 Percentage abundance summary, Llyn Llagi



7.1.4.2 Summary statistics, Llyn Llagi



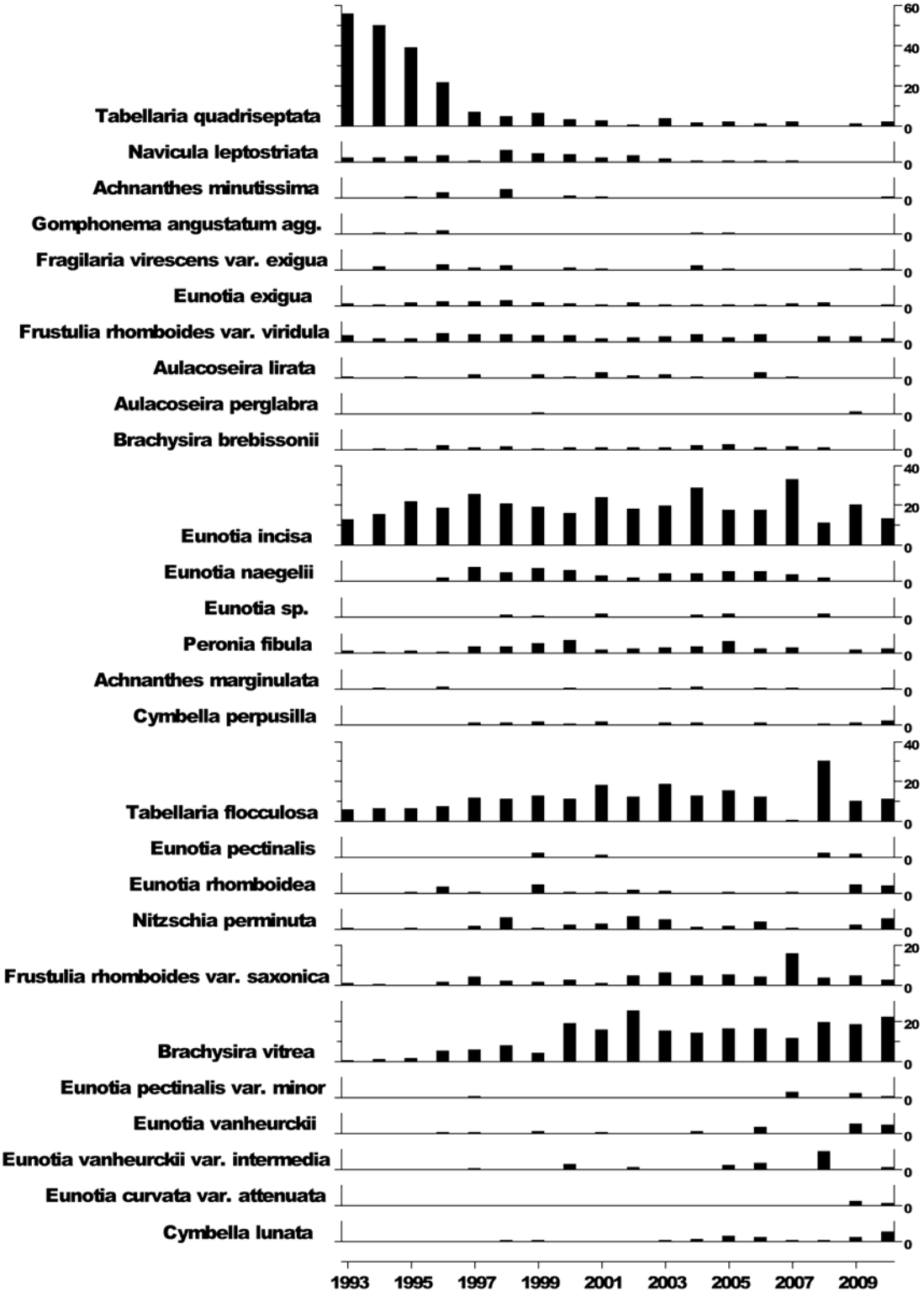
7.1.5 Aquatic macrophyte data, Llyn Llagi

Percentage Species Cover

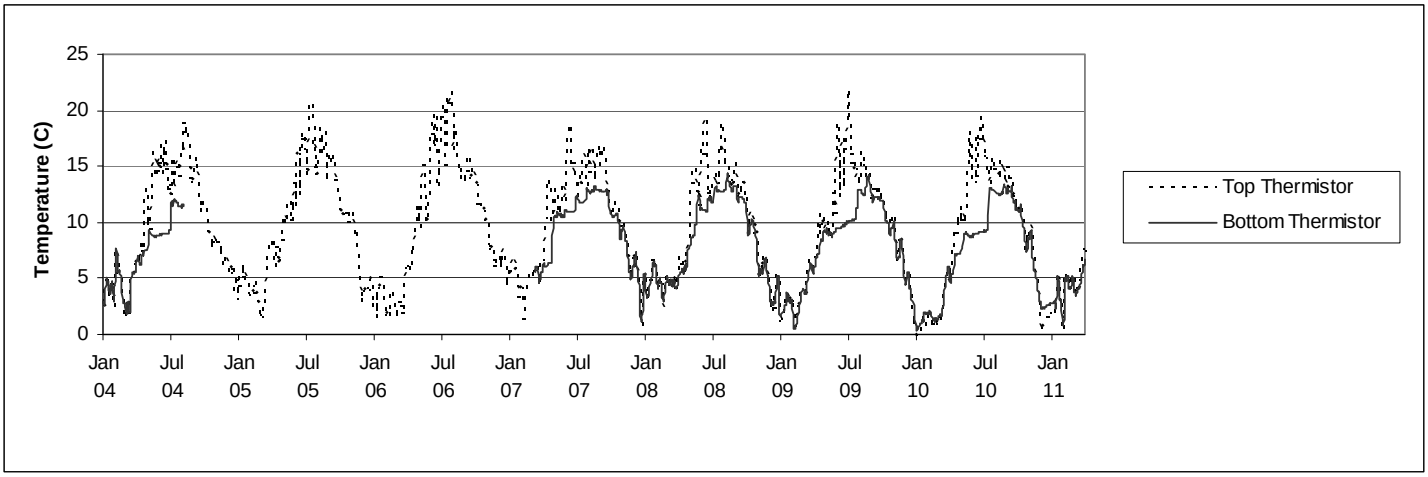
No survey in 2007 due to funding cuts

7.1.6 Sediment trap data, Llyn Llagi

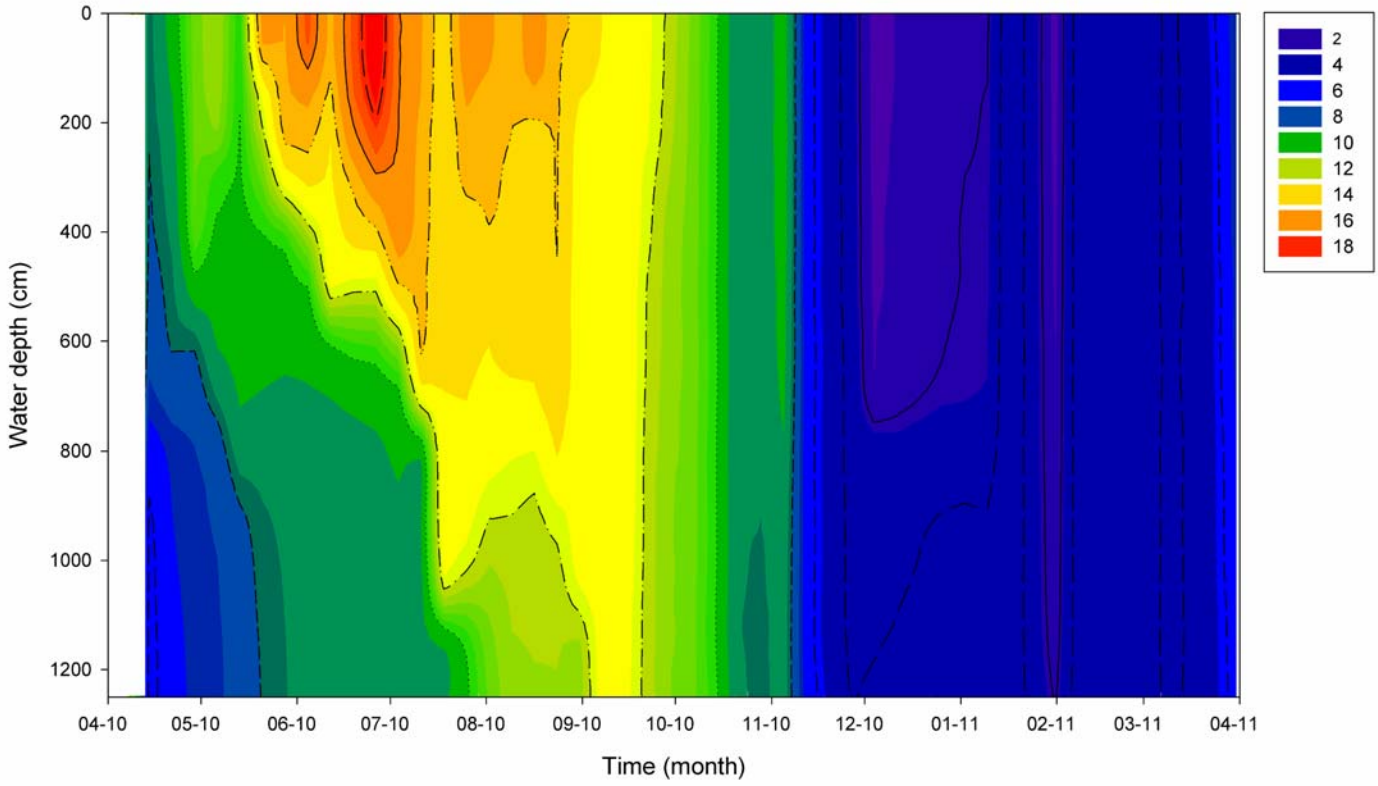
Relative percentage frequency of diatom taxa



7.1.7 Sediment trap thermistor data, Llyn Llagi



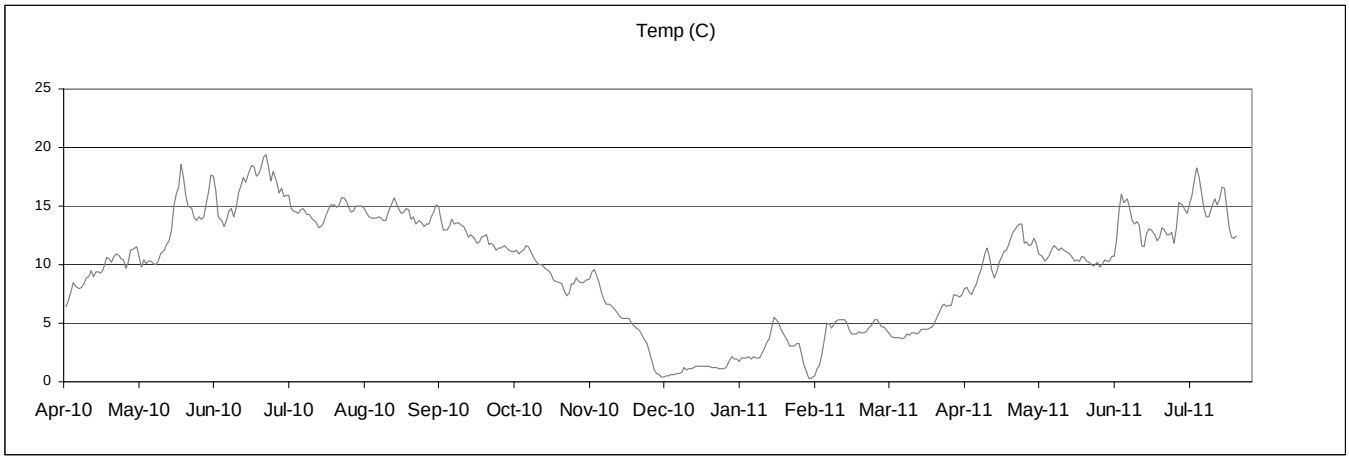
7.1.8 Thermistor chain data, Llyn Llagi

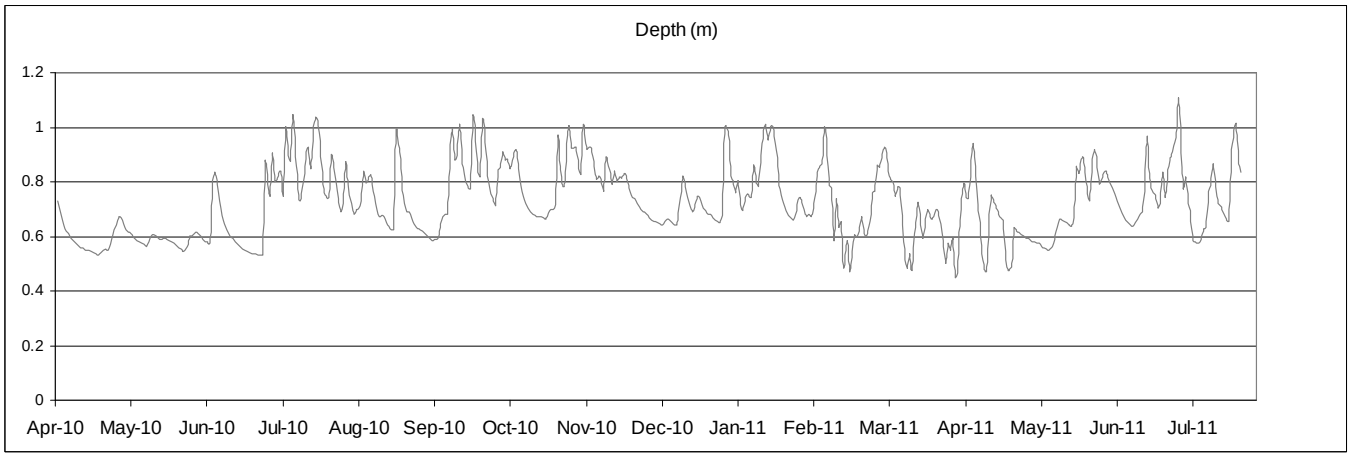


Time is presented along the x axis and water depth down the y axis – the top of the diagram thus represents the lake surface. Colours (isotherms) show temperature (^{0}C), with dark blue the coldest and red the warmest. A single colour from top to bottom at a given point in time is indicative of the lake being mixed whereas different colours across a vertical are indicative of thermal stratification.

7.1.9 Automatic sensor data, Llyn Llagi

7.1.9.1 Lake sensor data, Llyn Llagi





7.1.9.2 Outflow sensor data, Llyn Llagi