Cyfoeth
Naturiol
Cymru
Natural
Resources
Wales

Environmental Change Network Yr Wyddfa/Snowdon ECN Site Progress report for 2013-14 to Welsh Government

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NRW Evidence Report No 34

Contents

Crynodeb Gweithredol

Mae safle Rhwydwaith Newid Amgylcheddol ar yr Wyddfa wedi cael ei rhedeg gan Cyfoeth Naturiol Cymru, a chyn hynny gan Gyngor Cefn Gwlad Cymru, ar y cyd â Llywodraeth Cymru ers 1995. Mae'r gwaith monitro'n canolbwyntio ar effeithiau newid hinsawdd, llygredd a defnydd tir ar strwythur, swyddogaeth ac amrywiaeth ecosystemau dŵr croyw a daearol. Mae'r rhan ddaearol y safle'n gweithio ers 1995 a'r rhan dŵr croyw ers 2006.

Adroddiad cynnydd blynyddol i Lywodraeth Cymru yw'r adroddiad hwn.

Y pwyntiau allweddol ar gyfer y cyfnod samplo cyfan (1995-2014) yw:

- Dengys y tymheredd a gofnodwyd â llaw yn ystod y cyfnod 1996-2013 fod cyfartaledd wythnosol y tymheredd uchaf +0.32 ºC yn uwch a'r tymheredd isaf +1.12 ºC yn uwch nag yn y cyfnod cyfeiriol 1966-1977. Roedd cyfartaledd tymheredd y pridd +0.48 ºC yn uwch yn 2013 ac +0.85 ºC yn uwch yn gyffredinol yn ystod 1996-2013 o gymharu â'r cyfnod cyfeiriol. Nid yw'r y tueddiadau o ran y tymheredd uchaf, isaf a'r cymedr yn ystod y cyfnod 1996-2013 yn arwyddocaol.

- Disgynnodd yn arwyddocaol fwy o law ym 1996-2013 nac ym 1966-1977, sef +5.24mm / yr wythnos, neu 272.4mm yn fwy y flwyddyn. Mae yna dueddiad arwyddocaol i fwy o law ddisgyn yn ystod yr haf.

- Mae yna'n sylweddol llai o sylffwr deuocsid yn disgyn ar ôl lleihad mewn allyriadau ond, er gwaethaf lleihad cenedlaethol mewn allyriadau nitrogen, mae'r tueddiad yn dangos fod cymaint ag erioed o nitrogen deuocsid sych yn disgyn ar yr Wyddfa ond nid yw hynny'n arwyddocaol.

- Dengys canlyniadau monitro osôn ym Marchlyn Mawr fod yna ostyngiad cyson yn ystod y cyfnod 2000-2014 yng nghyfartaledd y crynodiad yn y gwanwyn ac yng nghyfartaledd y crynodiadau blynyddol. Nid welwyd lefelau osôn ar gyfer llystyfiant lled naturiol yn y gwanwyn yn mynd y tu hwnt i'r lefelau critigol ers 2006.

- Dengys dadansoddiad wythnosol o'r glaw sy'n disgyn gynnydd arwyddocaol mewn pH a gostyngiad hynod arwyddocaol mewn sylffad a nitrad. Dengys dyfroedd nentydd hefyd newidiadau arwyddocaol tebyg mewn pH, swlffad a nitrad. Bu yna hefyd leihad sylweddol mewn a alwminiwm ansefydlog, haearn, ffosffad, amoniwm a charbon organig toddedig.

- O ran llwythau critigol, bu yna ostyngiad arwyddocaol mewn nitrogen ac asidedd maetholion. Roedd lefelau nitrogen ac asidedd maetholion ar eu hisaf yn 2011-2013 er yn dal yn uwch na'r llwyth gofynnol ar gyfer y rhan fwyaf o gynefinoedd.

- Mae nifer chwilod carabid wedi lleihau'n arwyddocaol ers 1999 ond mae'r tueddiad wedi sefydlogi ac wedi adfer ychydig ers 2004. Yn wahanol iawn, nid yw nifer corynod neu bryfed cop wedi dangos unrhyw newid yn ystod y cyfnod cofnodi.

- O ran grifft llyffantod, ni fu yna unrhyw newid arwyddocaol ers 1996 o ran pa bryd yr oedd y grifft yn cael ei ddodwy ond mae'r cyfnod rhwng ei ddodwy a thrawsffurfio wedi lleihau'n arwyddocaol.

- Yr unig dueddiad arwyddocaol mewn gwerthoedd dangosyddion Ellenberg ar gyfer llystyfiant yw cynnydd arwyddocaol mewn R (*Reaction*) ers 2002 yn yr haen fasciwlaidd planhigion mewn glaswelltir calchog.

- Ni welwyd unrhyw newid arwyddocaol mewn macroffytiau na diatomau epithilig y dŵr ers dechrau cofnodi dŵr croyw yn Nant Teyrn yn 2007.

- Mae nifer y defaid wedi aros yn sefydlog yn y blynyddoedd diweddar ar tua 50% o’r nifer ym 1997. Bu cynnydd arwyddocaol yng nghyfartaledd nifer blynyddol y geifr gwyllt ers dechrau’r 2000au ac ym mhob tymor heblaw'r haf.

Y pwyntiau allweddol ar gyfer y cyfnod 2013-2014 yw:

- Roedd hi’n oer iawn ar y safle’n yn ystod gwanwyn 2013 ond fe'i dilynwyd gan yr haf cynhesaf a'r sychaf ers pum mlynedd. Roedd y tywydd yn ystod gaeaf 2013/14 ymysg y gwlypaf a‘r mwyaf gwyntog ers dechrau cofnodi ym 1995 gyda’r gwyntoedd cryfaf yn cyrraedd 83 milltir yr awr, cyfanswm o 1670mm law’n disgyn ac 85 o ddyddiau glawog allan o 89. Yn olaf, roedd gwanwyn 2014 yn eithriadol o sych a heulog.

- Achosodd y gwanwyn oer oediad mewn blodeuo yn y rhan fwyaf o rywogaethau planhigion, 47 diwrnod yn achos Llygad Ebrill (*Ranunculus ficaria*), parhaodd yr effaith drwy'r haf a dim ond yn niwedd Awst yr arafodd y raddfa o flodeuo hwyr a dechrau cyrraedd y cyfartaledd.

Rodd cyfartaledd tymheredd yr haf gyda’r uchaf a gafodd ei gofnodi erioed a disgynnodd llai o law nag yn ystod y saith mlynedd blaenorol. Roedd cyfartaledd tymheredd yr hydref yn agos at y cyfartaledd ac roedd cyfrif cronnol ffwng ar y safle yn cynyddu'n araf nes, yn y pen draw, fynd yn uwch na'r cyfrif uchaf o'r blaen yn 2010.

Executive Summary

The Environmental Change Network site on Yr Wyddfa/Snowdon has been operated by Natural Resources Wales (NRW) and previously the Countryside Council for Wales (CCW) in conjunction with the Welsh Government since 1995. The monitoring focus is on the impact of climatic change, pollution and land-use on the structure, function and diversity of both freshwater and terrestrial ecosystems. The site comprises a terrestrial component operational since 1995 and a freshwater component operational since 2006.

This report is an annual progress report to Welsh Government

The key points for the whole sampling period (1995-2014) are:

- Manually recorded temperature data indicate that over the period 1996-2013, the average weekly maximum and minimum temperatures were +0.32 ºC and +1.12 ºC higher respectively than in the reference period 1966-1977. Average soil temperatures were +0.48 ºC higher in 2013 and +0.85 ºC overall during 1996-2013 compared to the reference period. The trends in maximum, minimum and mean soil temperature over the period 1996-2013 is not significant.

- Rainfall during 1996-2013 was significantly higher than in 1966-1977 at +5.24mm/week, translating to an extra 272.4 mm/year. There is a significant trend for increased summer rainfall.

- Dry deposition of sulphur dioxide continues to show a significant decrease following reductions in emissions, but despite national declines in emissions of nitrogen, the trend for dry deposition of nitrogen dioxide at Snowdon is level and not significant.

- Ozone monitoring at Marchlyn Mawr continues to show a steady decrease over the period 2000-2014 in average spring concentration, and average annual concentrations. Critical levels of ozone for semi-natural vegetation in the spring have not been exceeded since 2006.

- Analysis of weekly precipitation shows a continuing significant increase in pH and highly significant declines in sulphate and nitrate. Stream water shows similar significant changes in pH, sulphate and nitrate. There have also been significant decreases in labile aluminium, iron, phosphate, ammonium and dissolved organic carbon.

- For critical loads, there has been a significant decrease in both nutrient nitrogen and acidity. The levels of nutrient nitrogen and acidity were at their lowest levels in 2011-2013 although still above the minimum load for most habitats.

- Carabid beetles numbers have shown a highly significant decline since 1999, but the trend has stabilized and recovered slightly since 2004. Spider numbers, in contrast, show no change over the recording period.

- For frog spawning, there has been no significant change in the timing of spawning since 1996, but the duration from spawning to metamorphosis has decreased significantly.

- Trends in Ellenberg indicator values for vegetation show no significant trends apart from a significant increase in R (Reaction) since 2002 for the vascular plant layer in calcareous grassland.

- No significant changes have been seen in aquatic macrophytes or epilithic diatoms since freshwater recording started at Nant Teyrn in 2007.

- Sheep numbers remain stable in recent years about 50% of those in 1997. Feral goat numbers have shown a highly significant increase in average annual numbers since the early 2000s, and in all seasons except summer.

The key points for the period 2013-2014 are:

- The spring of 2013 on the site was very cold but was followed by the warmest and driest summer for over 5 years. The weather during winter 2013/14 was some of the wettest and windiest since recording commenced in 1995 with maximum windspeeds reaching 83 mph, total winter rainfall reaching 1670mm and the number of raindays was 85 from a total of 89. Finally, the early spring in 2014 has proved to be remarkably dry and sunny.

- The cold spring retarded the flowering of most plant species, in the case of Lesser Celandine (*Ranunculus ficaria*) by 47 days, the impact persisted through the summer with the degree of late flowering only slowly decreasing until August when it approached the average.

- Average summer temperatures were amongst the highest recorded and there was lower rainfall than in the previous 7 years. Autumn temperatures were close to normal, and the cumulative count of fungi on the site slowly climbed higher to eventually overtake the previous high seen in 2010.

1. Introduction

The Environmental Change Network (ECN) is a multi-agency programme launched in 1992 with the aim of establishing a network to identify, assess and research environmental change nationally (Sier & Scott, 2009). It consists of a series of 12 terrestrial and 45 freshwater sites, each of which collects data from a range of physical, chemical and biological variables (www.ecn.ac.uk). The data generated is sent to the ECN Central Co-ordination Unit (CCU) at the Centre for Ecology and Hydrology (CEH) at Lancaster. The network is supported by a wide range of sponsors covering the majority of the environmental agencies in the UK. In May 2014, the network celebrated its 20 years of operation with a symposium at Lancaster University which looked both backwards to the successes of the network and forwards to the challenges of the future.

The Yr Wyddfa/Snowdon ECN site commenced in 1995 and is jointly funded by NRW (previously CCW) and the Welsh Government. Physical measurements include meteorology and surface water discharge. Chemical analysis is undertaken of rain water, surface water and soil water for pH, conductivity, a range of anion and cation determinands and alkalinity. Biological recording of birds, bats, frog spawning, butterflies, ground predators, spittle bugs and vegetation occurs seasonally and land-use is monitored all year. Non-ECN protocols include snow-lie duration, phenology, arctic-alpines, fungi and ticks. In addition samples are collected for other networks including UKEAP (UK Eutrophying and Acidifying atmospheric Pollutant network).

In 2007, a site at Nant Teyrn, an outflow of Llyn Teyrn, within the terrestrial ECN site, became a freshwater site in the network. Recording consists of monthly collection of water samples for analysis of a range of chemical determinands and pH, conductivity, Biological Oxygen Demand (BOD) and dissolved organic carbon (DOC). Temperature, conductivity and water discharge are recorded continuously. Epilithic diatoms and macrophytes are recorded annually and benthic invertebrates are sampled twice a year (Table 1). Chlorophyll-a levels are measured monthly.

The first part of the report is an operational overview of the project on the Snowdon site over the period April 2013 - March 2014, followed by a summary of notable events on the site. The core of the report comprises brief overviews of a subset of results for physical, chemical and biological variables, supported by data summaries, presented mainly in graphical format.

The report concludes with a look to the future.

2. Site Management

2.1 Staffing

Table 1: Staffing on the Yr Wyddfa/Snowdon ECN site in 2013-14

Name	Started / Finished	Role
Alex Turner	Apr 1995 - Jun 2000 Oct 2006 - continuing	ECN Project officer
Victoria Bowmaker	Apr 2007 – continuing (Sick leave May - Oct 2013)*	ECN Data officer
Dylan Lloyd	Apr 2008 - Sep 2008 Dec 2009 - continuing	Environmental Surveillance Officer

* when available, the following staff were drafted in to provide field cover: Dafydd Parry, Matty Murphy, Julia Korn and Stuart Smith. Admin support was provided by Rhonwen Williams, Annwen Hope, Angharad Evans and Chris Williams

2.2 Site maintenance

Weekly calibration and maintenance checks were carried out on the ECN Automatic Weather Station and the Nant Teyrn Weir during 2013-14 as a check on instrumental drift.

Table 2 Maintenance of Ozone and NO_x analysers at Marchlyn Mawr

Date	Staff / Engineer	Organization	Details
16-17 May 13	Steve Hall	Envirotechnology	6-monthly service & calibration
20 May 13	Ben Davies	Ricardo-AEA	Annual audit
02-03 Dec 13	Marcus Gardiner	Envirotechnology	6-monthly service & calibration
24 Mar 14	Darren Lane Esther Auzmendi	Ricardo-AEA	Annual audit

Monthly calibration checks were carried out for all months except May and August 2013, and March 2014.

2.3 Summary of measurements and data processing

Details of ECN terrestrial protocols can be found in Sykes & Lane (1996) and freshwater protocols in Sykes *et al.* (1999); both are available at the ECN website www.ecn.ac.uk. Additional non-ECN protocols undertaken on the site are covered more fully in section 3.

Table 3: ECN protocols undertaken on the Yr Wyddfa/Snowdon ECN site during 2013-14**.**

DRIVER OR RESPONSE VARIABLE	MEASUREMENT	METHOD	FREQUENCY	SAMPLING / DATA COLLECTION AT 01/06/14	DATA ENTRY AT 01/06/14
TERRESTRIAL: Physical					
Meteorology	Temperature, precipitation, wind speed and direction, solar irradiance,	Automatic weather station and manual measurements	Hourly and weekly	Up to date	Data entered up to Apr 14
Water discharge	Surface water discharge	Automatic recorder	Every 15 minutes	Downloaded up to end Oct 13; Data missing from Oct13 - Apr 14 due to technical problems.	Data entered to end Oct 13, and from Apr - Jun 14
Snow-cover recording	Snowline, snowpatch duration	Manual estimates of altitude and duration	Weekly (autumn – spring)	Up to date	Data entered up to 01 Apr 2014
		Automatic camera	Hourly	Up to date	Image data processed up to May 13
TERRESTRIAL: Chemical					
Atmospheric chemistry	Oxides of nitrogen	Diffusion tubes	Fortnightly	Up to date	Data entered up to Sept 13
	Sulphur dioxide	Diffusion tubes	Monthly	Up to date	Data entered up to Jul 13
	Ozone & oxides of nitrogen at Marchlyn Mawr for Welsh Air Quality Forum & UKEAP	Automatic analyzer	Hourly	Up to date	Data downloaded to Jan 14
	Ammonia for UKEAP at ECN site and Plas-y-Brenin	Diffusion tubes and Alpha sampler	Monthly	Up to date	n/a
	NO2 diffusion tube for UKEAP	Diffusion tubes	Monthly	Up to date	n/a
Rainfall chemistry	pH, conductivity, alkalinity, Na, K, Ca, Mg, Fe, Al, NO$_x$, SO$_4$, Cl, PO$_4$, DOC, Total-N, alkalinity	Chemical analysis	Weekly	Up to date	Data entered up to Apr 14
Rainfall chemistry for UKEAP		Chemical analysis by UKEAP	Fortnightly	Up to date	n/a
Water chemistry		Chemical analysis	Weekly	Up to date	Data entered up to Apr 14
Soil solution chemistry		Chemical analysis	Fortnightly	Up to date	Data entered up to Apr 14
Soils	Physical structure and chemistry	Physical and chemical analysis	5- and 20-yearly	Sampling completed	Data received, but not yet entered

DRIVER OR RESPONSE VARIABLE	MEASUREMENT	METHOD	FREQUENCY	SAMPLING / DATA COLLECTION AT 01/06/14	DATA ENTRY AT 01/06/14
TERRESTRIAL: Biological					
Vertebrates	Bats	Counts along two transects	Four times yearly	Completed	Data entered up to Apr 14
	Birds	Breeding Bird Scheme	Twice yearly	Completed	Data entered up to Apr 14
	Frog spawning	Timing of lifestage events, chemical analysis	Weekly during season	Completed	Data entered up to Apr 14
Invertebrates	Butterflies	Butterfly Monitoring Scheme	Weekly (April - September)	Completed	Data entered up to Apr 14
	Ground beetles and spiders	Species and individual counts	Fortnightly (March - November)	Completed	2013 samples currently being identified
	Pollinators	2 5 minute counts	Weekly	Trial completed	Data entered up end 2013
	Ticks for Health Inspectorate	10 transects sampled	Monthly (Mar-Jun & October)	Completed	No Ticks Detected In 2013
	Spittle bugs	Quadrat counts	Twice yearly	Completed	Data entered up end 2013
Vegetation	Fine-grain sampling	Quadrat counts	3-yearly/subset annually	Annual subset completed	Data entered up end 2013
	Coarse-grain sampling	Quadrat counts	9-yearly	n/a in 2013	n/a In 2013
	Arctic-alpines	Quadrat cell counts	3 yearly/subset annually	Annual subset completed	Data entered up end 2013
	Phenology for UK Phenology Network (in part)	Flowering species counts	Weekly	Completed for 2013; Protocol ceased in April 2014	Data entered up to Apr 14
Pollen for Pollen Monitoring Programme	Rainwater collection	Pollen grain counts	Quarterly	Up to date	Samples waiting to be sent to Univ of Hull for processing
Fungi	Fungi	Species counts	Fortnightly	Up to date	Selected 2013 samples awaiting identification
Land use	Sheep and goat numbers	Counts within sample areas	Weekly	Up to date	Data entered up to Apr 14
	Other mammals & birds by automatic camera	Automatic camera	Hourly	Up to date	Image data processed up to May 13
FRESHWATER: Physical & Chemical					
Chemistry	BOD, orthophosphate, SiO_3, As, Cd, Sn, Cu, Pb, Ni, Zn, V, Mn, Hg, Fe, SO_4, Na, K, Ca, Mg, NO_2, Total-P	Chemical analysis	Monthly	Up to date	Data entered up to Apr 14
Conductivity and temperature	Conductivity and temperature	Automatic logger	Every 15 minutes	Downloaded up to end Oct 13; Data missing from Oct13 - Apr 14 due to technical problems.	Data entered to end Oct 13, and from Apr - Jun 14

DRIVER OR RESPONSE VARIABLE	MEASUREMENT	METHOD	FREQUENCY	SAMPLING / DATA COLLECTION AT 01/06/14	DATA ENTRY AT 01/06/14
FRESHWATER: Biological					
Vegetation	Aquatic macrophytes	Species percentage cover	Annually	Completed	Data entered up end 2013
Phytoplankton	Chlorophyll-*a*	Acetone extract	Monthly	Up to date	Data entered up to Apr 14
Invertebrate fauna	Macro-invertebrates	Species counts from kick sampling	Twice yearly	Completed	Up to date aprt from 2011 & 2012 samples still awaiting identification
Diatoms	Epilithic diatoms	Slide counts from submerged rocks	Annually	Completed	Up to date

Key:

ECN core protocol
Other network data collection
NRW site specific protocol

Abbreviations:

BOD	Biological Oxygen Demand
UKEAP	UK Eutrophying and Acidifying Atmospheric Pollutants network

There have been some changes to the range of protocols recorded on the site since the last full report in 2012.

Tick monitoring on the site was ended by Public Health England in April 2013 after a reduction in the number of sites used for this protocol. Two sites from the network were selected for the recording to continue where large numbers of ticks are regularly found. In the period of recording on Snowdon, only three ticks were discovered, two of those on the first trial day.

Two new protocols were instituted in 2014. The first, monitoring pollinators, was trialled in late 2013. It uses the methodology employed by the Open Farm Sunday Pollinator Survey organized by CEH (2012) in conjunction with Syngenta. Two locations on the site, comprising the acidic and basic exclosures close to the meteorological site, are used and the protocol is carried out weekly between April and September if conditions are suitable.

The second protocol, is an attempt to collect some information on the cultural services provided by the ECN site. The methodology uses a rapid observational survey of the numbers of people taking part in activities on the ECN site each Wednesday while the normal weekly recording is taking place. The activities recorded range from sports, hobbies, training, education, and farming, military and mountain rescue activities. It is planned to continue the protocol all year round.

2.4 Educational activities

Dr Peter Dennis of Aberystwyth University brought a party of around 50 undergraduate students to the ECN site on the 16th November 2013. The students were following B.Sc. courses in in Ecology and Environmental Biosciences.

Two student dissertations were undertaken on or in relation to the Snowdon ECN site over the 2013-14 period. The first, an M.Sc. dissertation by Valentina Vitali of Bangor University, entitled “Montane Grassland response to Landslide disturbance at Llyn Llydaw, Snowdonia National Park”, was supervised by Dr Morag McDonald.

A second dissertation, loosely based on an ECN site proposed project, was produced in 2014 following field-work in the summer of 2013 by Frances Stoakley of Aberystwyth University. The B.Sc. dissertation, entitled “An exploration of the Cultural Ecosystem Services provided to walkers by Snowdon (North Wales) using Volunteer-Employment Photography”, was supervised by Dr Peter Dennis and was submitted in May 2014.

A single paper was published in the journal Biogeochemistry by Stephanie McGovern et al (2014), entitled “Increased inorganic nitrogen leaching from a mountain grassland ecosystem following grazing removal: a hangover of past intensive land-use?” following on from her PhD based on the ECN site in 2008-11.

2.5 Notable events in 2013/14

As noted in the Interim report (Turner 2014), 2013 and early 2014 were notable for the short-term changeability of the weather on the site. A very cold spring in 2013 was followed by the warmest and driest summer for over 5 years and then the weather during the winter was some of the wettest and windiest since recording commenced in 1995. Finally, the early spring in 2014 has proved to be remarkably dry and sunny.

The cold spring in 2013 had the lowest spring temperatures since recording started in 1995 (Figure 1) with mean temperature at +3.43ºC, whereas the spring temperature in 2014 was close to the mean value at +6.03ºC.

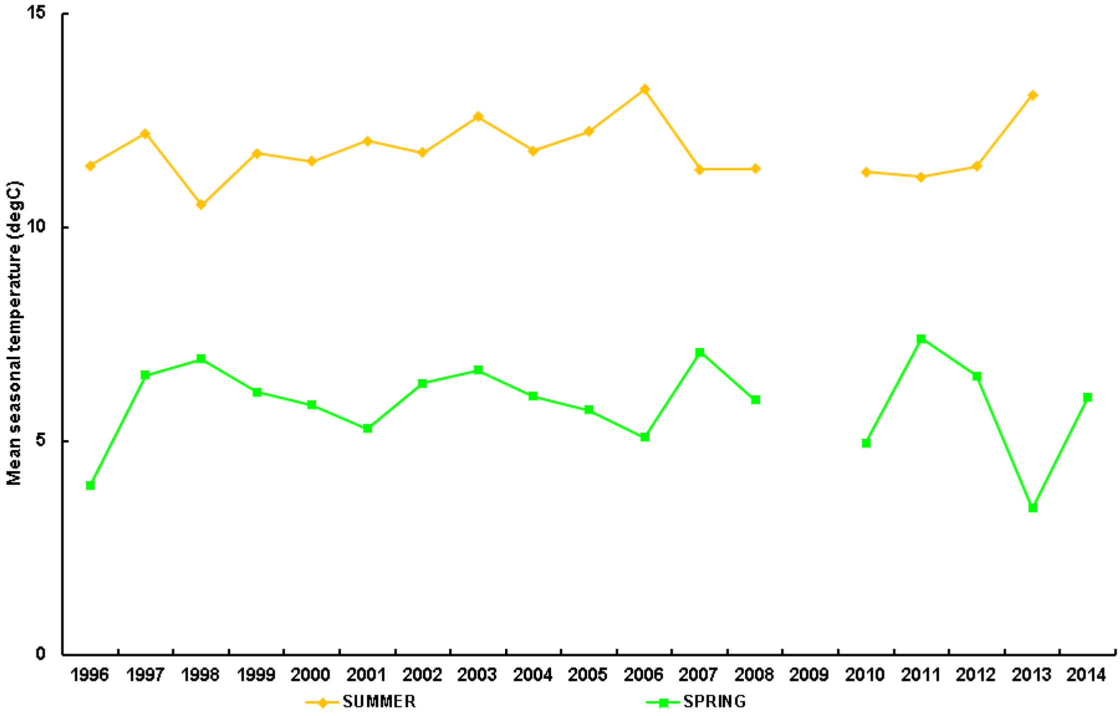


Figure 1. Average spring (left) and summer temperatures (right) over the period 1996 - 2013/14.

The cold spell in 2013 followed a warm February, and the impact of this can be seen in Figure 2 which shows the relative advance in flowering of many of the dicotyledonous species seen on the site. Purple saxifrage (*Saxifraga oppositifolia*) which flowers early managed to take advantage of the February warm weather, but most of the other spring flowering species were retarded in their flowering, in the case of Lesser Celandine (*Ranunculus ficaria*) by 47 days. The impact of the cold spring persisted through the summer with the degree of late flowering only slowly decreasing over the course of the year, until August when it approached the average. The warm weather of spring 2014 by contrast allowed early flowering for Purple saxifrage and increasingly early flowering for other species as the spring and early summer progressed.

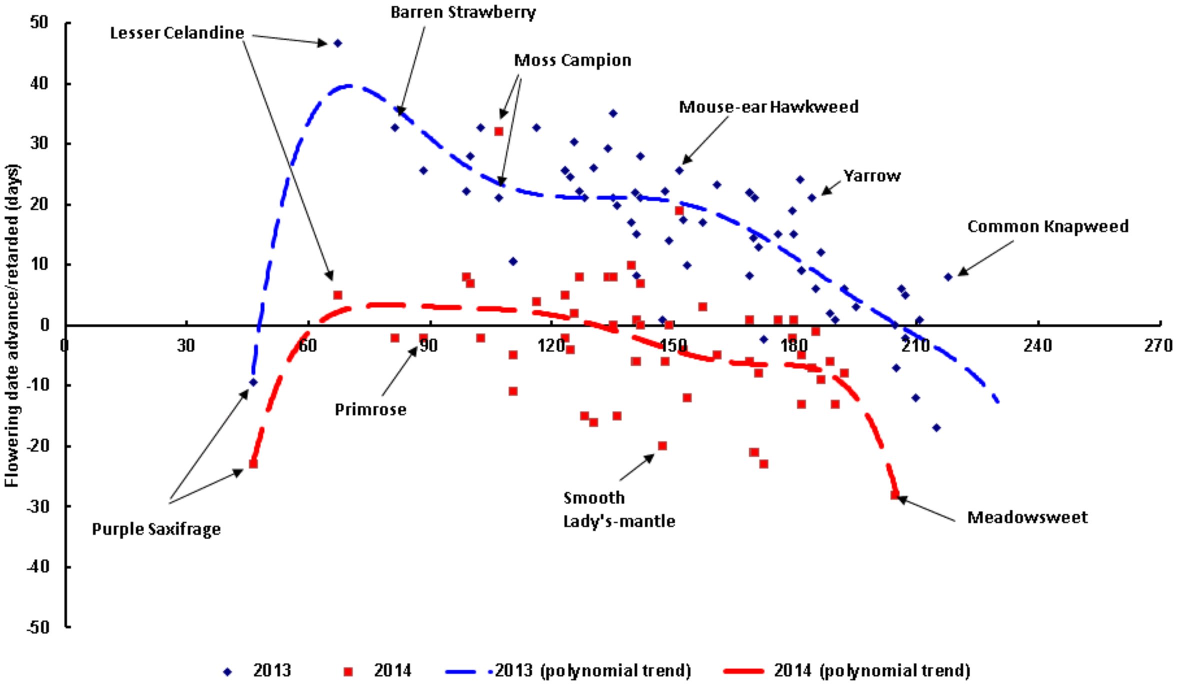


Figure 2. Deviation from average flowering dates for 2013 and spring and early summer 2014. Points represent individual species, positive values indicate number of days behind average flowering date, negative numbers advanced flowering dates.

The warm spring in 2014 enabled the frogs spawning in the two ECN ponds to complete their development and metamorphosis in an almost record 98 days, and unlike many recent years, there was no mass mortality due to late frosts or snow.

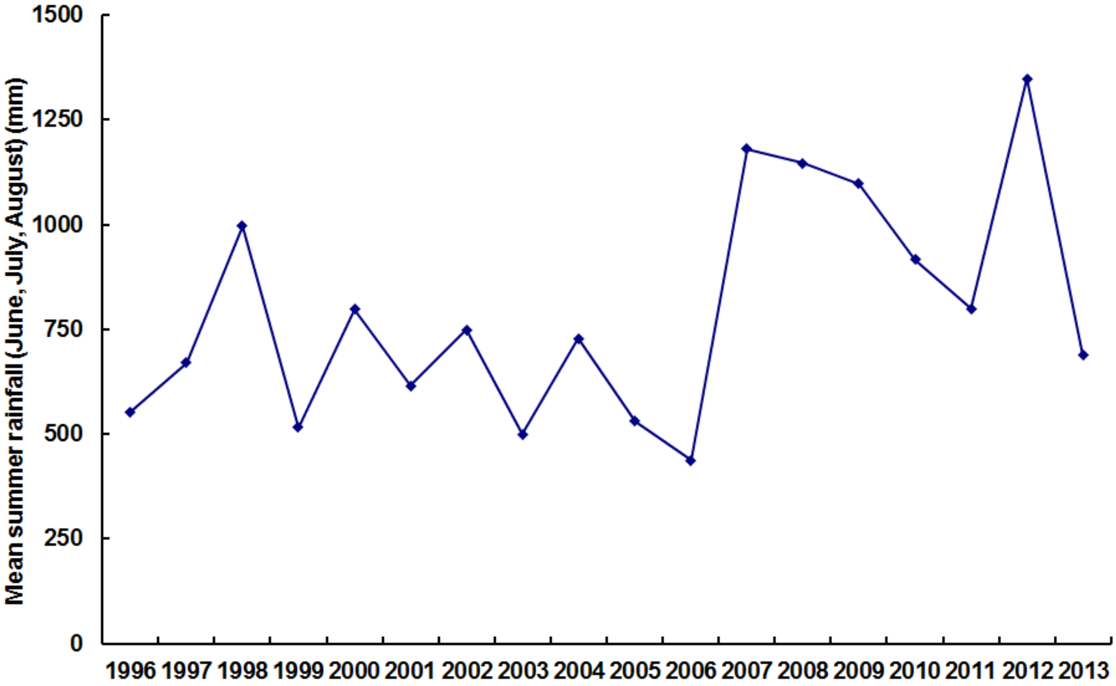


Figure 3. Average summer rainfall 1996-2013.

Average summer temperatures were amongst the highest recorded (Figure 1) and there was lower rainfall than in the previous 6 years (Figure 3). Despite this there was not a significant increase in butterflies, birds or bats, probably because the summer of 2012 had been so bad. The bird surveys in spring 2014, however, showed an increase in numbers, and initial 2014 butterfly transects indicate a large increase in numbers which point to a lag in response to the change to warmer weather in 2013.

Autumn temperatures were close to normal, and the cumulative count of fungi on the site slowly climbed higher to eventually overtake the previous high seen in 2010 (Figure 4).

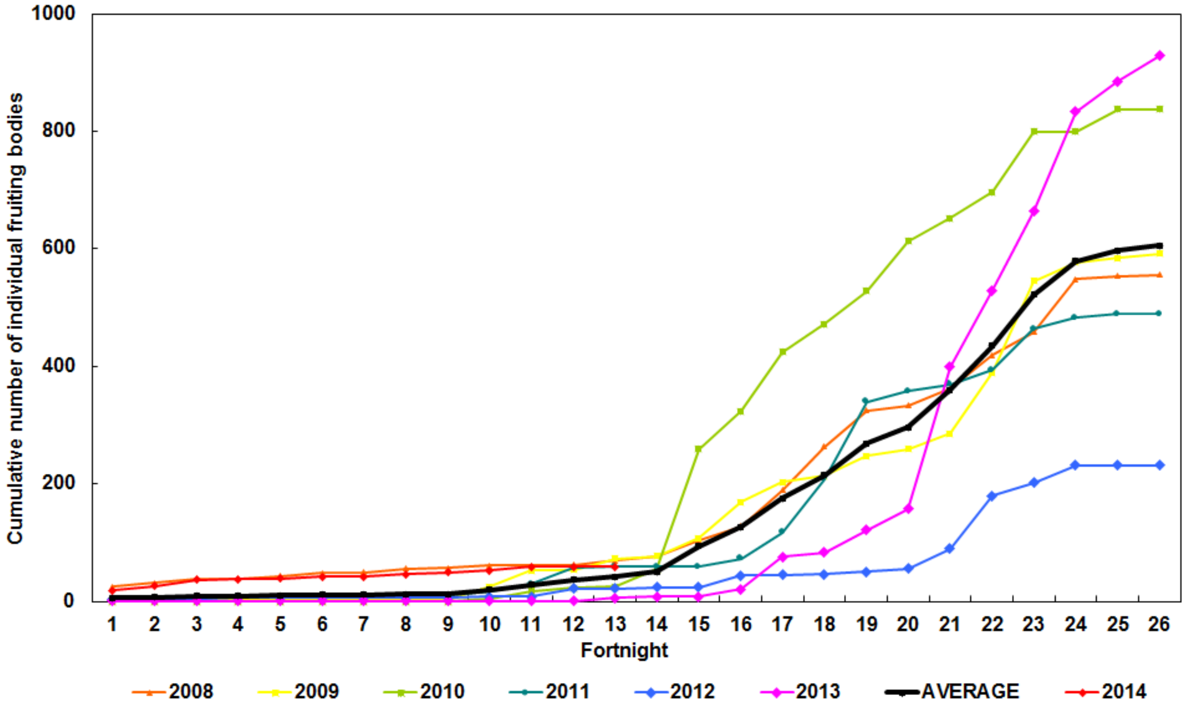


Figure 4. Cumulative annual fungal fruitbody count.

The weather in the winter of 2013/14 was notable for the higher than average rainfall and high windspeeds, originating from a succession of deep cyclonic depressions travelling at high speed towards the UK along a strong relatively low-latitude jet-stream. Gust speeds on 27th December locally reached 102 mph at Aberdaron on the Lleyn peninsula and 87mph at nearby Capel Curig. Again on the 12th February, these speeds were exceeded by 108 mph at Aberdaron and 93mph at Capel Curig. The meteorological station on the ECN site is relatively sheltered from very strong south-westerly winds by the bulk of Snowdon and the maximum gust speed on these two dates was 83mph and 70mph. Also to indicate the sheltered nature of the ECN met site (alt 490m), only on one day during the winter did the gust speed exceed Beaufort Force 12, whereas at the Capel Curig met station (alt 216m), Force 12 was recorded on 18 days (data from www.metoffice.gov.uk). Although the ECN AWS has only been measuring gust speeds since 2009, Figure 5 indicates, however, how unusual the 2013/14 winter period was. Figure 6, showing winter maximum and minimum temperatures, highlights the warmth of the winter with the highest minimum temperature (-1.78 ºC) which led to the least number of frost days recorded since 1996, the average a year being 28.

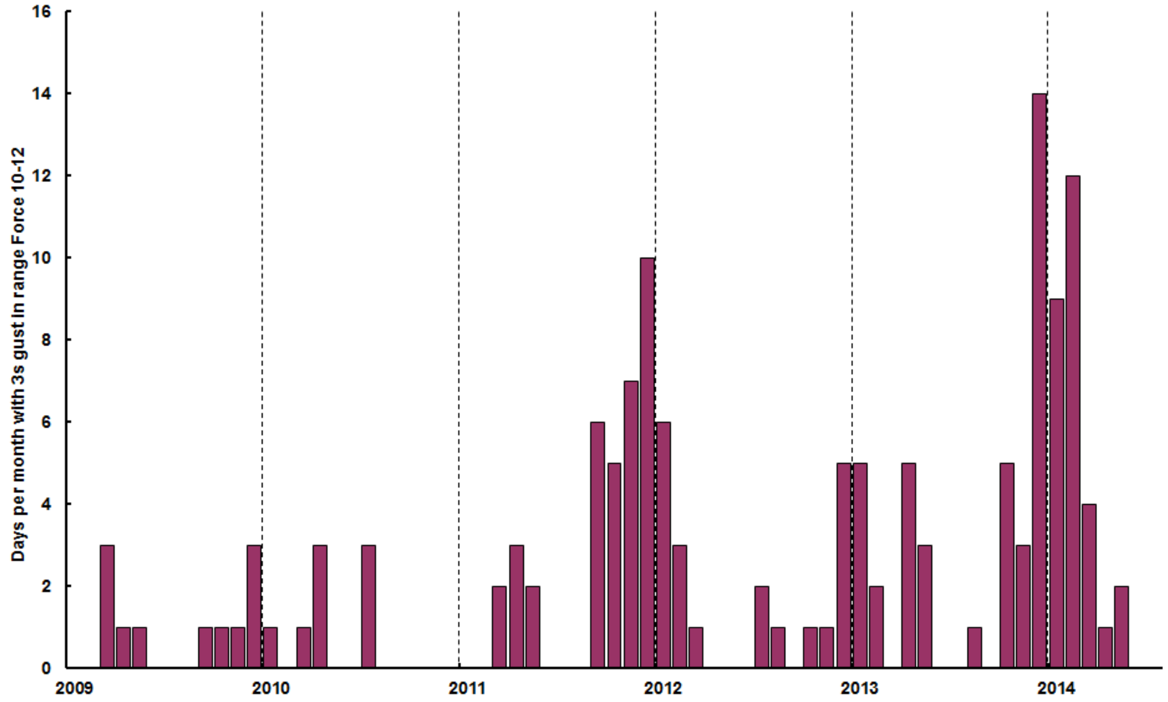


Figure 5. Number of days per month with 3 second gusts in the Beaufort range 10-12 (Storm to Hurricane Force, >=55 mph) over the period 2009-2014. Data missing from Aug & Nov 2009, Aug 2010-Feb 2011.

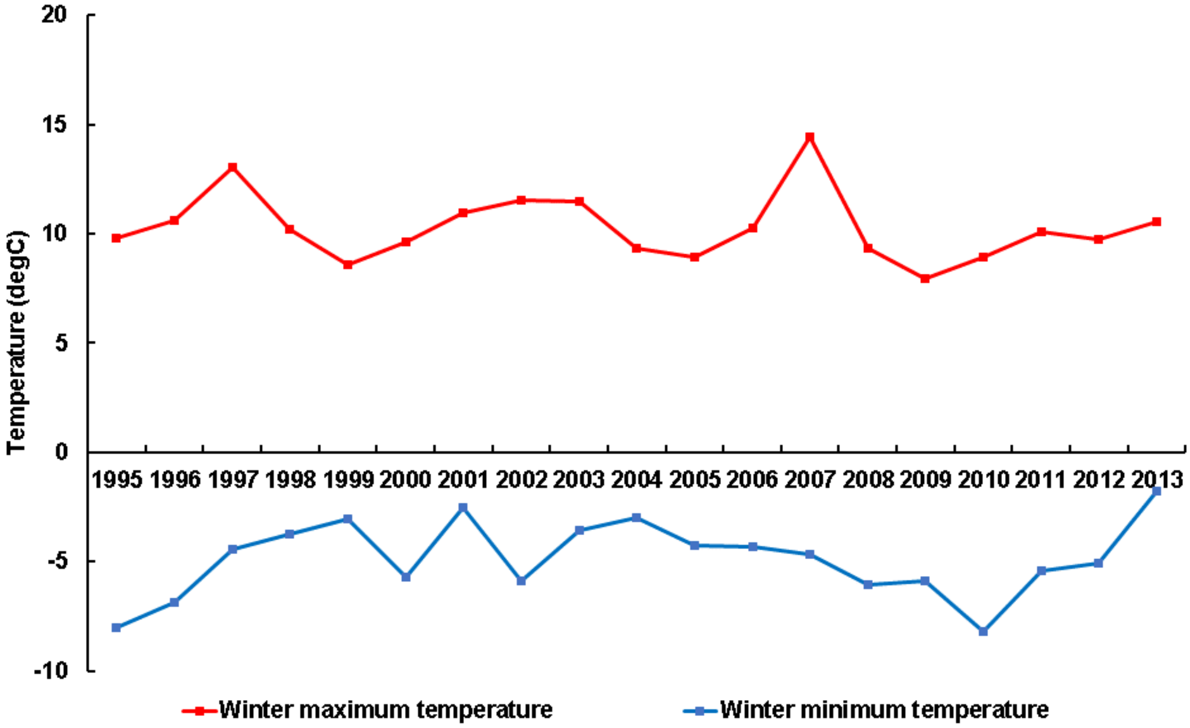


Figure 6: Winter maximum and minimum temperatures over the period 1996-2014.

3. Terrestrial and Freshwater overview

3.1 Physical variables overview

Manually recorded temperature data from the ECN site indicate that over the period 1996-2013, the average weekly maximum and minimum temperatures were +0.32 ºC and +1.12 ºC higher (Table 4) than in the reference period 1966-1977 when temperature data was collected as part of the International Biological Programme (IBP) (Heal and Perkins 1978). Over 2013, the differences were -0.29ºC and +0.32 ºC respectively. The trend in maximum and minimum manual dry-bulb temperatures over the period is not significant (Figure 7). Data from the automatic weather station over 1996-2013 agrees with the manual data.

Average soil temperatures were +0.48 ºC higher in 2013 and +0.85 ºC overall during 1996-2013 compared to the 1966-1977 period (Table 4). The soil temperature trend is also not significant.

Rainfall during 1996-2013 was slightly but significantly higher than in 1966-1977 at +5.24mm/week, which translates into an extra 272.4 mm/year (Figure 9). There is also a significant trend for increased summer rainfall (Figure 13). The winter rainfall for 2013/14 reached a maximum of 1670mm, the highest since recording started in 1995.

The monthly rainfall pattern has a strong link to the Arctic Oscillation index, in particular since mid-2009 (Figure 11), and since then there has been greater autocorrelation between months, and greater deviations from the mean monthly temperature.

Due to increased amounts of snowfall over recent winters, previously significant trends towards earlier snow melting no longer apply (Figure 14). During the warm winter of 2013/14 there was little snow seen below 500m. Large amounts fell above that altitude, however, which together with very strong winds (Figure 6) led to a large amount of drifting and local accumulation and consequently the day of last snow melt on north-facing slopes (14th May) was not appreciably earlier than in the last 5 years.

3.2 Data summary physical variables – Terrestrial

Terrestrial: Manual Meteorology (MM)

Manual meteorological data collected as part of the IBP from 1966-1977 are used as a baseline to assess average weekly temperatures changes recorded on the ECN site over 1995-2013. From Table 4, it can be seen that maximum and minimum temperatures in 2013 were -0.29ºC below and +0.32 ºC above the 1966-77 average levels respectively. Grass minimum and soil temperatures were higher in 2013 at +1.61 ºC and +0.48 ºC respectively, while over the current recording period as a whole, the residuals are +2.11 ºC and +0.85 ºC respectively.

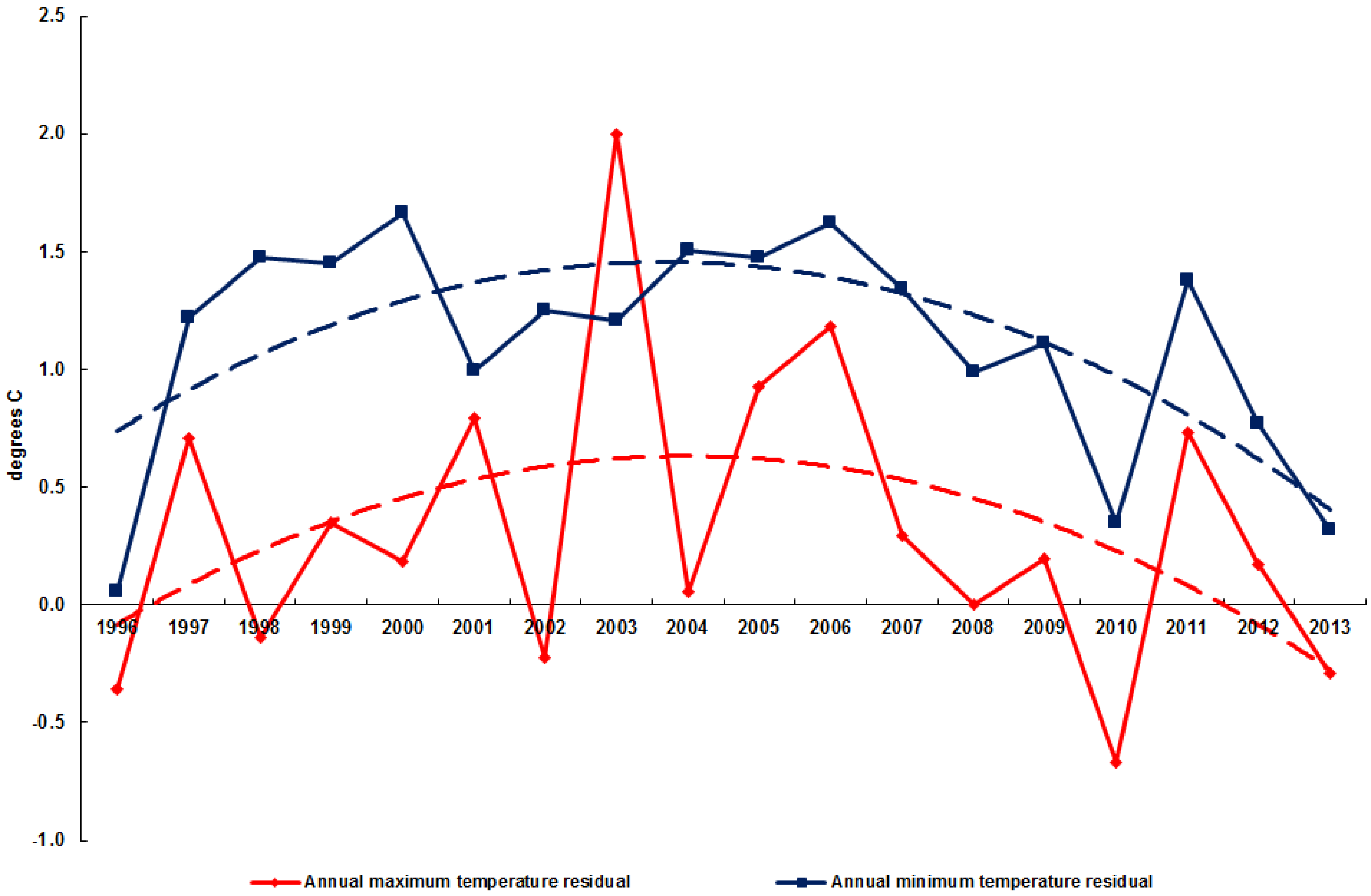
Table 4: Residuals for weekly maximum, minimum, grass minimum and soil temperatures, temperature range and weekly rainfall for 1996 to 2013, compared with mean values for 1966-77.

Year	Statistic	Maximum temp. residual (deg C)	Minimum temp. residual (deg C)	Temperature range residual (deg C)	Mid-range temp. residual (deg C)	Grass min. temp. residual (deg C)	Soil temp. residual (deg C)	Manual rainfall residual (mm)
1996 to 2013	Mean	0.32	1.12	-0.82	1.33	2.11	0.85	5.24
	SD	3.11	2.34	3.12	2.43	3.29	1.29	55.53
	n	906	925	906	910	893	923	923
	SE	0.10	0.08	0.10	0.08	0.11	0.04	1.83
1996	Mean	-0.36	0.06	-0.42	0.51	1.24	-0.11	-11.02
1997	Mean	0.71	1.22	-0.51	1.63	2.77	0.98	-5.48
1998	Mean	-0.14	1.47	-1.61	1.33	3.48	0.86	13.09
1999	Mean	0.35	1.45	-1.10	1.56	1.33	0.88	12.31
2000	Mean	0.18	1.66	-1.48	1.59	0.38	0.62	22.87
2001	Mean	0.79	1.00	-0.36	1.61	-0.10	0.64	-8.60
2002	Mean	-0.22	1.25	-1.47	1.18	-1.23	0.87	11.60
2003	Mean	2.00	1.21	0.81	1.20	2.67	1.26	-5.84
2004	Mean	0.06	1.51	-1.45	1.45	2.43	1.28	5.28
2005	Mean	0.92	1.48	-0.55	1.87	2.58	1.39	5.56
2006	Mean	1.18	1.62	-0.44	2.07	2.49	1.49	7.92
2007	Mean	0.29	1.34	-1.05	1.48	1.78	1.30	6.31
2008	Mean	0.00	0.99	-0.99	1.16	2.69	0.65	18.16
2009	Mean	0.20	1.11	-0.92	1.32	3.66	0.69	4.72
2010	Mean	-0.67	0.35	-1.02	0.51	3.60	0.30	-2.32
2011	Mean	0.73	1.38	-0.64	1.72	2.16	1.07	4.53
2012	Mean	0.17	0.77	-0.71	1.18	3.81	0.62	13.30
2013	Mean	-0.29	0.32	-0.61	0.68	1.61	0.48	-0.80

Table 5: Average weekly maximum, minimum, grass minimum and soil temperatures, temperature range and weekly rainfall for the period 1966-1977.

Year	Statistic	Maximum temp. (deg C)	Minimum temp. (deg C)	Temperature range (deg C)	Mid-range temp. (deg C)	Grass min. temp. (deg C)	Soil temp. (deg C)	Manual rainfall (mm)
1966 to 1977	Mean	12.53	2.69	9.84	7.60	-0.64	7.91	55.09
	SD	5.26	4.45	3.33	4.58	4.68	3.64	48.21
	n	599	599	599	600	523	570	598
	SE	0.21	0.18	0.14	0.19	0.20	0.15	1.97

Terrestrial: Manual Meteorology (MM)



Temperature:

Maximum and minimum manual dry-bulb temperatures are +0.32°C and +1.12°C respectively over the period 1996-2013, in relation to the International Biological Programme base-line data from the site for 1966-1977. The increases are significant ($p < 0.05$ and $p < 0.001$, respectively)

The overall trends since the start of recording on the ECN site in 1995, has been for a rise up to around 2003-04, followed by a fall with the colder winters of 2010-2012.

Figure 7: Annual maximum and minimum manual dry-bulb temperature residuals in relation to baseline IBP data from 1966-1977.

Terrestrial: Manual Meteorology (MM)

Soil temperature:

Soil temperature changes more slowly than air temperature, so the weekly readings can be used as a good proxy for the mean soil temperature. Compared to the 1966-77 data, soil temperatures over the period 1996-2013 are +0.85°C higher ($p < 0.001$).

As with the maximum and minimum temperature residuals (Figure 7), the trend over the period is best fitted with a 2nd degree polynomial.

Figure 8: Annual soil temperature residuals for the period 1996-2013 in relation to baseline IBP data from 1966-1977.

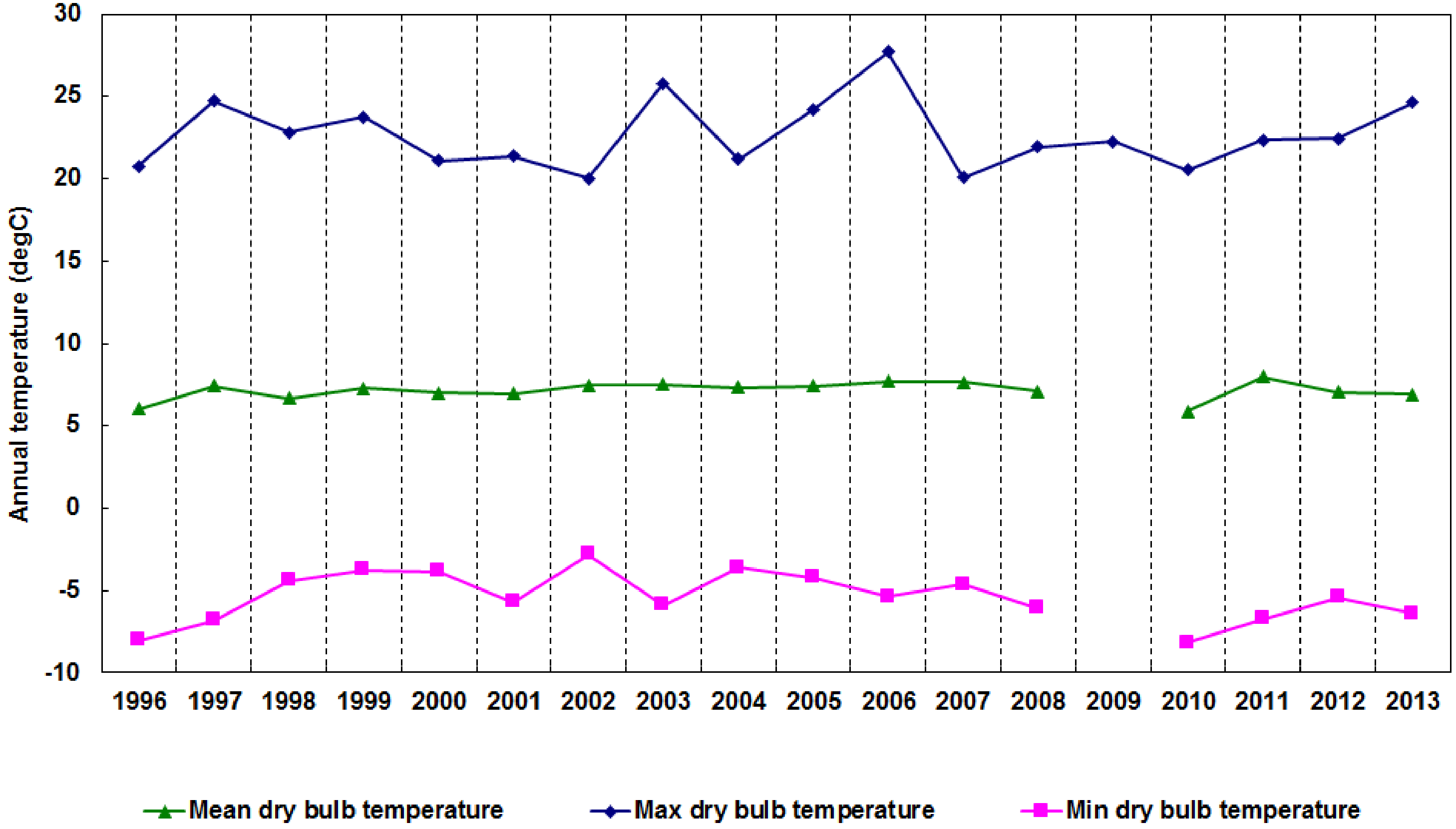
Terrestrial: Manual Meteorology (MM)

Rainfall:

Averaged weekly manual rainfall residuals (in relation to averaged weekly IBP data) are significantly higher per week than in the 1966-77 period (5.24mm on average, $p < 0.05$). This translates to an increase in annual rainfall of 272.4mm. The trend over the period 1996-2013 is not significant. There is quite considerable year-to-year variation e.g. an excess of 22.87 mm/week translates to an extra 1189mm annually in 2000, whereas in 1996 a deficit of 11.2mm/week equates to a reduction of 582mm.

Figure 9: Averaged weekly rainfall residuals for the period 1996-2013 in relation to weekly baseline IBP data from 1966-1977.

Terrestrial: Automatic Weather Station (MA)



Temperature:

Maximum, minimum and mean automatic weather station (AWS) dry-bulb temperatures showed an increasing trend up to 2006, but with recent cooler years the trend is no longer significant.

Despite the ECN AWS datalogger being stolen in August 2010, hourly temperature recording was maintained throughout the period before replacement using a number of calibrated TinyTag recorders. The 2009 missing data is due to intermittent datalogger malfunction.

Figure 10: Mean, maximum and minimum annual temperature data from 1996-2013.

Terrestrial: Automatic Weather Station (MA)

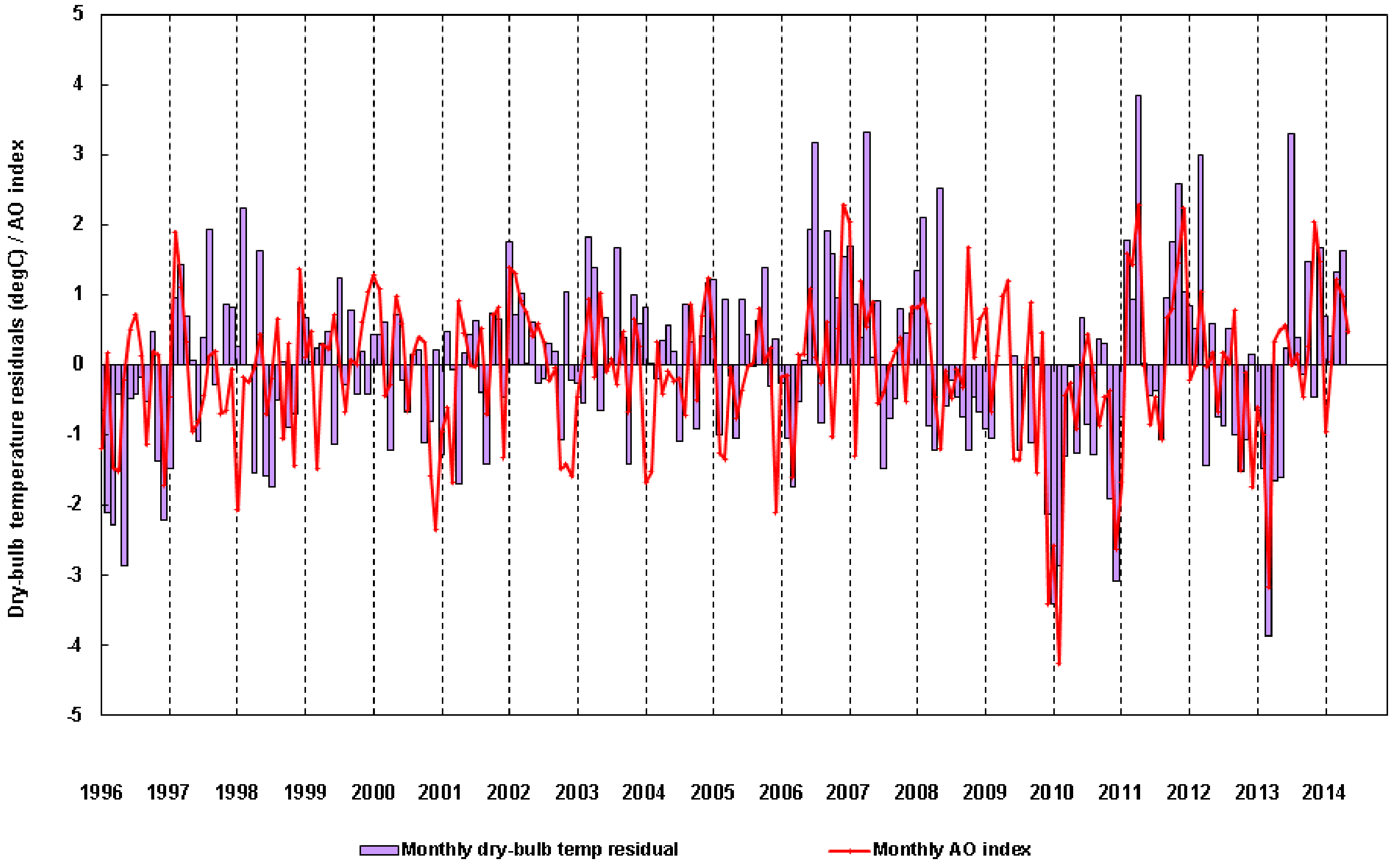


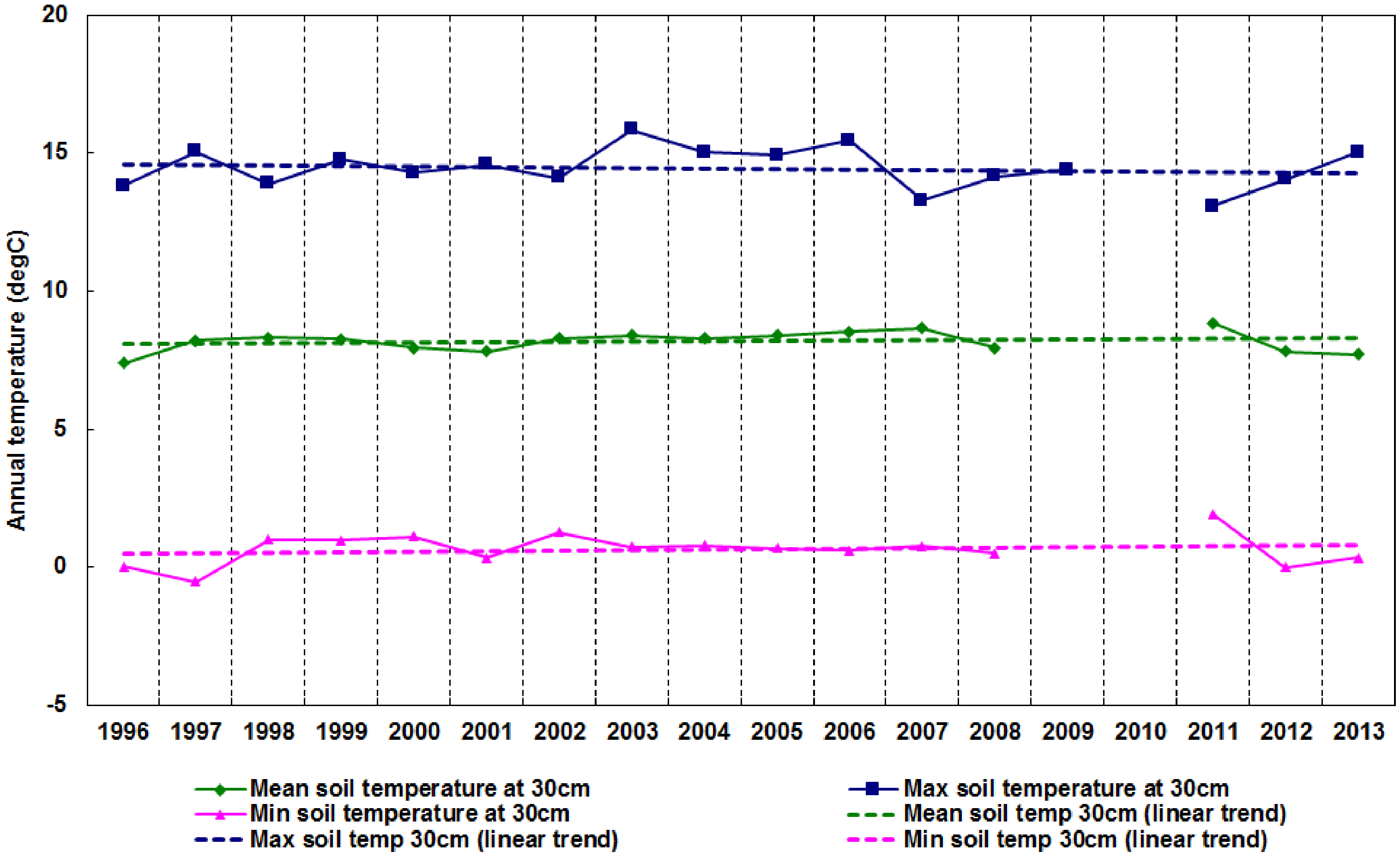
Figure 11: Monthly AWS dry-bulb temperature residuals and monthly Arctic Oscillation (AO) index from 1996-2011. Residuals are calculated in relation to mean temperature data for the same period. Above line = warmer or positive index, below line = cooler or negative index.

Temperature and Arctic Oscillation index:

Monthly dry-bulb temperature residuals across the period of recording clearly show strongly negative values during the winter and spring of 2013. After May 2013, however, the residuals are mostly positive, including through the winter and spring 2014. It is noticeable that the maximum size of residuals each year is larger from around 2010 onwards. Also the residuals are more clumped after 2009 i.e. there is a greater degree of autocorrelation between monthly values after 2009.

There is a good correlation between the sign of the temperature residuals and the sign of the Arctic Oscillation index ($\chi^2 = 12.97$, df=1, $p < 0.001$). Correlation between residuals and AO values is weak before 2008 ($R^2 = 0.081$), but much stronger from 2009 onwards ($R^2 = 0.46$). What this change represents is as yet unclear.

Terrestrial: Automatic Weather Station (MA)



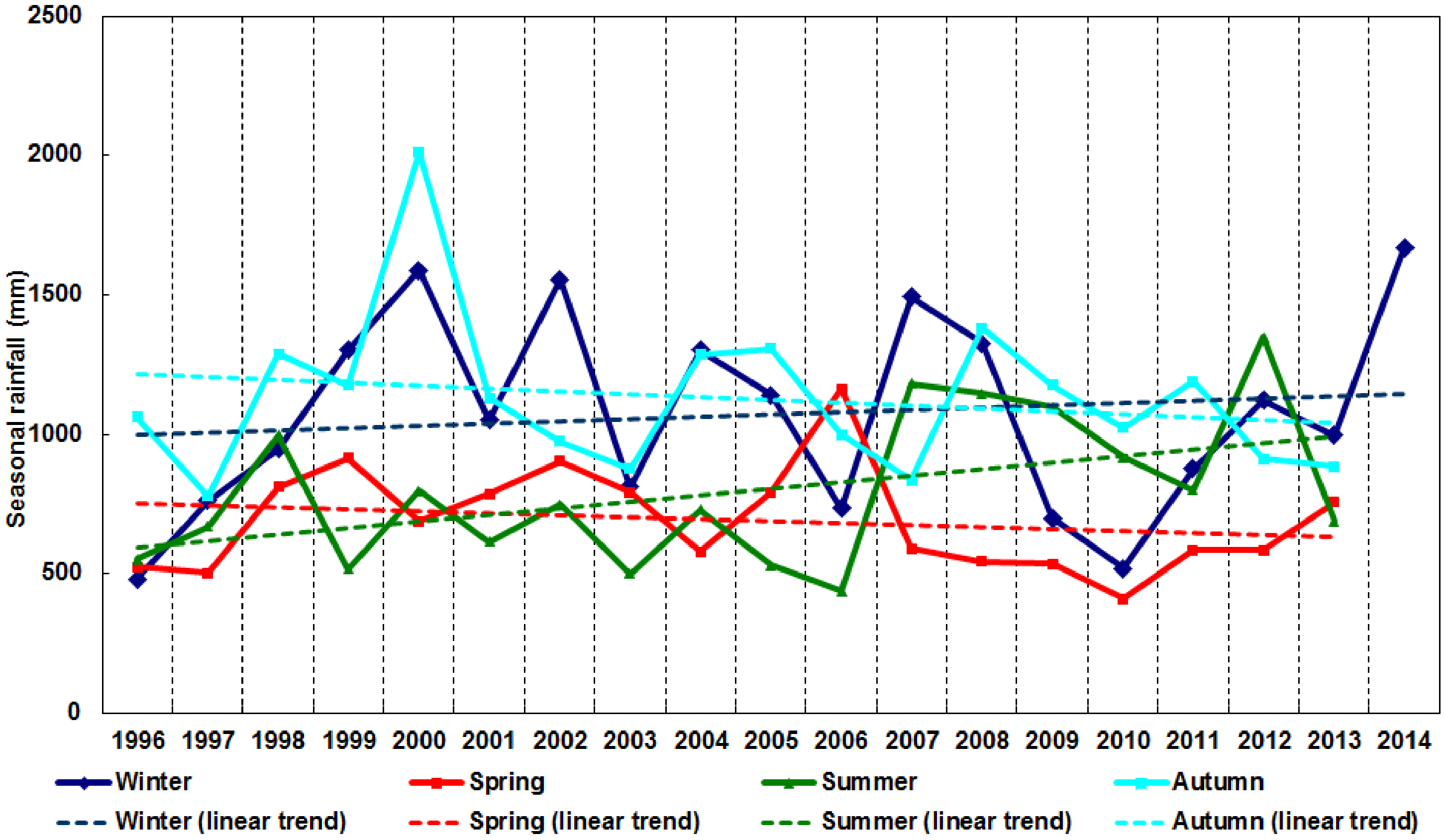
Soil temperature:

Maximum, minimum and mean soil temperature measured at a depth of 30cm showed a small upward trend in previous years but this is no longer significant.

Data are missing, from 2009 due to datalogger malfunction and from 2010 from theft.

Figure 12: Mean, maximum and minimum annual soil temperatures at 30cm from 1996-2013.

Terrestrial: Automatic Weather Station (MA)



Seasonal rainfall:

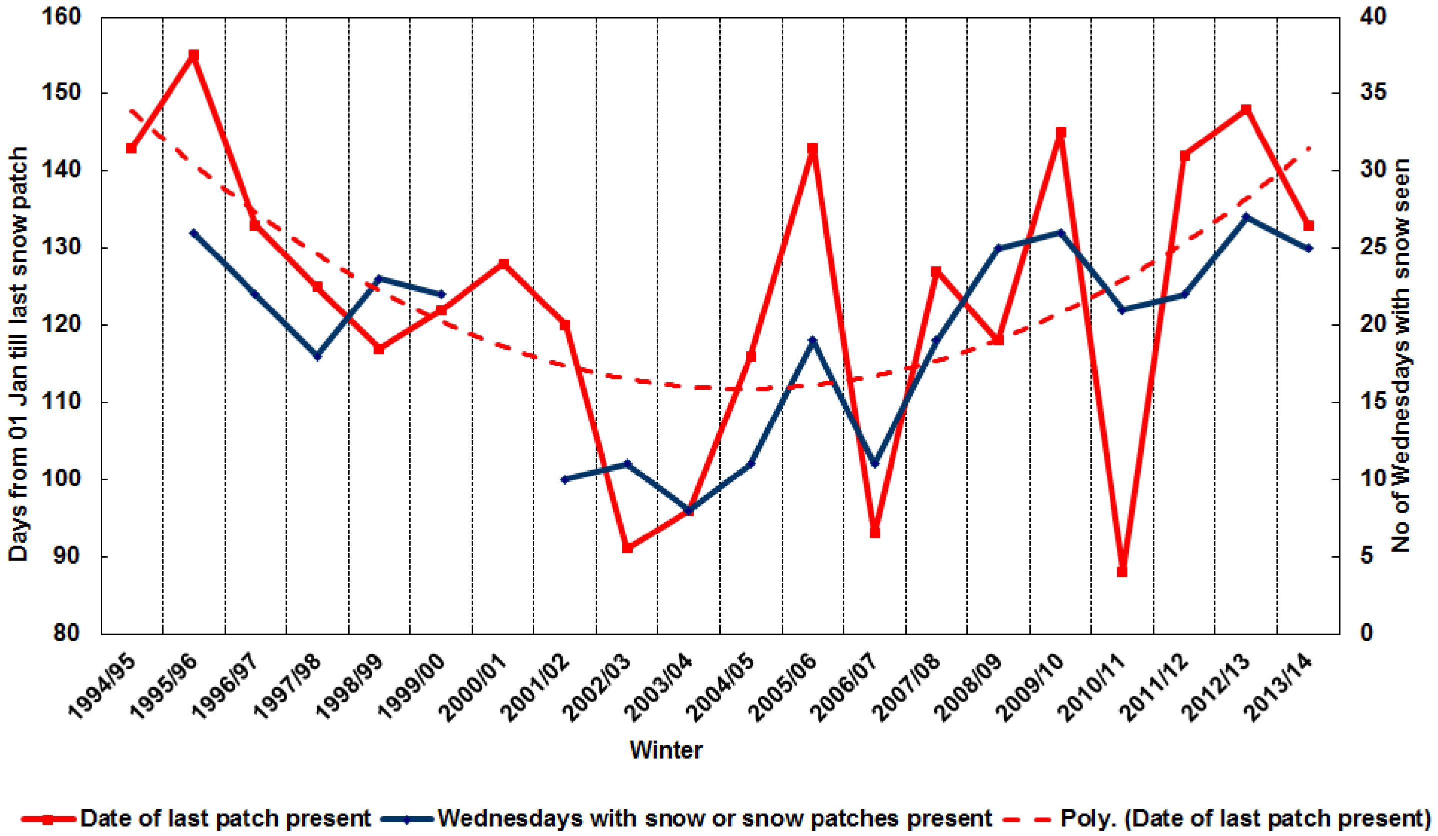
The rising trend for summer rainfall totals is mainly due to a series of wet summers from 2007-2012. The trend is significant ($p < 0.05$).

The formerly significant upward trend in the number of summer raindays (days with >= 0.2mm precipitation) is no longer significant.

The spring, autumn and winter rainfall totals, show no clear trend. The winter rainfall in 2013/14 was the highest since recording began in 1995/6, and rain fell on 85 out of 89 days.

Figure 13: Seasonal rainfall totals from Winter 1995/6 to Winter 2013/4.

Snow Duration Recording



Snow:

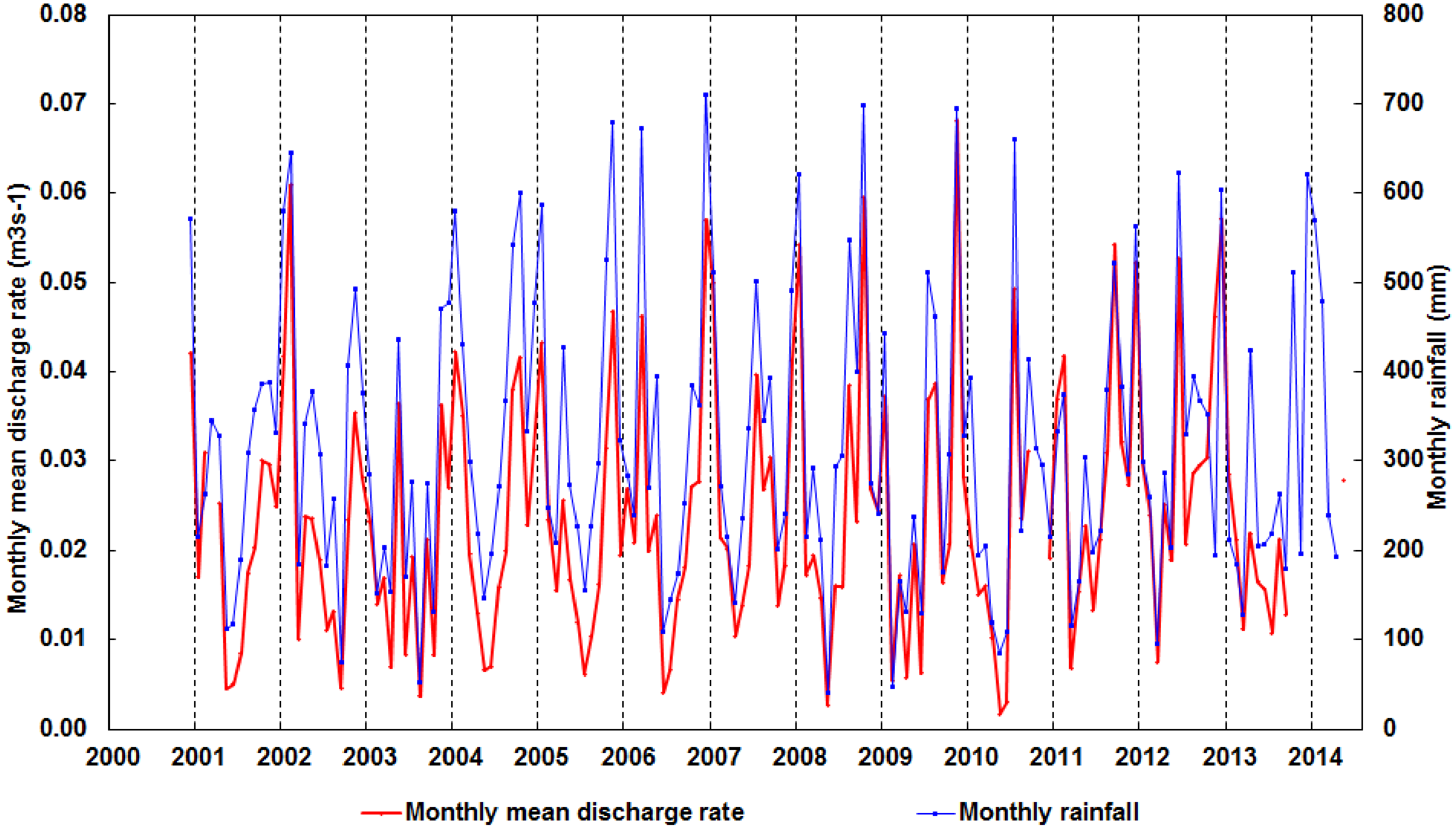
Snow duration recording is a non-ECN protocol which has been undertaken since 1995.

The 2013/2014 winter was very mild and at lower levels in Gwynedd there was little or no snow. At altitudes above 600m, however, there was a considerable amount of snow, the last remnants of which lasted until mid-May which is comparable with melt dates in the mid-1990s.

Figure 14: Date of last snow patch present on ECN site and number of Wednesdays with continuous snow or snow patches present somewhere on the site.

3.3 Data summary physical variables – Freshwater

Terrestrial: Surface Water Discharge (WD) and Freshwater: Surface Water Discharge (FWD)



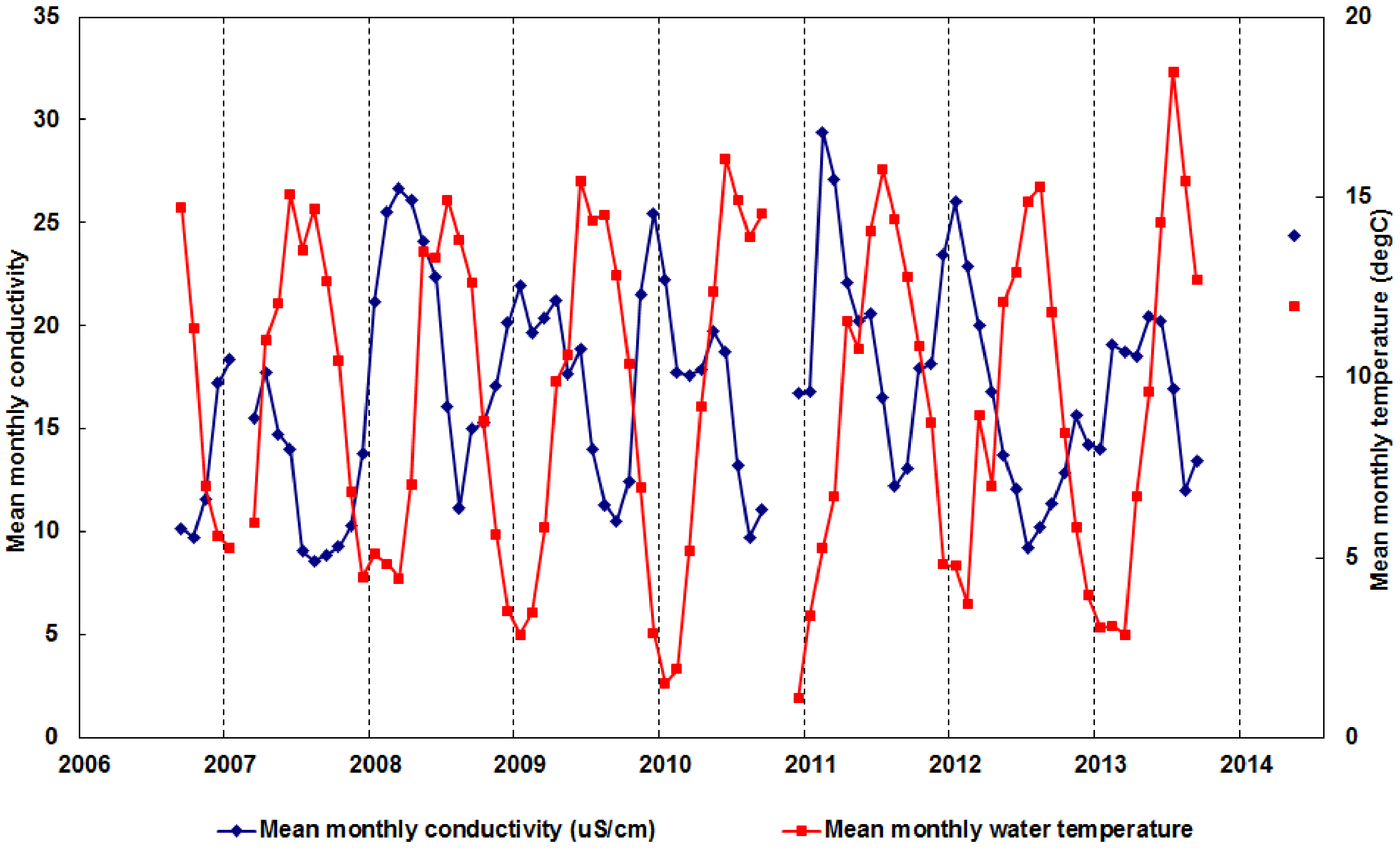
Nant Teyrn discharge:

Monthly mean discharge rate closely matches monthly rainfall and shows a pronounced seasonal variation with a minimum generally in spring to early summer, and a maximum often in the winter period.

Summer peaks are also seen for the years 2007 to 2012.

Figure 15: Monthly mean discharge rate across Nant Teyrn weir and monthly rainfall at ECN weather station**.**

Freshwater: Physical Variables (FWA)



Conductivity and temperature:

Water conductivity and temperature are sampled continuously at the Nant Teyrn weir.

Mean monthly conductivity shows a distinct seasonal pattern with low mean values (10-12 µScm-1) during late summer and early autumn and high values (17-26 µScm-1) during the winter and early spring.

Mean monthly temperature during winter is around 3-7 ºC and 12-19 ºC in spring and summer.

Figure 16: Monthly mean conductivity and temperature at Nant Teyrn. Missing data due to datalogger malfunction.

3.4 Chemical variables overview.

Diffusion tube samplers, used to monitor dry deposition, continue to show a significant decrease in sulphur dioxide following reductions in emissions (Figure 18). Despite similar national declines in nitrogen dioxide, the trend at Snowdon is level and not significant (Figure 17), but the concentration is low in relation to national concentrations. Ammonia sampling on the ECN site and at Plas y Brenin, undertaken on behalf of UKEAP, indicates that levels are low, but no trend is evident (Figures 19 and 20).

Continuous ozone monitoring at Marchlyn Mawr continues to shows a steady decrease over the period 2000-2014 in average spring concentration, and average annual concentrations (Figures 21 and 23). Critical levels of ozone for semi-natural vegetation in the spring have not been exceeded since 2006 (Figure 23). In comparison with other remote rural background sites in the uplands in the UK, the downward trend in concentration is unusual (Figure 22).

Chemical analysis of weekly precipitation shows a continuing significant increase in pH (Figure 24) and highly significant declines in sulphate and nitrate (Figures 25 and 30).

Stream water collected from Nant Teyrn, originating in Llyn Teyrn, shows similar significant changes in pH, sulphate and nitrate. Significant decreases in labile aluminium, iron, phosphate, ammonium and dissolved organic carbon (DOC) (Figures 26, 27, 28, 31 and 32) are also seen. The highest spike in chloride concentration was seen in February 2014 after a series of vigorous depressions crossed the UK (Figure 37) deposited captured sea-water.

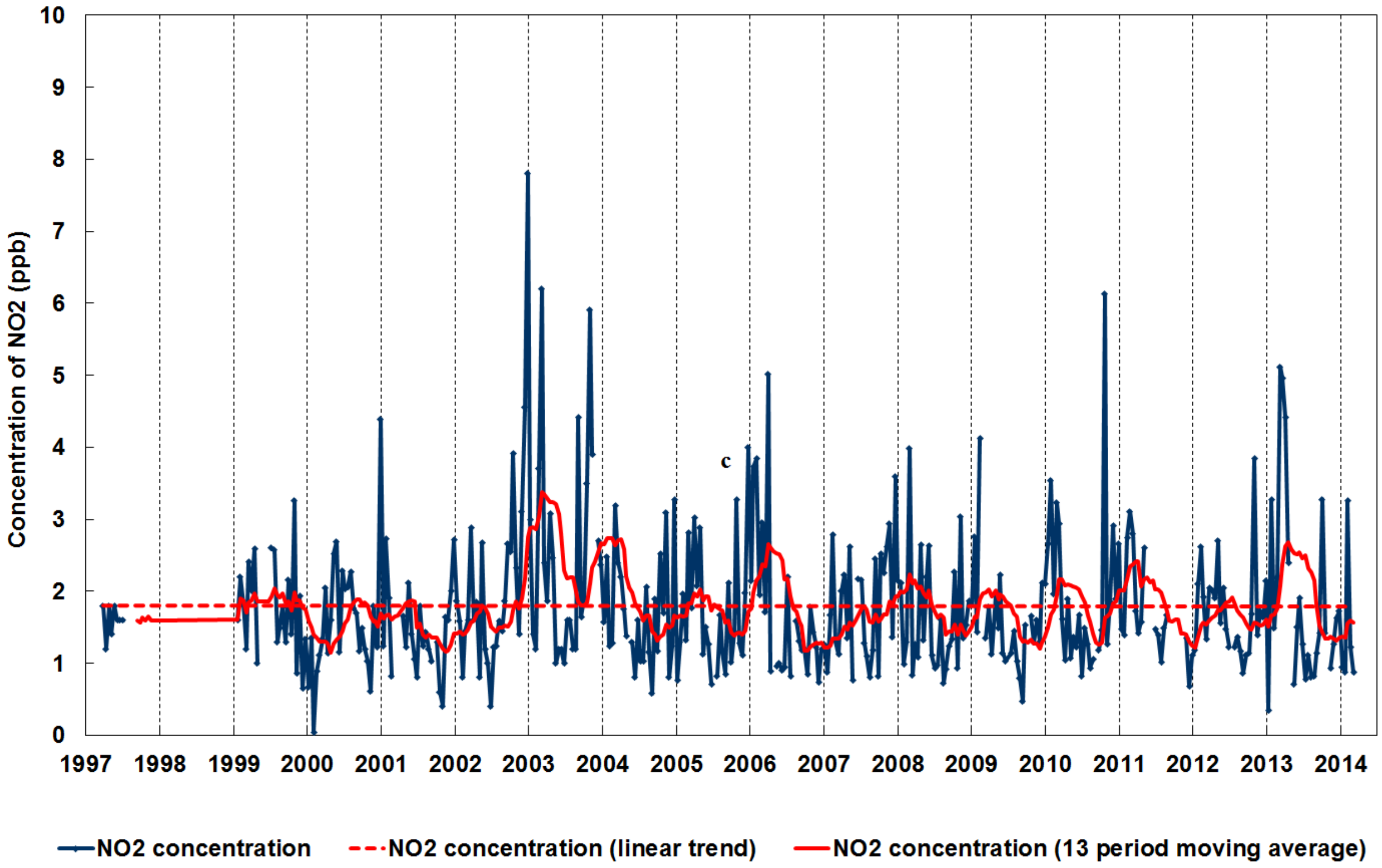
Changes in soil solution chemistry show some parallels with those for precipitation and surface water, including the increase in pH and decreases in sulphate at both the shallow and deep levels. Ammonium, chloride and dissolved organic carbon also show decreases at both levels (Figures 29, 31 and 32). At shallow levels, but not deep, phosphate and iron show decreases (Figures 26 and 28), while conversely aluminium shows a decrease at deep levels but not shallow (Figure 27).

Monthly freshwater sampling has been undertaken at the Nant Teyrn site for 8 years, but the data runs for individual heavy metals are mainly too short, when they are above the limit of detection, to indicate significant or meaningful trends. Dissolved copper, mercury and silicate are, however, falling significantly (Table 9 in Appendix 1). A spike in zinc, copper, nickel, silicate and calcium concentrations was noted in December 2013 (Figure 35) and may be associated with sedimentary input to Llyn Teyrn. Acid Neutralizing Capacity has shown no significant change.

In terms of critical loads, there has been a significant decrease in both nutrient nitrogen and acidity. The level of nutrient nitrogen (NH_3-N + NO_3-N) was at its lowest in 2011-13, and although below the maximum critical load for most Annex I heath, grassland and fen habitats on the site, still above the minimum load for most habitats (Table 6). Levels of acidity, expressed as nutrient nitrogen plus non-marine sulphate, were also at their lowest level since sampling began in 1997 (Figure 33).

3.5 Data summary chemical variables – Terrestrial

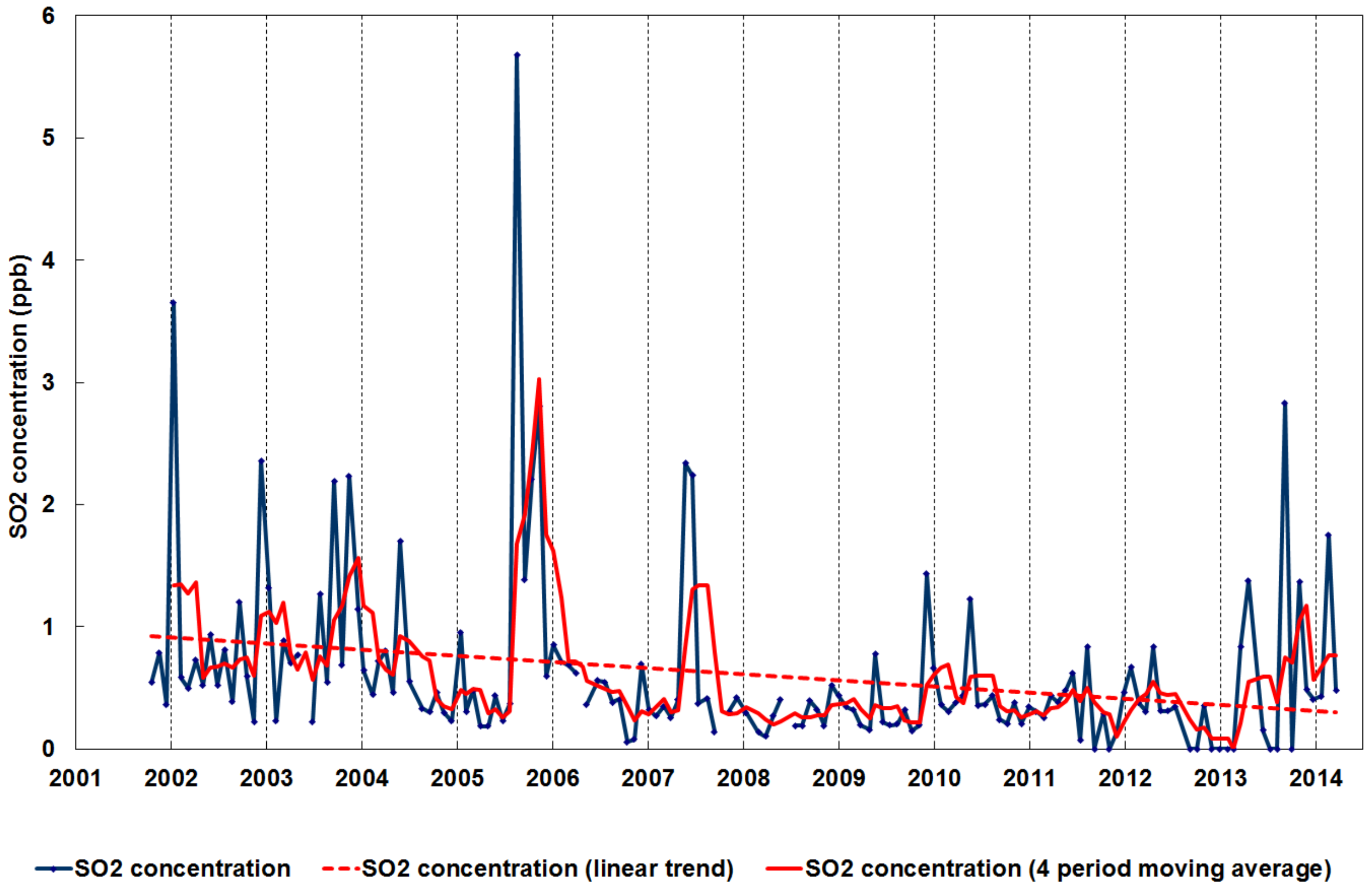
Terrestrial: Atmospheric chemistry (AN & AS)



Nitrogen dioxide:

Despite a degree of variability, there is very little change in the average level of dry deposition of NO_2 over the recording period. A 3-month moving average reveals an annual cycle, with a maximum in late winter and spring and a minimum in summer and early autumn.

Figure 17: Fortnightly concentration of NO_2 at Yr Wyddfa/Snowdon ECN site over the period 1997-2014.



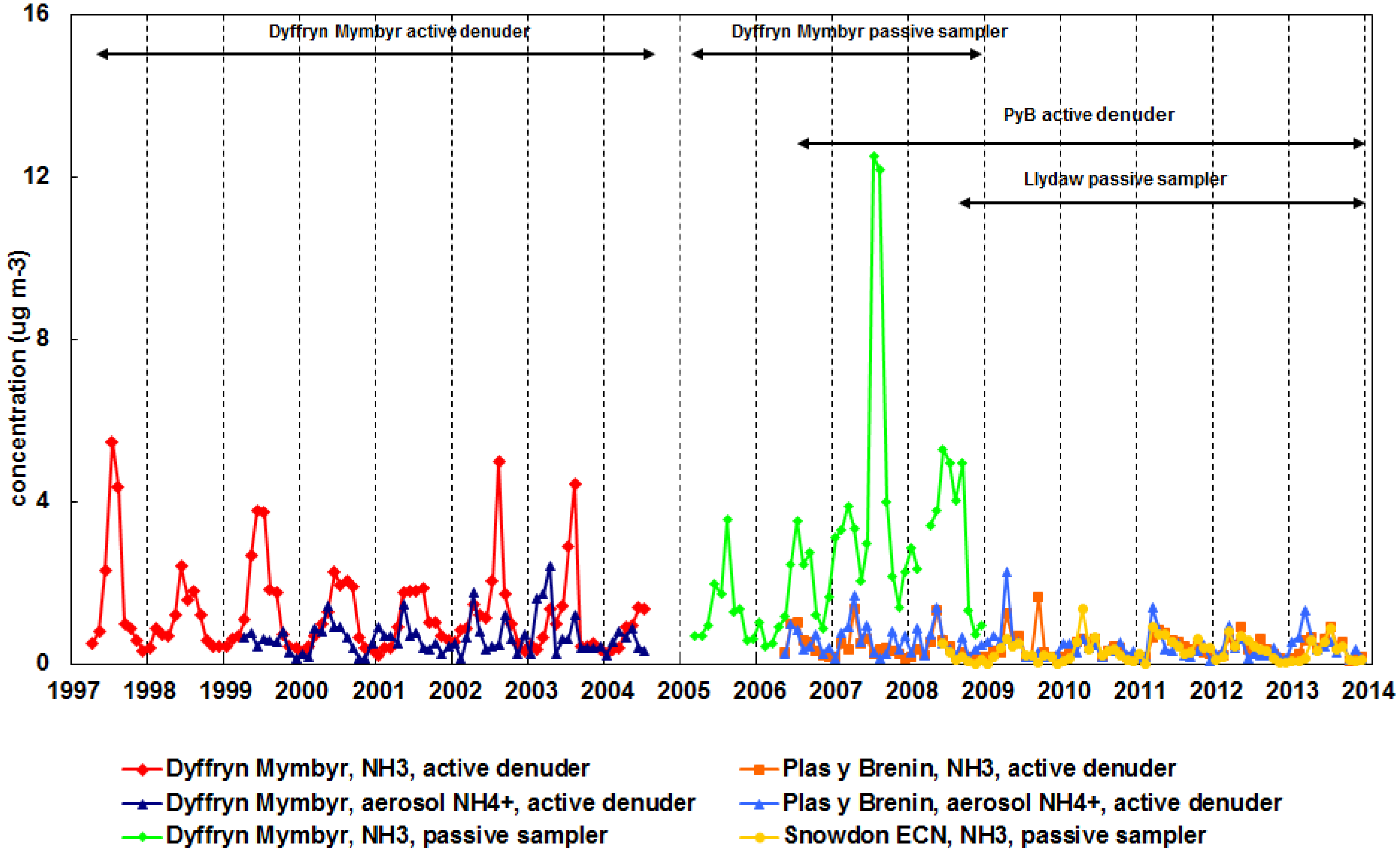
Sulphur dioxide:

Dry deposition of SO_2 on Snowdon shows a clear and significant decline over the recording period ($p < 0.05$).

Concentrations in 2013-14 have risen slightly in comparison to the years 2008-12, possibly as a result of reduced precipitation. The year with the highest concentration also had the lowest summer rainfall.

Figure 18: Monthly concentration of SO_2 at Yr Wyddfa/Snowdon ECN site over the period 1997-2014.

Ammonia – All sites, 1997-2012



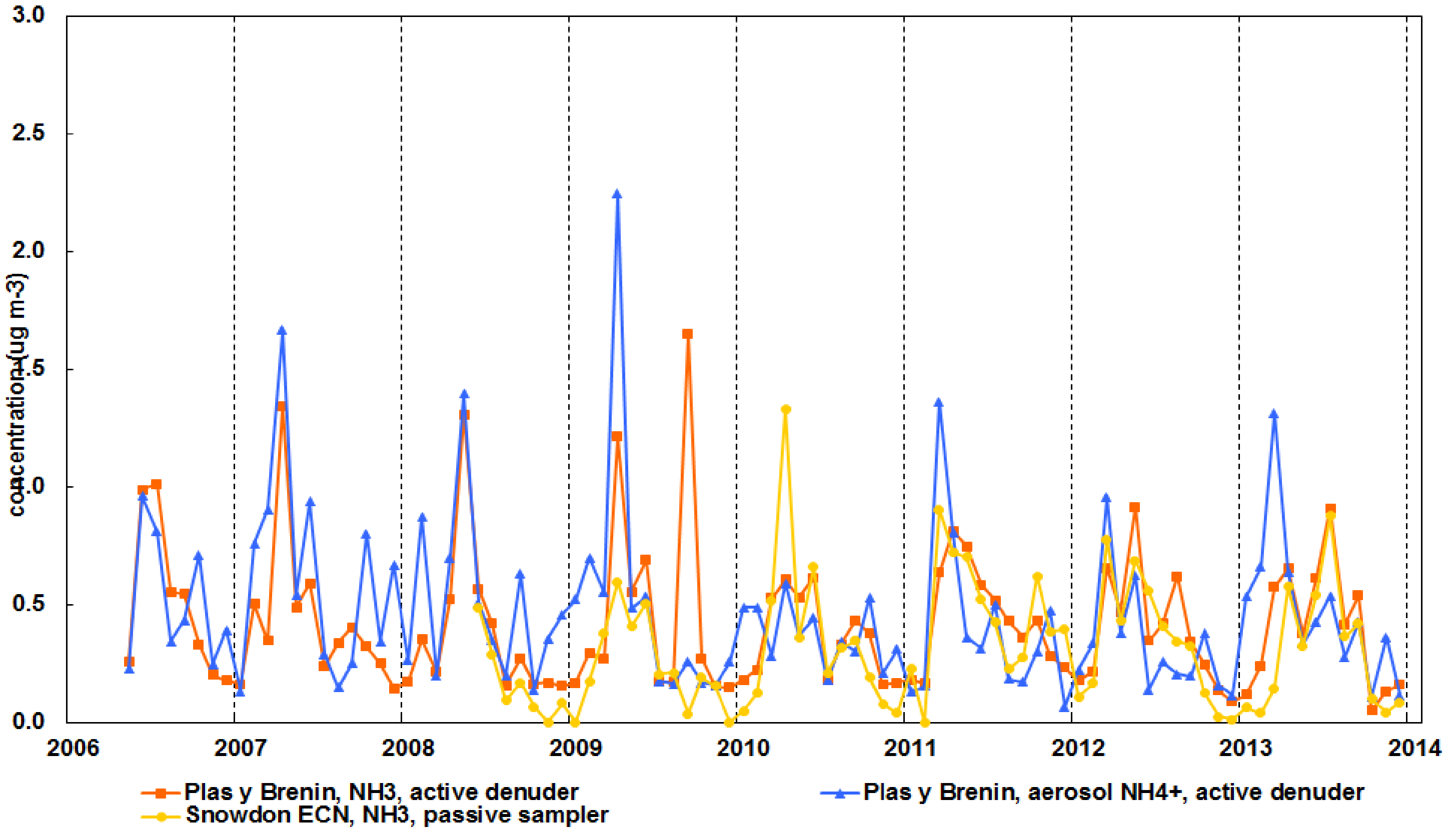
Ammonia:

Monitoring is undertaken for the UK Eutrophying and Acidifying Atmospheric Pollutants network at the ECN site and at Plas y Brenin (8km away). Recording from 1997-2004 was initially at Dyffryn Mymbyr (5.7km from the ECN site), but following a change of ownership, the sampler was moved to Plas y Brenin (8km from the ECN site). Additional passive samplers were installed on the ECN site in 2006.

Levels of NH_3 and NH_4^+ at Dyffryn Mymbyr are much higher than at the other two locations, due to its occasional agricultural use, whereas levels at Plas y Brenin and the ECN site are more typical of background levels.

Figure 19: Concentrations of NH_3 and NH_4^+ at Dyffryn Mymbyr, Plas y Brenin and Yr Wyddfa/Snowdon ECN site over the period 1997-2013. Data courtesy of Sim Tang, CEH Edinburgh.

Ammonia – Plas y Brenin and Yr Wyddfa/Snowdon ECN site, 2006-2012



Ammonia:

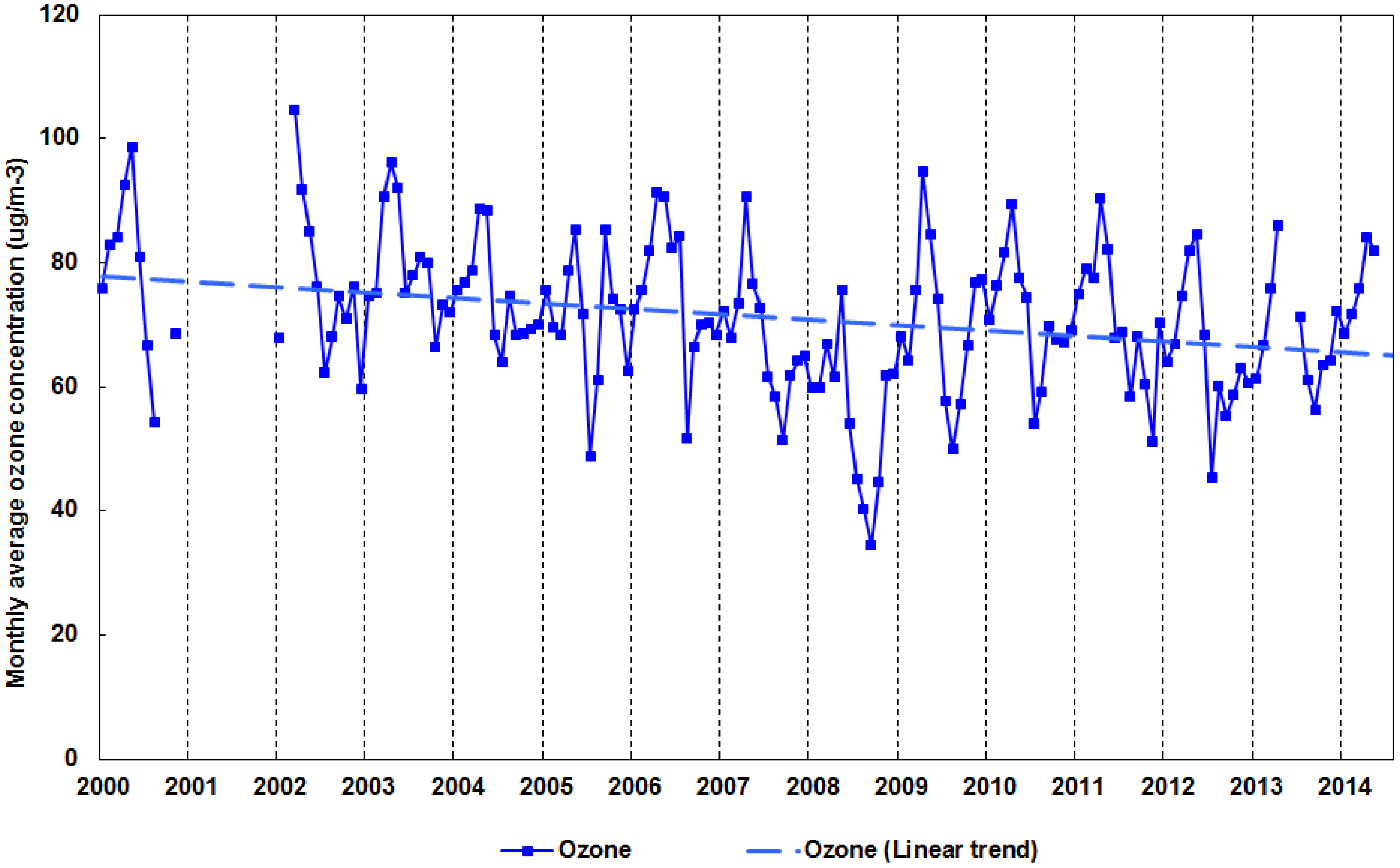
Levels of NH_3 and NH_4^+ at Plas y Brenin and the Snowdon ECN site show very similar annual variation with a peak during the drier part of the spring to early summer, and a minimum in winter.

There is no obvious trend with such a short run of data.

UK NH_3 emissions peaked in the 1980s and have declined by 15% since. Ambient concentrations, however, have changed little in the same period (RoTaP, 2012).

Figure 20: Four-weekly concentration of NH_3 and NH_4^+ at Plas y Brenin and NH_3 at Yr Wyddfa/Snowdon ECN site over the period 2006-2013. Data courtesy of Sim Tang, CEH Edinburgh.

Ozone



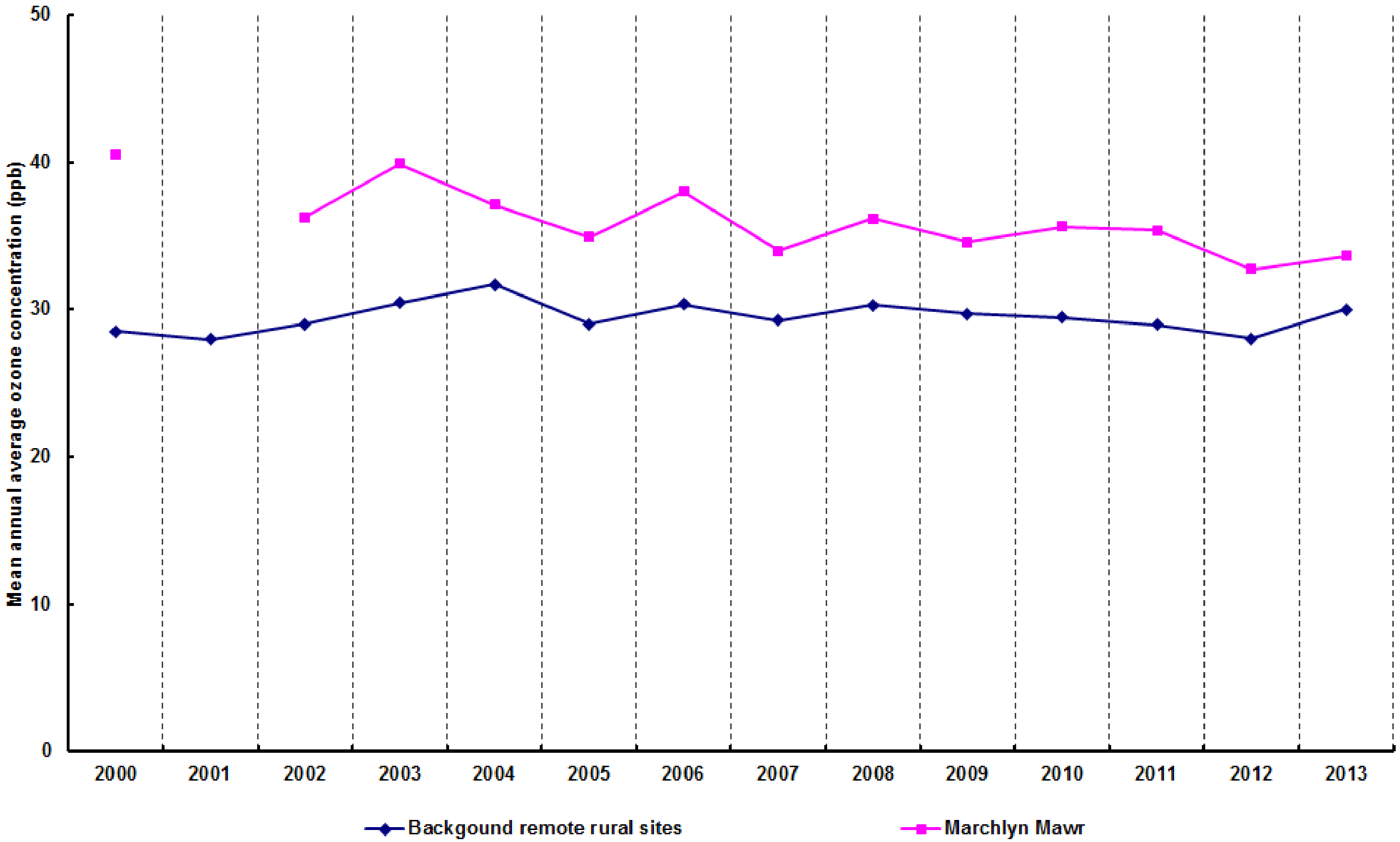
Ozone:

Continuous ozone and NO_x monitoring is undertaken at Marchlyn Mawr. The downward trend in monthly ozone concentration is significant ($p < 0.01$). The downward trend in NOx (not shown) is also significant ($p < 0.01$). Also not shown, Spring ozone concentrations show a significant decline from an average of 46ppb in 2000 to 40ppb in 2013 ($p < 0.05$).

Data is ratified by Ricardo-AEA on behalf of the Welsh Air Quality Forum (www.welshairquality.co.uk/).

Figure 21: Monthly mean ozone concentration at Marchlyn Mawr over the period 2000-2013.

Ozone



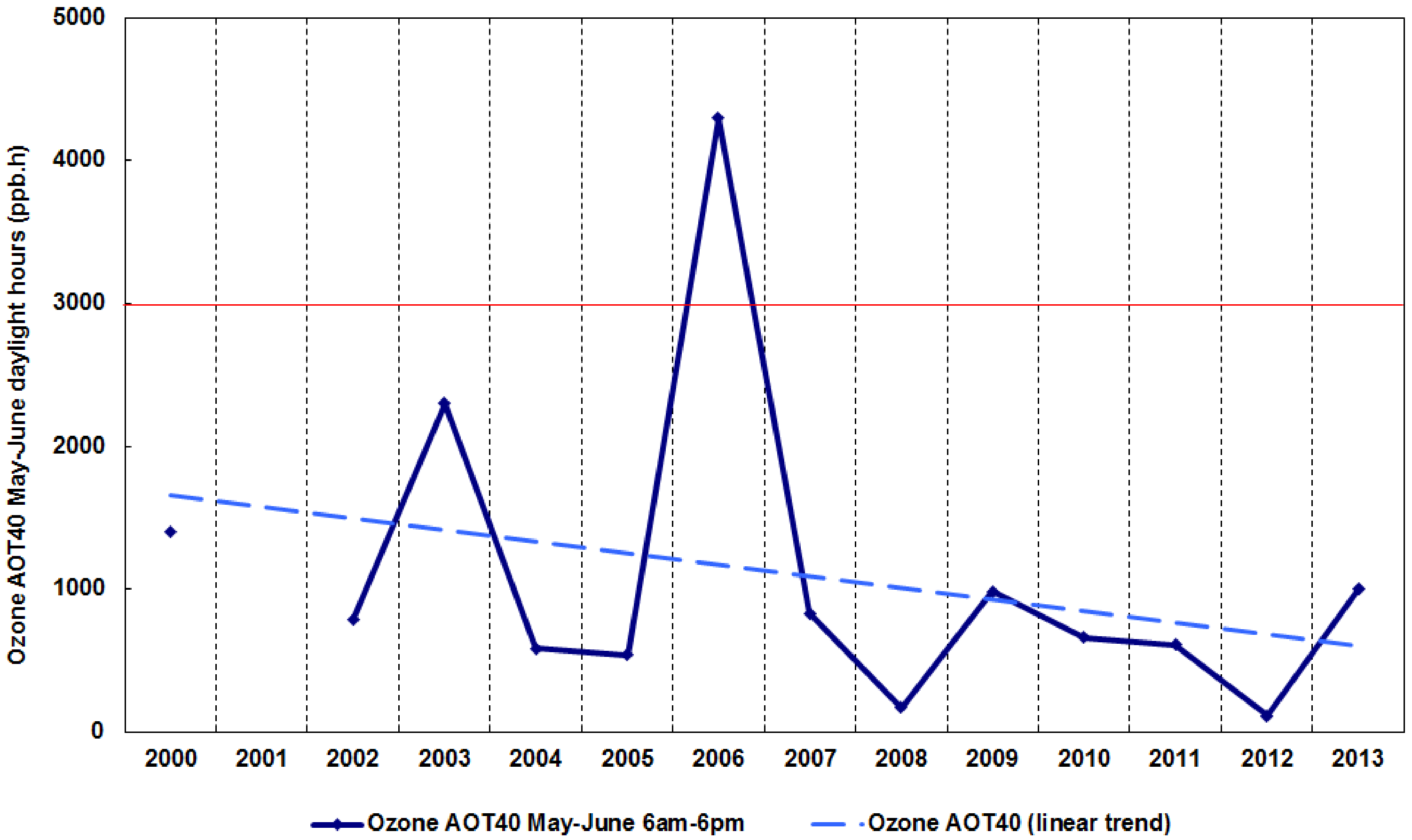
Ozone:

Compared with other similar remote sites, Marchlyn Mawr’s decline is atypical. The figure shows a comparison with averaged annual ozone concentrations from other Rural Background Natural sites (uk-air.defra.gov.uk/data). These comparable, generally upland sites, classed as remote, are Strathvaich, Eskdalemuir, Great Dun Fell, High Muffles, Ladybower Reservoir and Yarner Wood (2000-11) and all are part of the Automatic Urban and Rural Network (AURN).

In general, the levels at Marchlyn Mawr are higher than at these other sites.

Figure 22: Average annual ozone concentration at Marchlyn Mawr over the period 2000-2013 in comparison with remote Rural Background Network sites in the UK uplands.

Ozone

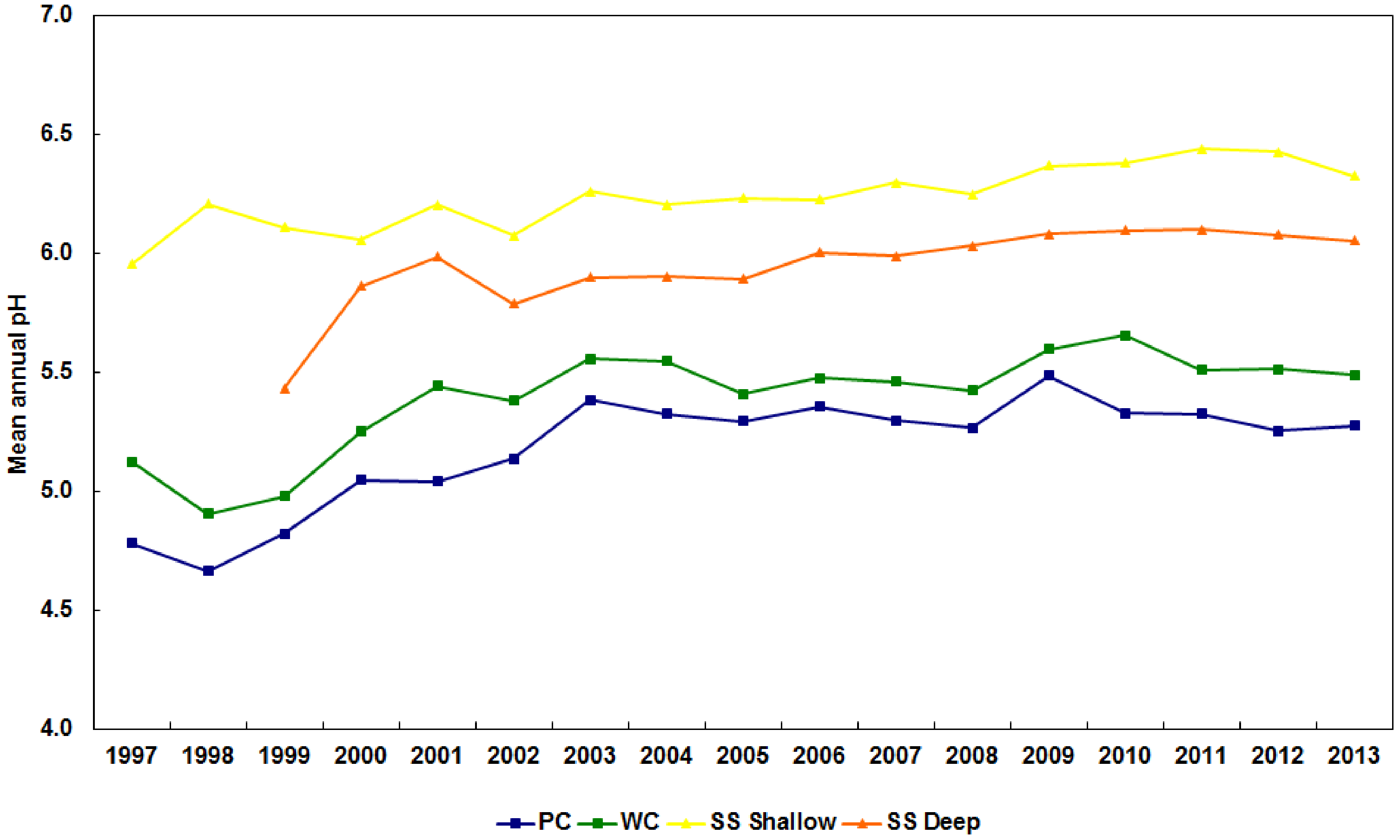


Ozone:

High levels of ground-level ozone have been implicated in damage to vegetation. AOT40, the accumulated dose over 40ppb during daylight hours in May-July is a measure of the potential harmful effect of ozone on vegetation. At Marchlyn Mawr, there is a gentle downward trend over the recording period, but it is not significant. The critical level for AOT40 for semi-natural vegetation, 3000 ppb.h, hasn't been exceeded since 2006.

Figure 23: Accumulated dose over the threshold concentration of 40ppb (AOT40) at Marchlyn Mawr during daylight hours in May-July over the period 2000-2013.

Precipitation chemistry (PC), Surface water chemistry (WC) and Soil solution chemistry (SS)



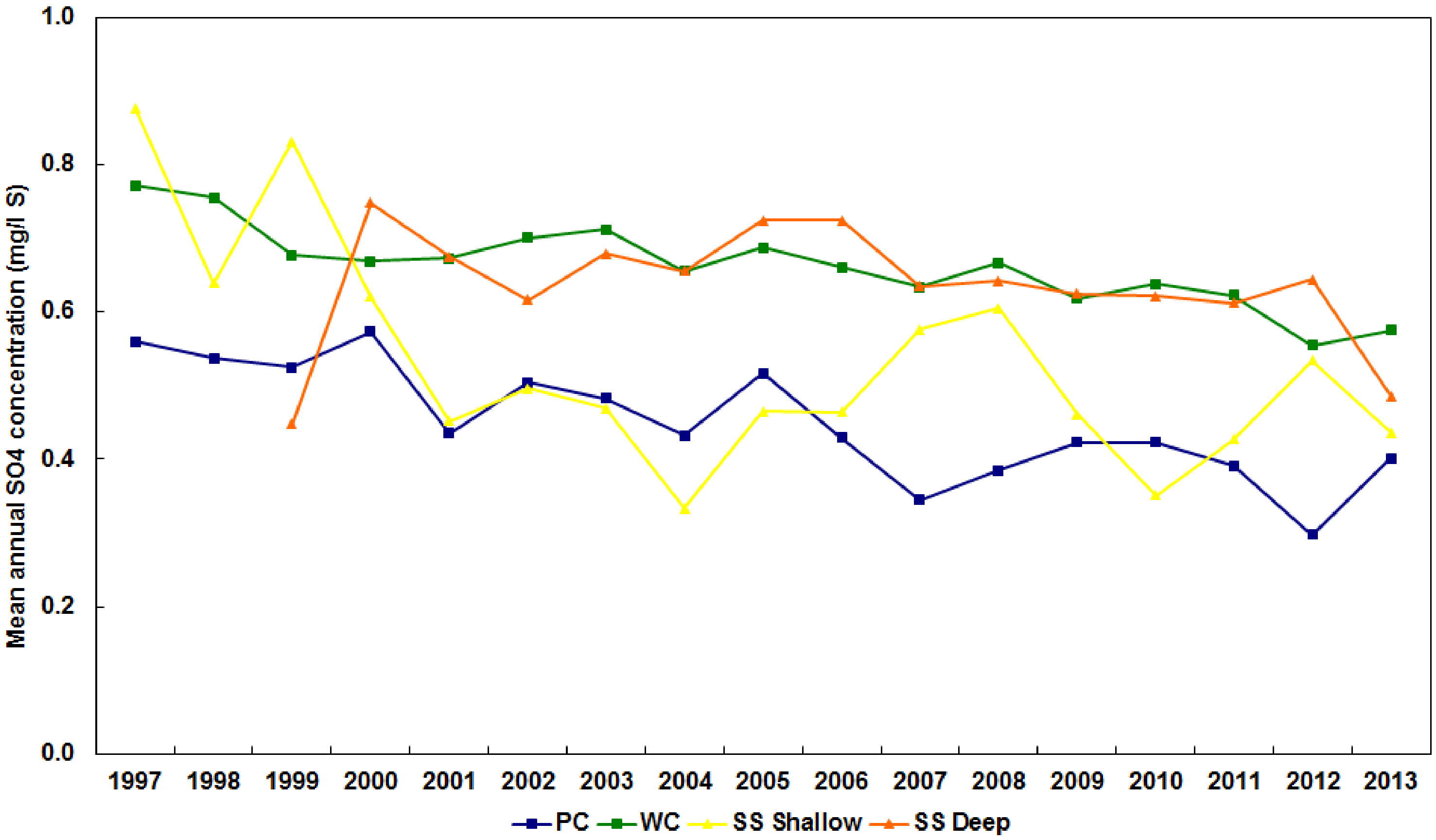
pH:

Trends in rainfall acidity are continuing to decline across the UK (1986-2007) (RoTaP, 2012) due to the cumulative effect of emission controls.

On Snowdon, surface and soil water pH levels have continued to increase significantly in line with the rise in rainfall pH, the rise being steeper from 1997-2003, followed by a more gradual increase to 2013. For precipitation, surface waters and soil waters the rise is highly significant ($p < 0.001$).

Figure 24: Mean annual pH for precipitation (PC), surface water (WC), and soil solution (SS=shallow, SD=deep) for the period 1997-2013.

Precipitation chemistry (PC), Surface water chemistry (WC) and Soil solution chemistry (SS)



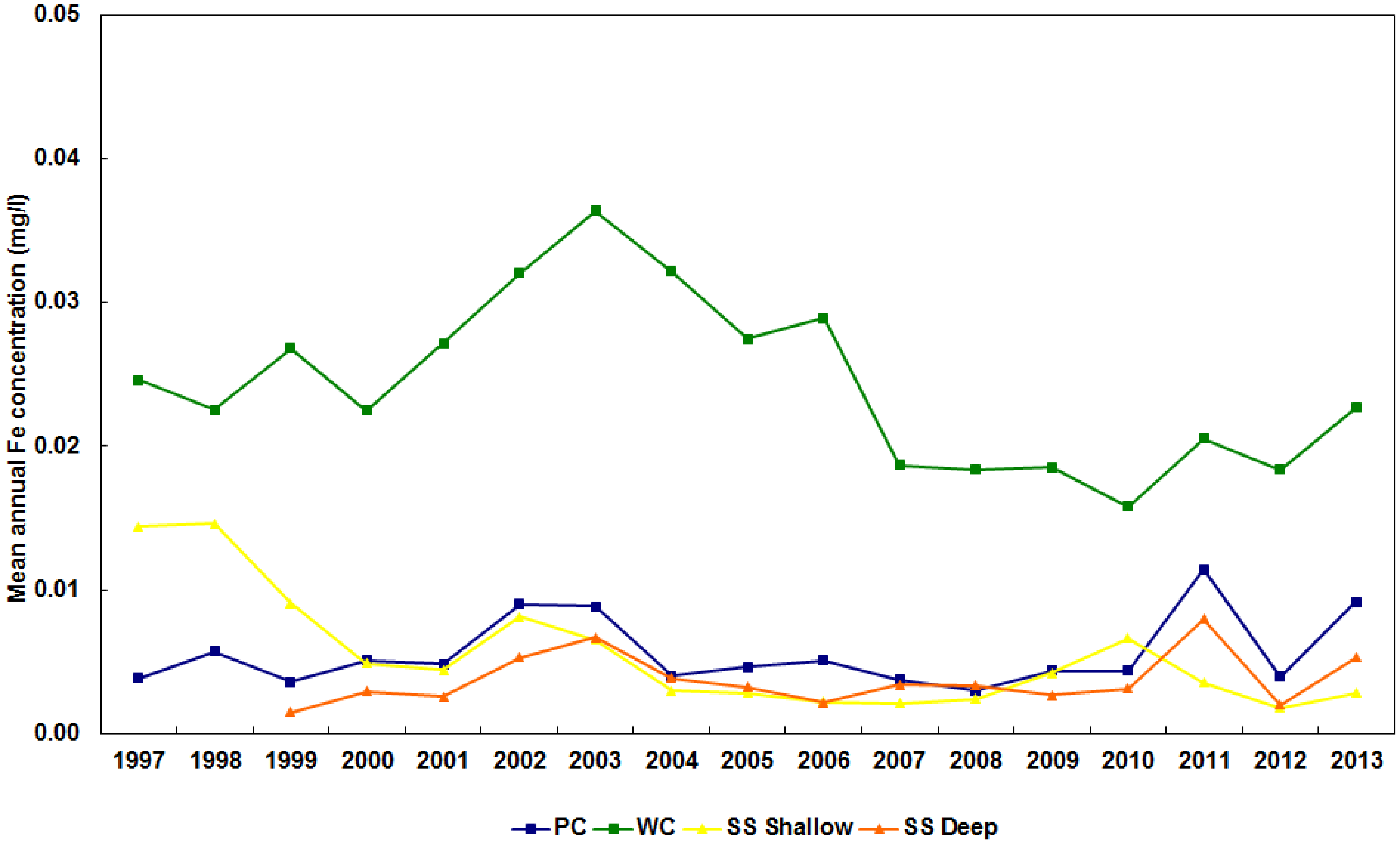
Sulphate:

UK sulphur emissions have decreased by 90% since the 1970s (RoTAP, 2012).

As a consequence, falls in deposition have been noted including on Snowdon where a highly significant downward trend in sulphate levels in rainwater and surface water can be seen ($p < 0.001$). The picture in soil water is more complex with a moderately significant decrease at shallow levels ($p < 0.01$), but a less significant change at deeper levels ($p < 0.05$).

Figure 25: Mean annual concentration of dissolved sulphate (SO_4) for precipitation (PC), surface water (WC), and soil solution (SS=shallow, SD=deep) for the period 1997-2013.

Precipitation chemistry (PC), Surface water chemistry (WC) and Soil solution chemistry (SS)



Iron:

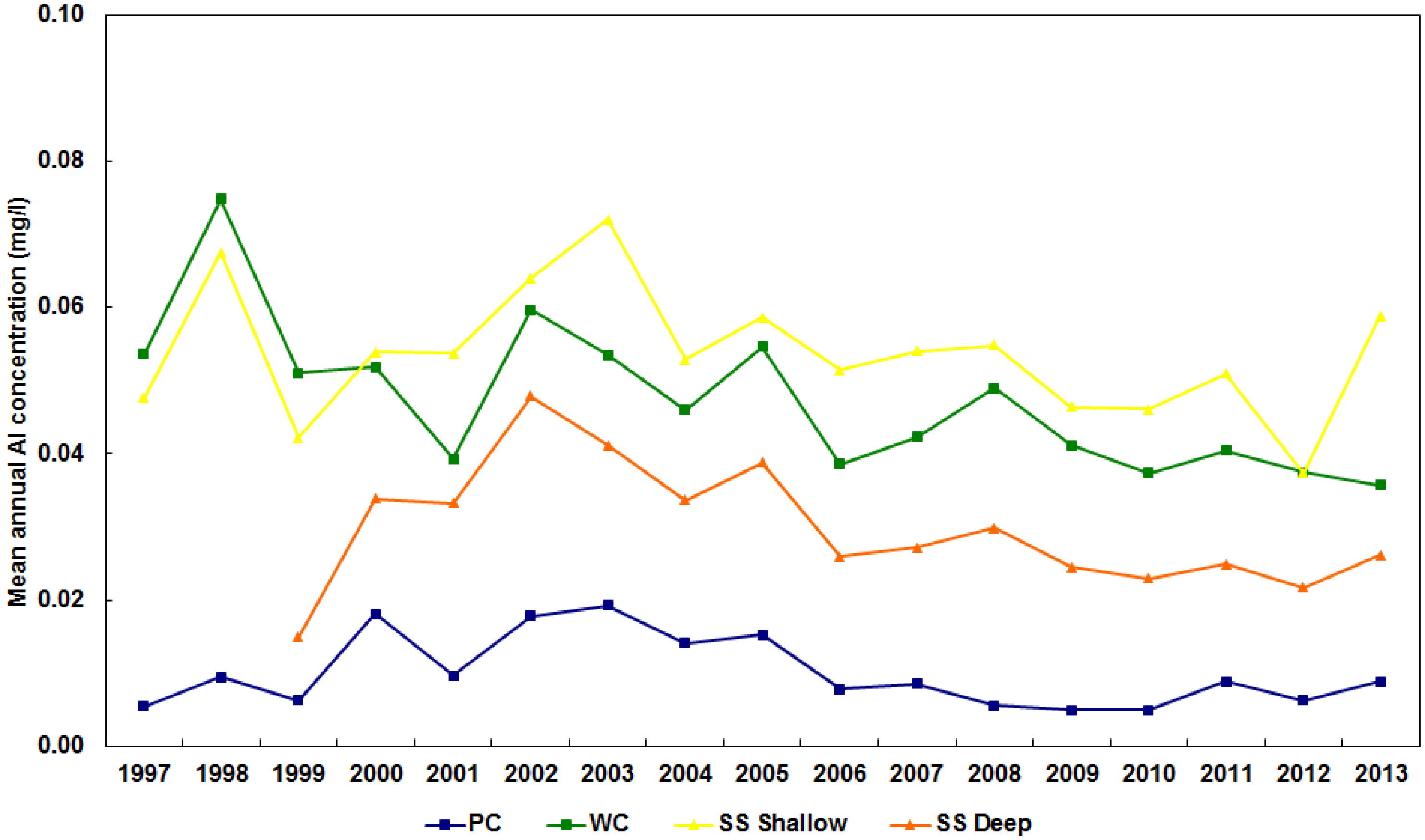
Higher levels of soluble iron in surface water from Nant Teyrn occurred during the period 2002-2006 when the summers were drier and warmer, whereas from 2007-2010, with cooler wetter summers, the concentrations have been much lower. Levels have been increasing again since 2011.

Iron concentrations in shallow level soil water and surface water show significant declines since 1997 ($p < 0.01$ and $p < 0.05$ respectively).

Trends in rain water and deeper level soil water are not significant.

Figure 26: Mean annual concentration of dissolved iron (Fe) for precipitation (PC), surface water (WC), and soil solution (SS=shallow, SD=deep) for the period 1997-2013.

Precipitation chemistry (PC), Surface water chemistry (WC) and Soil solution chemistry (SS)



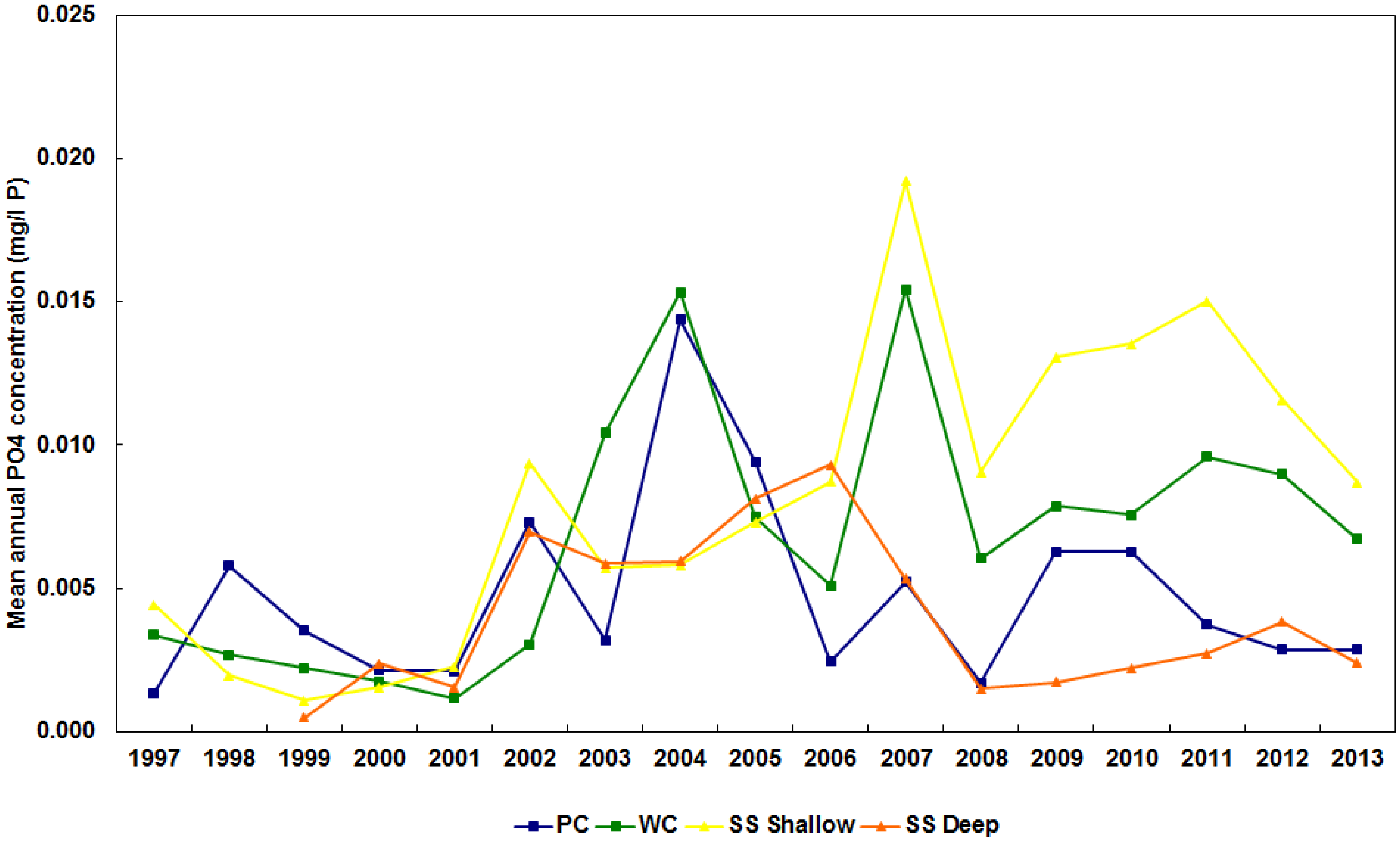
Aluminium:

Acid deposition can result in an increase in dissolved Al when soil buffering capacity is exceeded. Falls in levels of acid deposition should be associated with falls in mobile aluminium which is seen to fall in surface waters, where the declining trend is highly significant ($p < 0.001$).

For the calcareous grassland soil samplers the trend in the deep level samplers is significant ($p < 0.05$), while although the shallow level matches the deep level trend, it is not significant.

Figure 27: Mean annual concentration of dissolved aluminium (Al) for precipitation (PC), surface water (WC), and soil solution (SS=shallow, SD=deep) for the period 1997-2013.

Precipitation chemistry (PC), Surface water chemistry (WC) and Soil solution chemistry (SS)



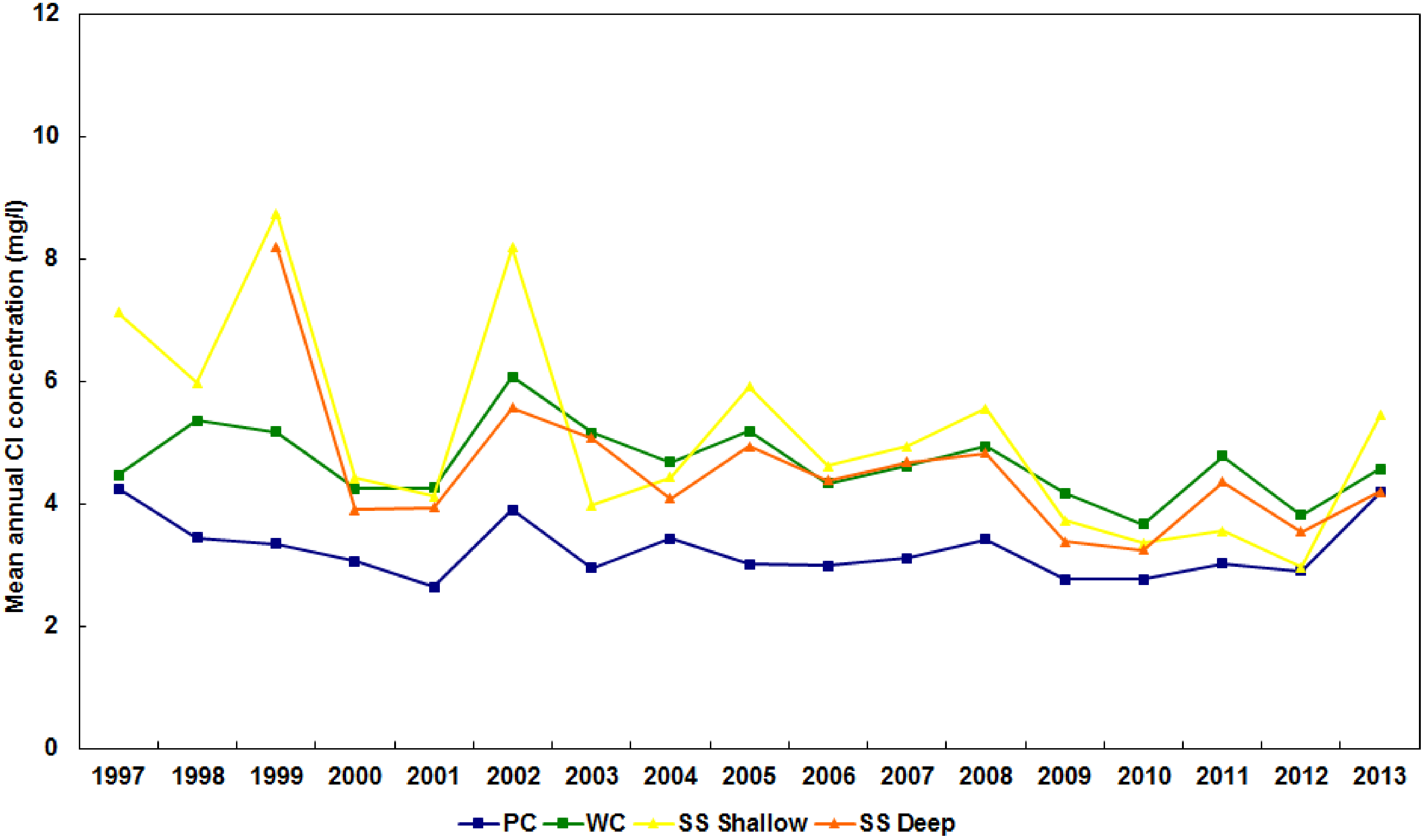
Phosphate:

Phosphate levels on Snowdon appear to be rising with the trend in surface waters and shallow level soil samplers both significant ($p < 0.01$ and $p < 0.001$ respectively).

The deep level samplers, parallel the shallow level ones up to 2006, but then decline and the trend is not significant.

Figure 28: Mean annual concentration of phosphate (PO_4-P) for precipitation (PC), surface water (WC), and soil solution (SS=shallow, SD=deep) for the period 1997-2013.

Precipitation chemistry (PC), Surface water chemistry (WC) and Soil solution chemistry (SS)



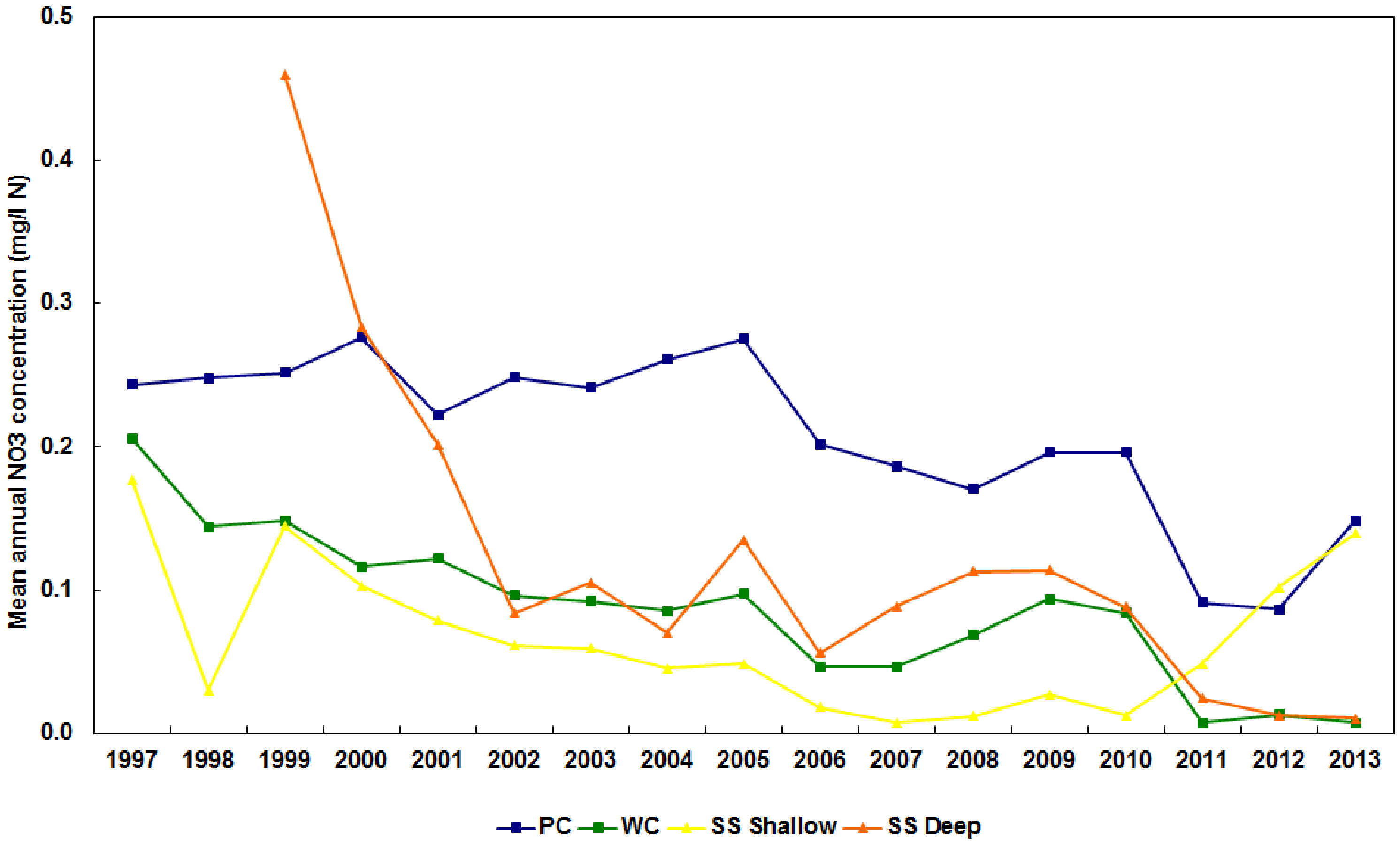
Chloride:

Chloride deposition mainly results from marine inputs associated with vigorous low pressure systems with strong westerly or south-westerly winds such as occurred during winter 2013-14.

Overall mean input concentrations from rainfall have fallen slightly, but not significantly, since 1997. There has been significant decline in both shallow and deep level soil concentrations ($p < 0.01$ and $p < 0.05$ respectively).

Figure 29: Mean annual concentration of chloride (Cl) for precipitation (PC), surface water (WC), and soil solution (SS=shallow, SD=deep) for the period 1997-2013.

Precipitation chemistry (PC), Surface water chemistry (WC) and Soil solution chemistry (SS)



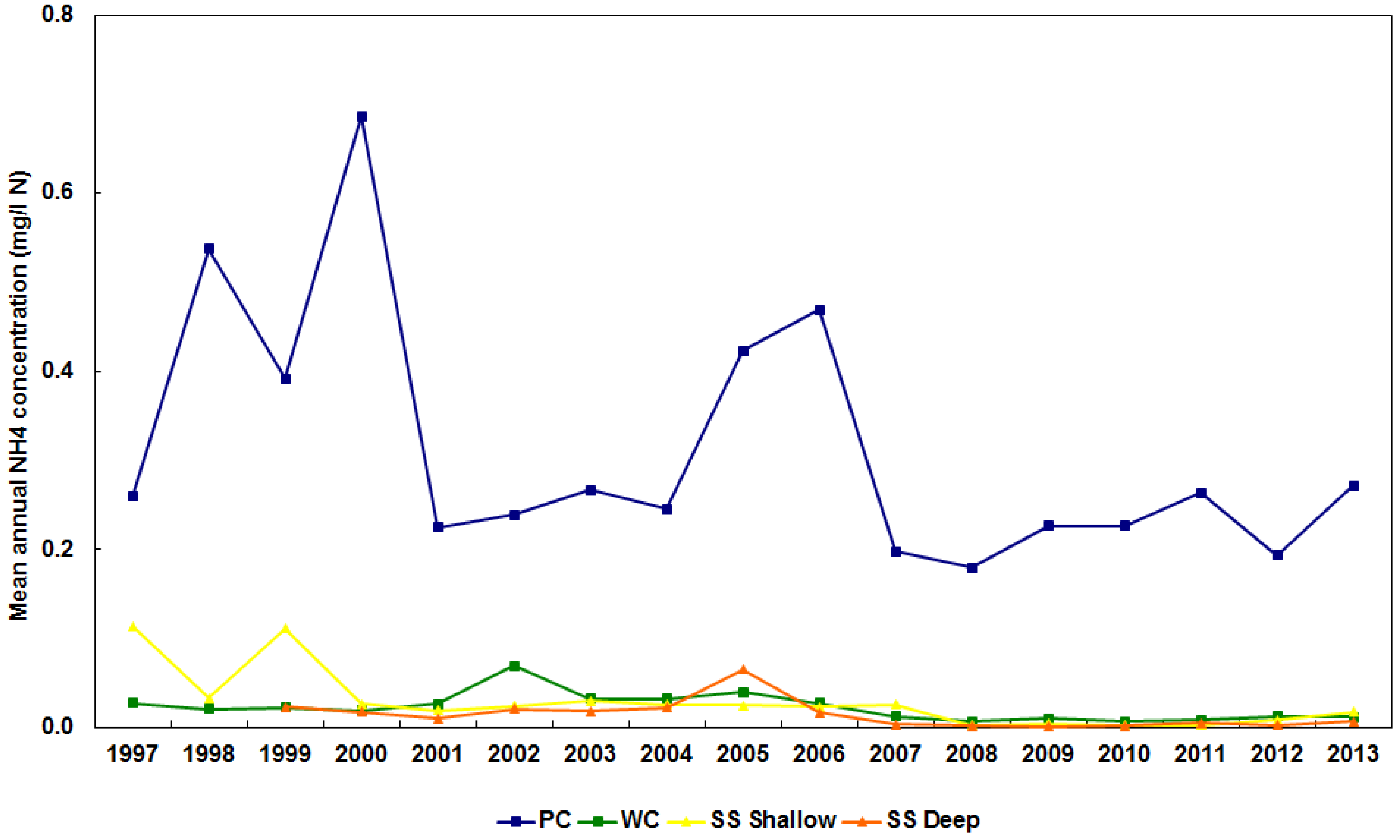
Nitrate:

Highly significant downward trends in concentrations of Nitrate (NO_3-N) in rain water, deep layer soil water and surface water can all be seen ($p < 0.001$). These falls agree with falls in emissions of NOx in the UK (RoTAP, 2012) although the trend for NO_x on the site is not significant.

The differing trajectories for the deep and shallow layer samplers indicate differential capture and sequestration of nitrate through the soil profile, the precise mechanism for which is unclear.

Figure 30: Mean annual concentration of nitrate (NO_3-N) for precipitation (PC), surface water (WC), and soil solution (SS=shallow, SD=deep) for the period 1997-2013.

Precipitation chemistry (PC), Surface water chemistry (WC) and Soil Solution chemistry (SS)

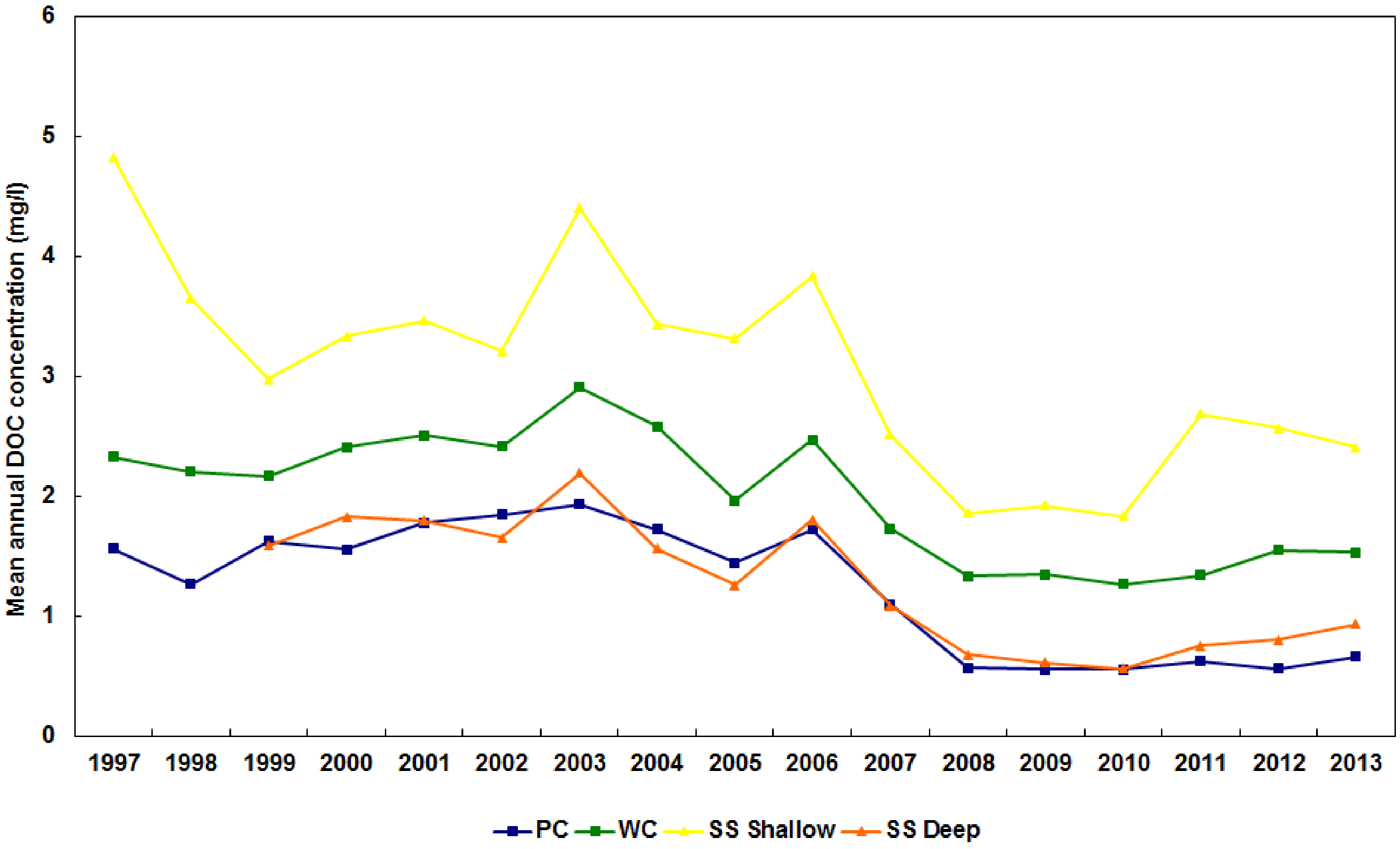


Ammonium:

The apparent decline in concentrations of ammonium in rainfall is not significant, but those in surface water and soil water are, especially in the shallow layer ($p < 0.001$). Most of the ammonium falling in rainfall is quickly taken up by vegetation with levels in surface water and soils much lower in concentration. The trend for surface water and deep level soil water are significant at the level $p < 0.05$.

Figure 31: Mean annual concentration of ammonium (NH_4-N) for precipitation (PC), surface water (WC), and soil solution (SS=shallow, SD=deep) for the period 1997-2013.

Precipitation chemistry (PC), Surface water chemistry (WC) and Soil solution chemistry (SS)

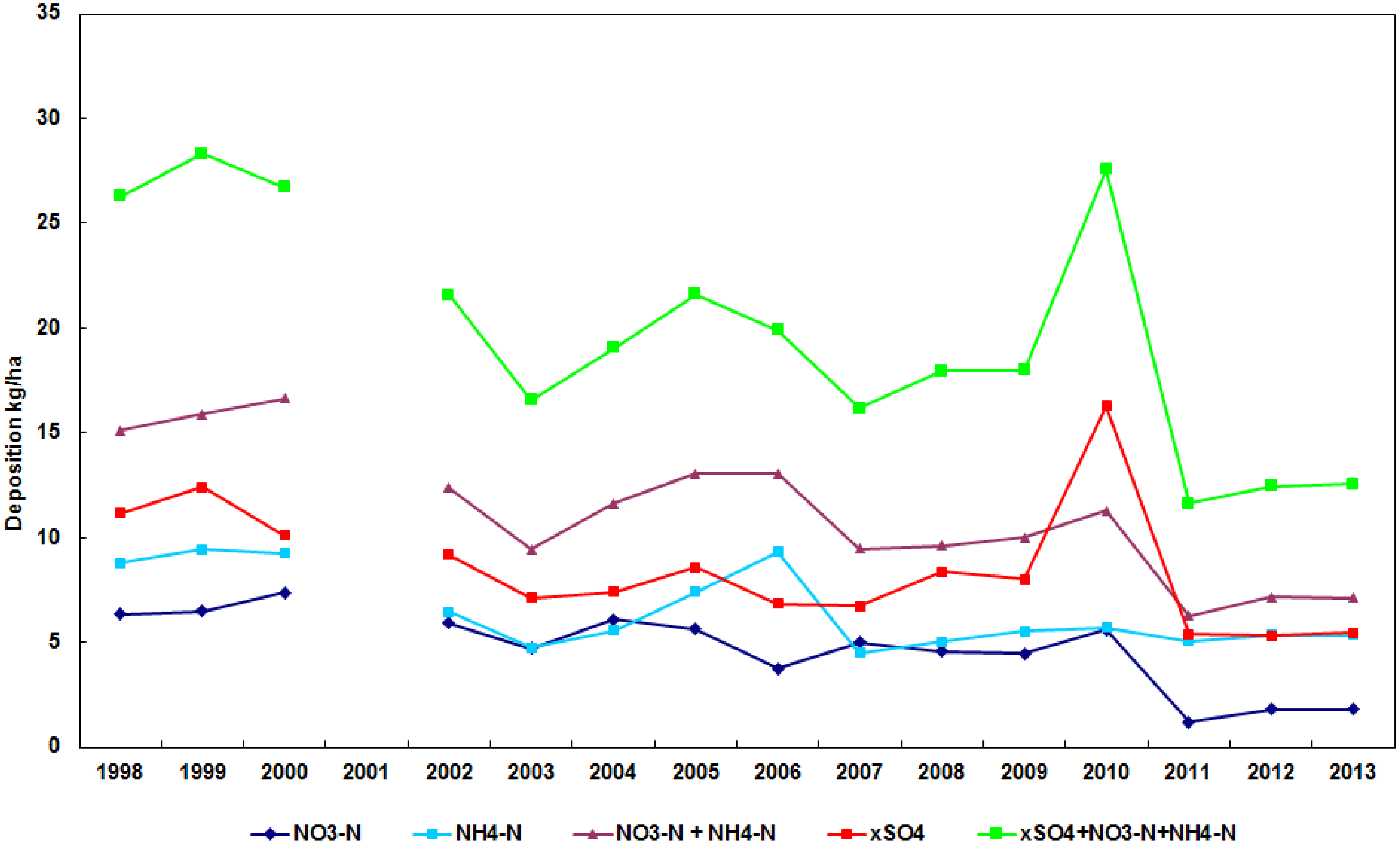


Dissolved Organic Carbon:

Trends for Nant Teyrn, a proxy for Llyn Teyrn, show a significantly declining concentration of DOC in surface water with the main decrease since 2003 ($p < 0.05$). Changes in DOC concentrations for soil water samplers mirror those for surface waters ($p < 0.01$).

The downward trend in concentration of DOC is in contrast to results reported by UK Acid Waters Monitoring Network which found a rising trend across many sites, and in particular at Llyn Llagi, the adjacent freshwater ECN site to Nant Teyrn (Monteith *et al.*, 2007).

Figure 32: Mean annual concentration of dissolved organic carbon (DOC) for precipitation (PC), surface water (WC), and soil solution (SS=shallow, SD=deep) for the period 1997-2013.



Critical loads:

Combined NH_4-N, and NO_3-N inputs give a good indication of nutrient nitrogen loading and demonstrate a continued significant decline ($p < 0.01$).

2011-13 values, despite being the lowest seen, still exceed maximum CL limits for nutrient nitrogen for a couple habitats, and for the minimum CL for almost all habitats found on the site (Table 6).

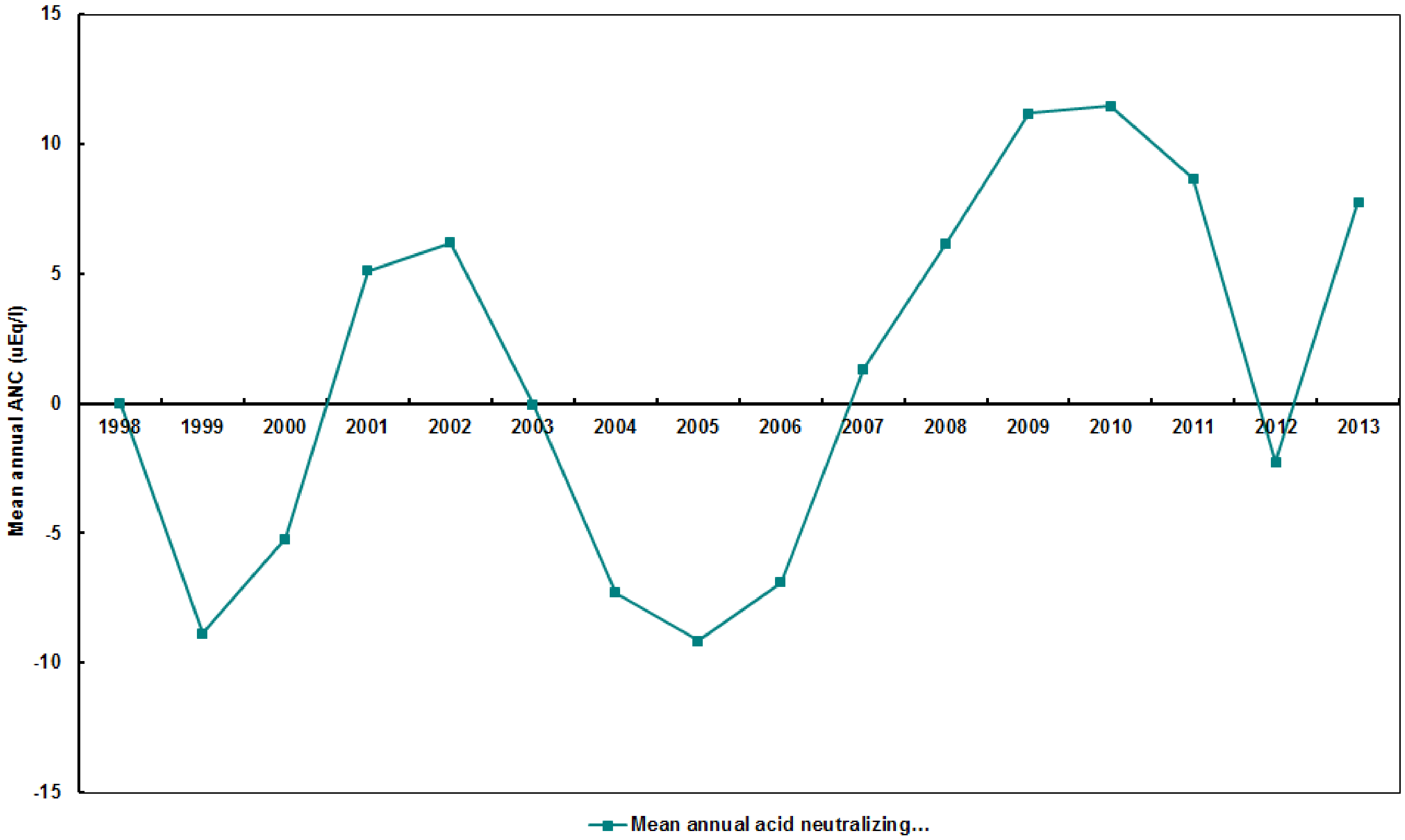
Acidity, as measured by combined nutrient nitrogen and non-marine sulphate (xSO_4^{2-}), also shows a significant decline ($p < 0.01$) and similarly reaches its lowest level since recording started in 1998.

Figure 33: Annual deposition of non-marine sulphate (xSO_4^{2-}), nitrate (NO_3-N) and ammonium (NH_4-N) for the period 1998-2013. Missing data from 2001 due to Foot and Mouth restrictions.

Table 6: Critical Loads for nutrient nitrogen for Annex 1 habitats occurring on the Yr Wyddfa/Snowdon ECN site. Values from APIS website (http://www.apis.ac.uk/overview/issues/overview_Noordwijkerhout_text.html. (Bobbink & Hettelingh, 2011)) and Evans *et al.* (2007) (*)

Annex I Code	**Annex I Habitat**	**Equivalent EUNIS habitat code**	**Critical Load minimum (kgN/ha/yr)**	**Critical Load maximum (kgN/ha/yr)**	**Exceedence of CL minimum in 2013**	**Exceedence of CL maximum in 2013**
H3130	Oligotrophic to mesotrophic waters with standing vegetation	C1.1	3	10	**Y**	N
H4010	North Atlantic wet heaths (*Erica tetralix*)	F4.1	10	20	N	N
H4030	European dry heaths	F4.2	10	20	N	N
H4060	Alpine and boreal heaths	F2.2	5	15	**Y**	N
H6150	Siliceous alpine and boreal grasslands	E4.3	10	15	N	N
H6170	Alpine and subalpine calcareous grasslands	E4.4	10	15	N	N
H6430	Hydrophilous tall-herb fringe communities (plains, mountains)	E5.5	10*	15*	N	N
H7130	Blanket bogs	D1.2	5	10	**Y**	N
H7230	Alkaline fens	D4.1	15	35	N	N
H7240	Alpine pioneer formations (*Caricion bicoloris-atrofuscae*)	D4.2	15	25	N	N
H8110	Siliceous scree of montane to snow levels	H2.3	5*	15*	**Y**	N
H8120	Calcareous and calcschist screes of montane/alpine levels	H2.4	5*	15*	**Y**	N
H8210	Calcareous rocky slopes with chasmophytic vegetation	H3.2	10*	15*	N	N
H8220	Siliceous rocky slopes with chasmophytic vegetation	H3.1	5*	15*	**Y**	N

Surface water chemistry (WC)



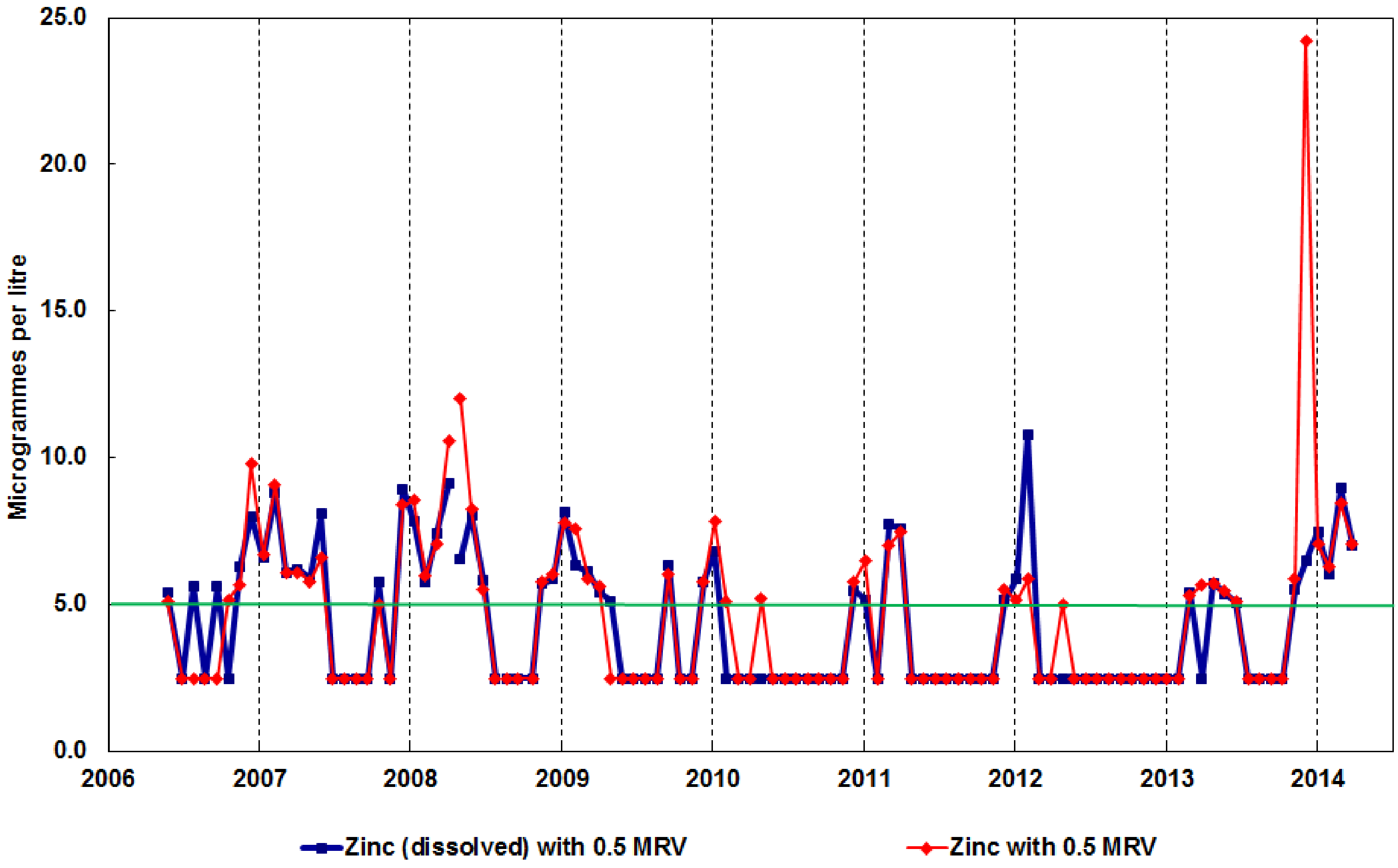
Acid Neutralizing Capacity:

Acid neutralizing capacity (ANC) of Nant Teyrn stream water is a good measure of the acid freshwater status of Llyn Teyrn (the lake adjacent to the sample station). The trend over the whole period, although apparently increasing, is not significant. The saw tooth pattern over the longer term masks much shorter term variation. In particular there are frequent bursts of chloride and sulphate input from marine sources, particularly in winter generally followed by a more gentle recovery (see Figure 37).

Figure 34: Ionic Balance Acid Neutralizing Capacity for Nant Teyrn for the period 1997-2013.

3.6 Data summary chemistry variables – Freshwater

Chemical variables (FWC)



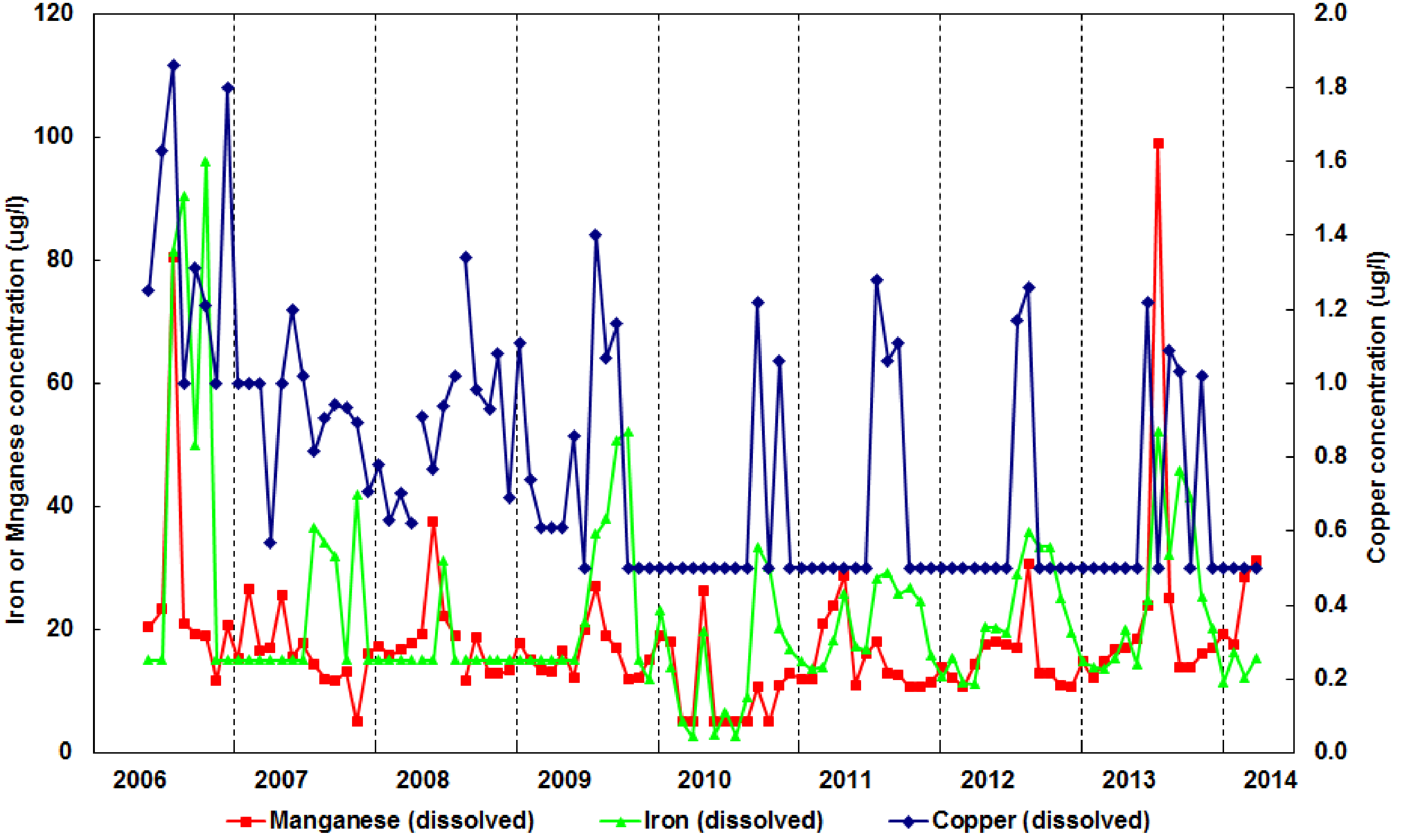
Zinc:

Zinc exhibits a fairly strong seasonality with peaks in the winter and spring periods followed by low values (below the limit of detection) during late summer and autumn. The peaks are possibly caused by erosion within the catchment over the winter period. The peak in late 2013 occurred before the stormy weather started, but there is also a similar peak in copper, nickel, silicate and calcium so could possibly reflect sedimentary input to Llyn Teyrn triggered by heavy precipitation.

No clear trend is visible over the short period of sampling.

Figure 35: Concentrations of dissolved and total zinc in Nant Teyrn 2006-14. Horizontal green line is the limit of detection. Values below this have been set at 0.5 MRV.

Chemical variables (FWC)



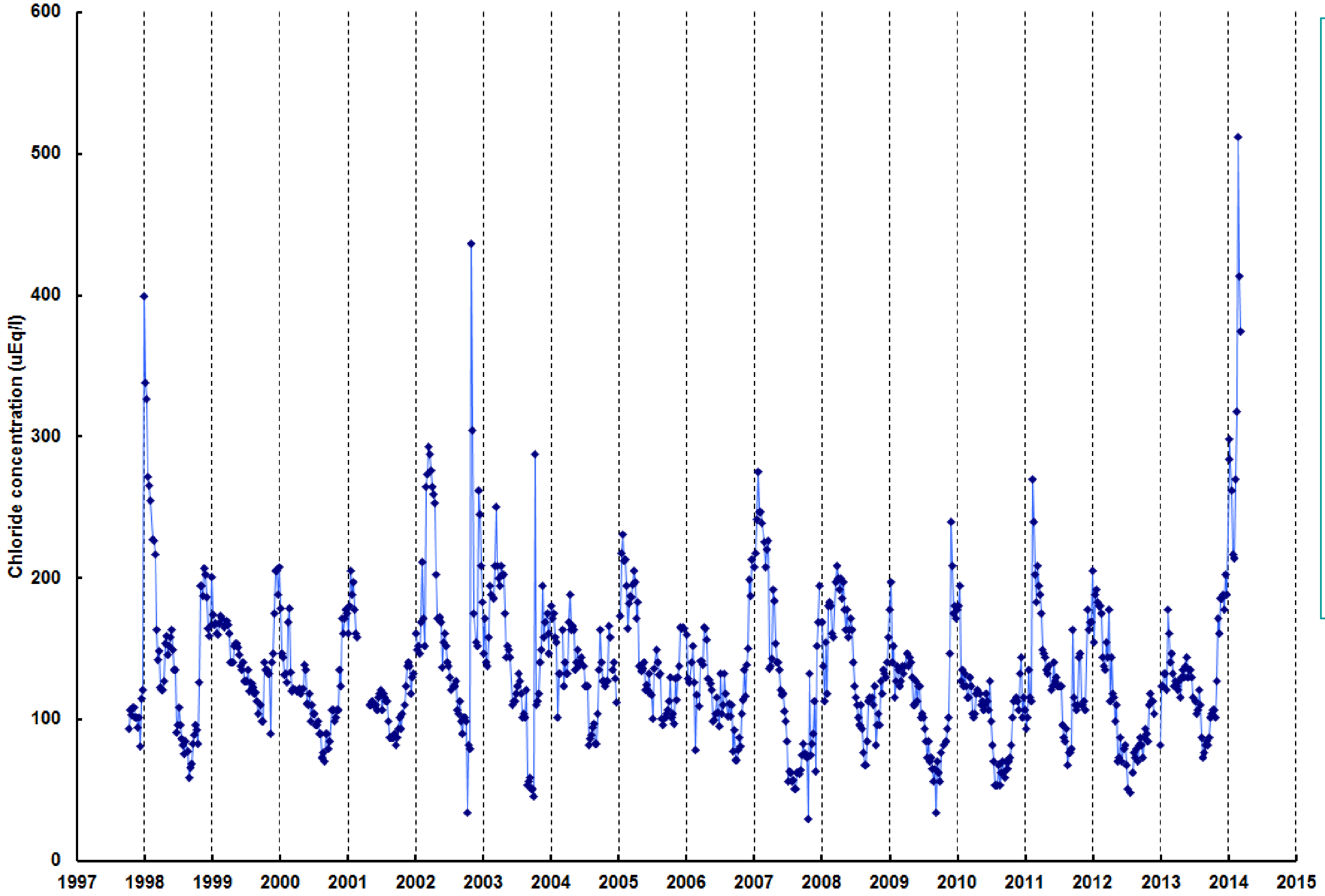
Manganese, iron and copper:

Mean annual concentrations for dissolved iron from 1997 are shown more fully in Figure 26. Over the shorter period of running freshwater ECN protocols, summer peaks in manganese and iron concentrations appear to follow similar trends, with both declining but the data run is not significant.

Annual mean dissolved copper concentrations are significantly falling from a peak in 2006, and 50% of the samples in 2010-2013 fell below the limit of detection. Some of the peaks in copper concentration coincide with elevated levels in dissolved Iron.

Figure 36*:* Concentrations of dissolved manganese, iron and copper in Nant Teyrn 2006-14.

Chemical variables (FWC)



Chloride:

Annual chloride concentrations generally peak during the winter months as a result of strong westerly or south-westerly winds associated with vigorous Atlantic depressions. During February 2014, the concentration in Nant Teyrn, and by extension Llyn Teyrn, peaked at over 500 μEql^{-1}, the highest since recording began in 1997. This was the cumulative result of at least eight rainfall episodes with concentrations exceeding 300 μEql^{-1} including one with over 650 μEql^{-1}.

Figure 37: Weekly chloride concentrations from Nant Teyrn from 1997 to 2014.

3.7 Biological variables overview

The series of very wet summers of 2007-2012 produced lower numbers of butterflies with lower diversity, following the peak numbers seen during the warmer and drier summers of 2004-2006. The drier summer of 2013 allowed a slight recovery in diversity, but numbers remained low (Figure 39). The long-term trend in numbers is not significant. The Shannon diversity index, H', for butterflies, has shown a significant decline since 2000 (Figure 38).

Pitfall trapping of carabid beetles has continued since 1999, with numbers in all three transects declining to a minimum during the years 2004-2006. Since then there has been some recovery with numbers having stabilized (Figure 40). The trend over the whole period shows a highly significant decrease for all three transects, but since 2004, the trend is not significant.

Spittle bug monitoring has been undertaken since 1998. Numbers of different colour morphs have varied over the period but with no obvious significant pattern (Figure 42).

Numbers of spiders, which have been trapped since 2000, show no significant trend in numbers (Figure 41).

Bat activity is generally relatively low and there is a low species richness amongst the bats sampled (Figure 43). As noted in the last report, it is likely that the ECN bat protocol as applied in upland areas is missing significant numbers of bats through starting too late and finishing too early. From 2012, increased sampling intensity has been carried out and certainly in 2014 more bats have been seen in the early part of the season.

There is no significant trend in the timing of spawning, and dates often seem to be determined by the temperature in early spring, leaving the spawn or young tadpoles vulnerable to late frost or snowfall with an ensuing high mortality. The duration time from spawning to metamorphosis has fallen significantly, with 2012 and 2014 having the two shortest durations yet recorded, possibly indicating some selection process at work (Figure 44).

There have been no significant changes seen in bird numbers on the site. The peak in numbers in 2001 coincided with the national picture in Wales, but also coincided with the exclusion of sheep from the site due to Foot and Mouth restrictions (Figure 45). Return dates for Meadow Pipits, which are short range migrants, are clearly correlated with mean spring temperature, unlike the long-range migrants Ring Ouzel, Wheatear and Common Sandpiper (Figure 46).

A selection of fine-grain vegetation plots were rerecorded in 2013. Trends in Ellenberg indicator values still show no significant trends (Figures 49-51), apart from for a significant increase in R (Reaction) since 2002 for the vascular plant layer in the calcareous grassland (Figure 50).

Phenological recording of around 80 flowering plant species takes place weekly on the site. Of these species, four woodland species, which have been monitored since 1999, show more or less parallel trends, although only for Primrose (*Primula vulgaris*) is the trend towards earlier flowering significant (Figure 52). The timing of first flowering is closely linked to the average spring temperature.

Purple saxifrage (*Saxifraga oppositifolia*) first flowering has been monitored since 1997. Although the trend towards earlier flowering was significant until 2010, following the colder winters of 2010-2012, it is no longer so. The date of first flowering in 2014 was the earliest yet recorded (Figure 53).

Arctic-alpine plot monitoring was undertaken in 2013 and a subset of the total, the six plots on Diffwys, were rerecorded; there was no significant change (Figure 54).

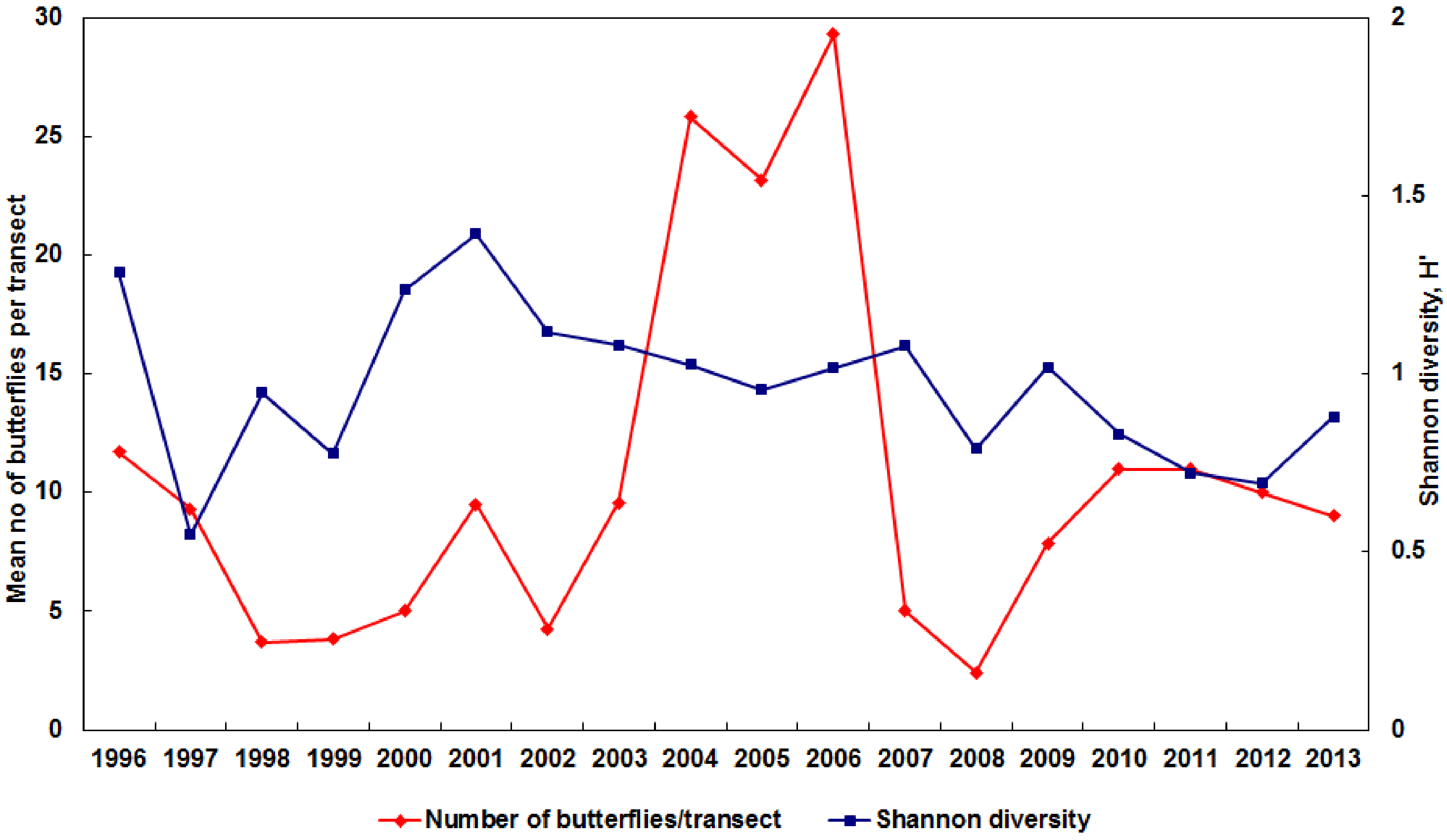
Fortnightly fungi recording has now taken place for almost seven years. New species continue to be discovered after seven years monitoring with the total now standing at 48 (Figure 56). 2013 had the highest cumulative total number of fungal fruitbodies since recording began in 2007.

At Nant Teyrn, the freshwater site, despite significant decreases in acidity, there has been no obvious change in the aquatic macrophyte vegetation (Figure 59). Chorophyll-a, sampled monthly shows changes consistent with recent poor summers with 2012 having the lowest levels (Figure 57). Epilithic diatoms, sampled at three locations in Nant Teyrn once a year, have a species complement typical of a low-nutrient watercourse. There is no significant trend over the short recording period.

Sheep numbers remain stable in recent years and at about 50% of those in 1997. Feral goat numbers have shown a highly significant increase since the early 2000s, with particular increase in activity during all seasons except summer, where they may be grazing at higher altitudes. As noted in the previous report (Turner *et al.* 2012), the proportion of adult females to total population has fallen significantly, possibly reflecting management actions elsewhere. Low-level cattle grazing on the site, started in 2009, has been discontinued.

3.8 Data summary biological variables - Terrestrial

Butterflies (IB)



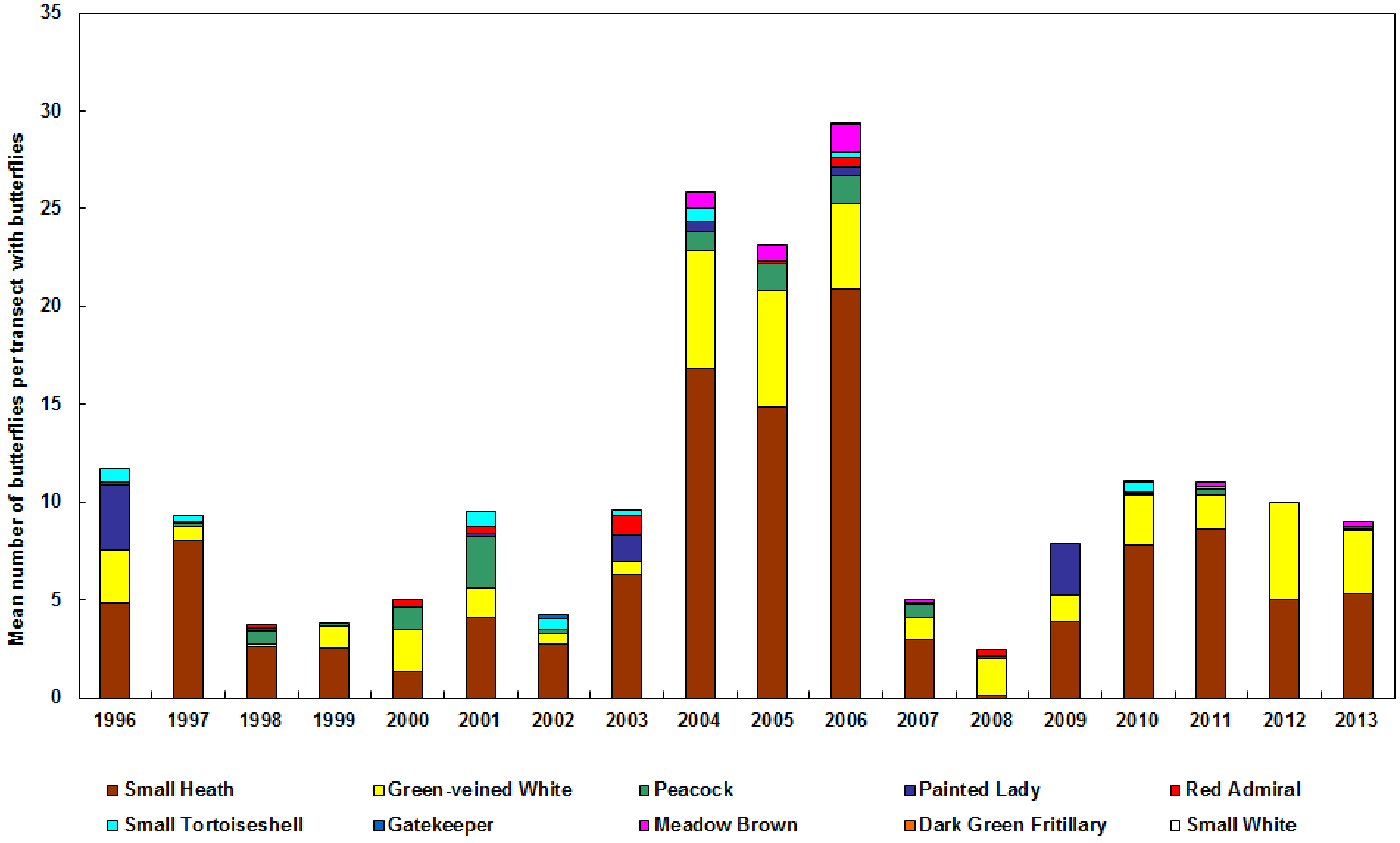
Butterfly numbers and diversity:

During the drier and warmer summers of 2004 to 2006, numbers increased dramatically. Since then numbers per transect fell to a minimum in 2008, recovering somewhat in 2010 and 2011.

There has been a fairly steady decline in the Shannon diversity index, H', of the butterflies recorded, from around 2000 to the present, which is highly significant (p < 0.001).

Figure 38: Average number of butterflies per transect and Shannon diversity, H', on Snowdon over the period 1996-2013.

Butterflies (IB)

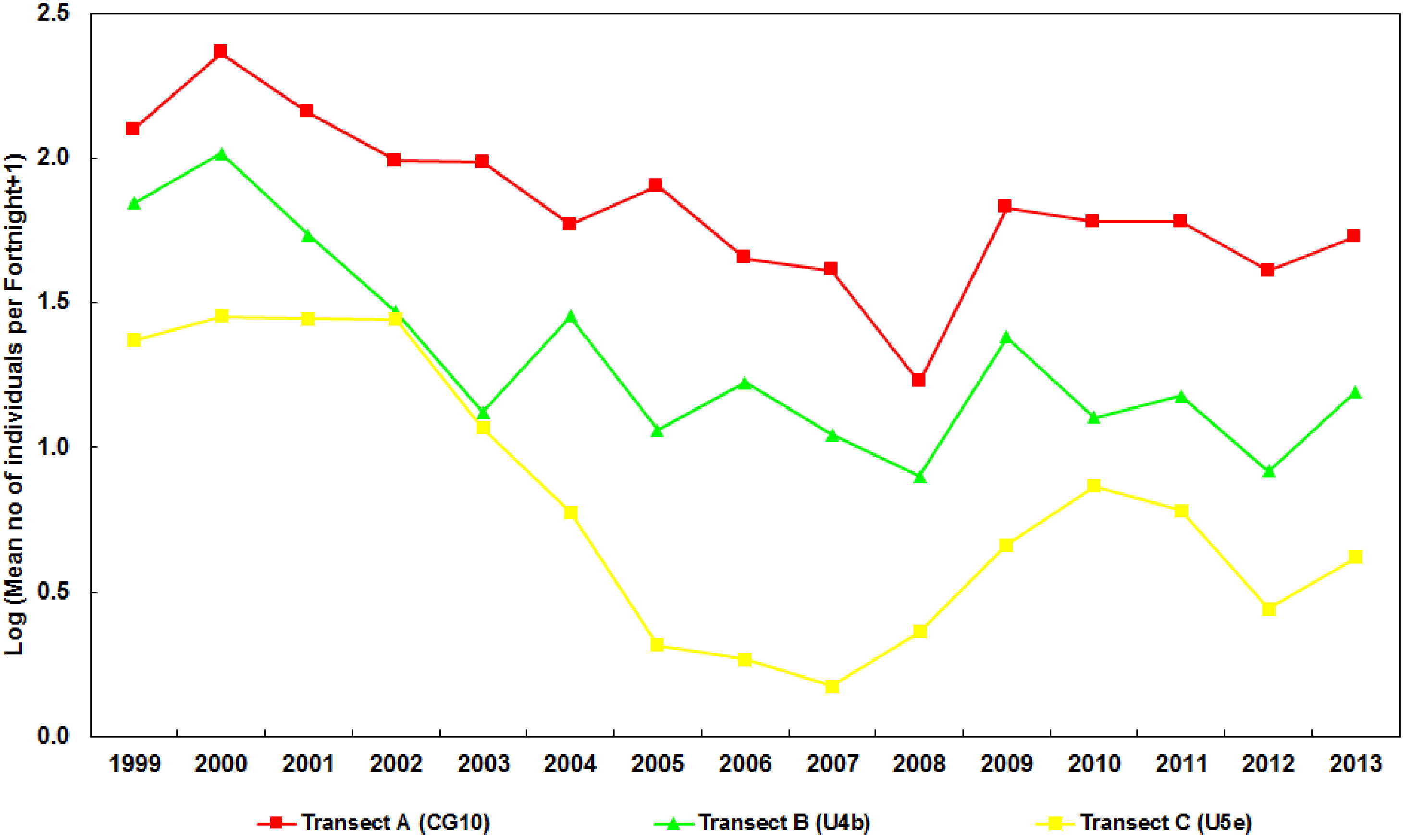


Butterfly species:
The drier and warmer summers in the mid-2000s produced larger numbers of butterflies on the site, and new migrant species were recorded such as Meadow Brown, *Maniola jurtina* and Gatekeeper, *Pyronia tithonus*. The migrant proportion of the total number during these warm summers was, however, relatively low.

The very wet summers of 2007-2012 produced lower numbers with lower diversity and the virtual disappearance of the migrants. The warm summer in 2013 has allowed a small recovery with much greater numbers seen already in 2014.

Figure 39: Average numbers of individual species of butterflies per transect for Yr Wyddfa/Snowdon over the period 1996-2013.

Ground Predators (IG) - Ground beetles (Carabidae)



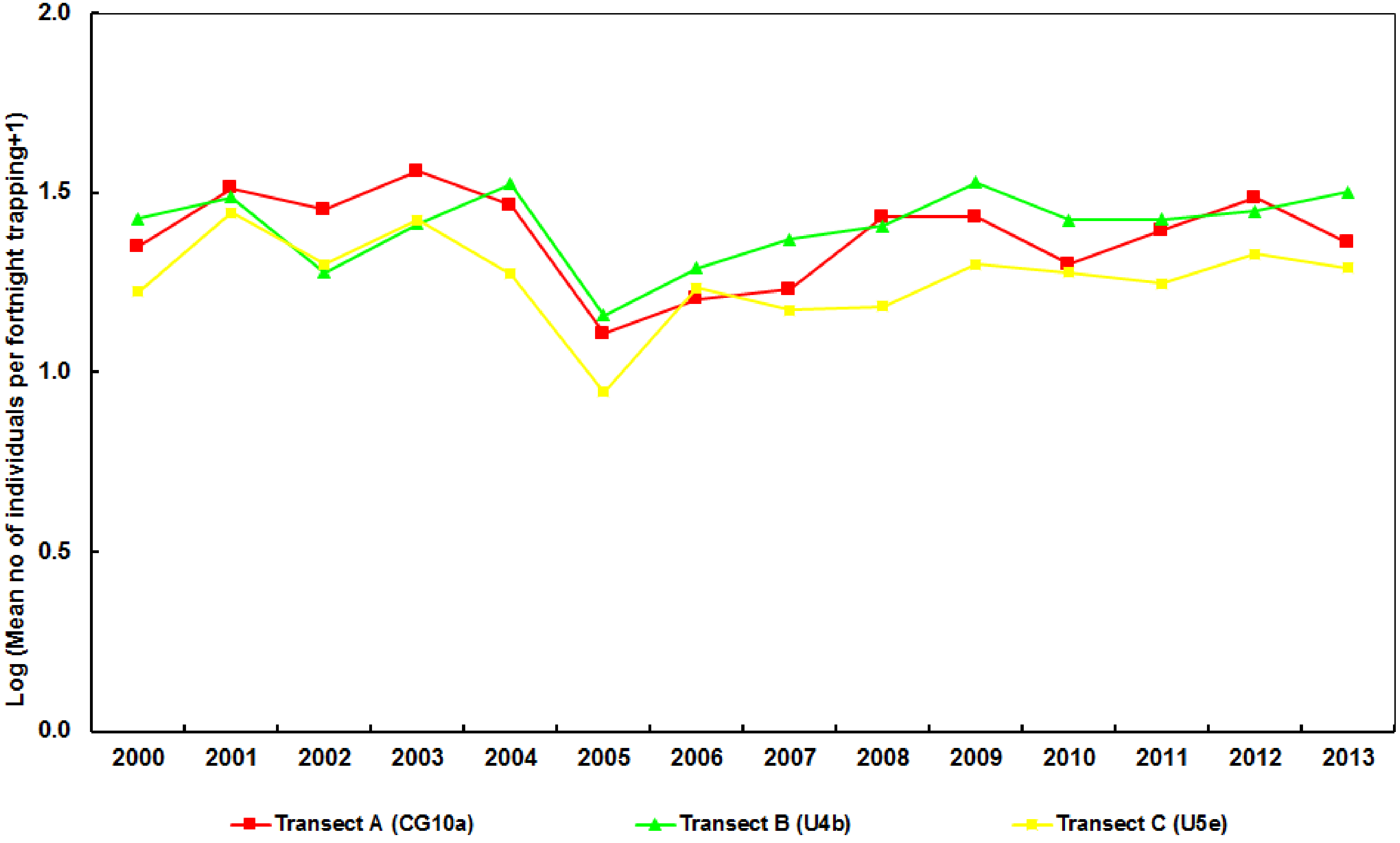
Ground beetles:

Ground beetle numbers at the site appear to have levelled out since 2004, following a significant decline.

The trends over the period since 1999 all still show a significant decline ($p < 0.001$, $p < 0.01$ and $p < 0.05$ for transects A, B and C respectively). Over the shorter period 2004 to 2012, however, the trends are all non-significant.

Figure 40: Log of mean number of Carabid beetles per fortnightly transect for transects A to C on Snowdon for the period 1999 to 2012.

Ground Predators (IG) - Spiders



Spiders:

Unlike beetle numbers, spider numbers have not changed appreciably since trapping commenced in 2000, although there was a minimum around 2005-06. The higher dispersal potential of spiders (e.g. by ballooning for small individuals) means that there is a constant ‘rain’ of new individuals into the site which helps to even out numbers. This might also account for the slight differences in numbers between the three habitat types.

Figure 41: Log of mean number of spiders for transects A-C on Snowdon for the period 1999-2013

Spittle Bugs (IS)

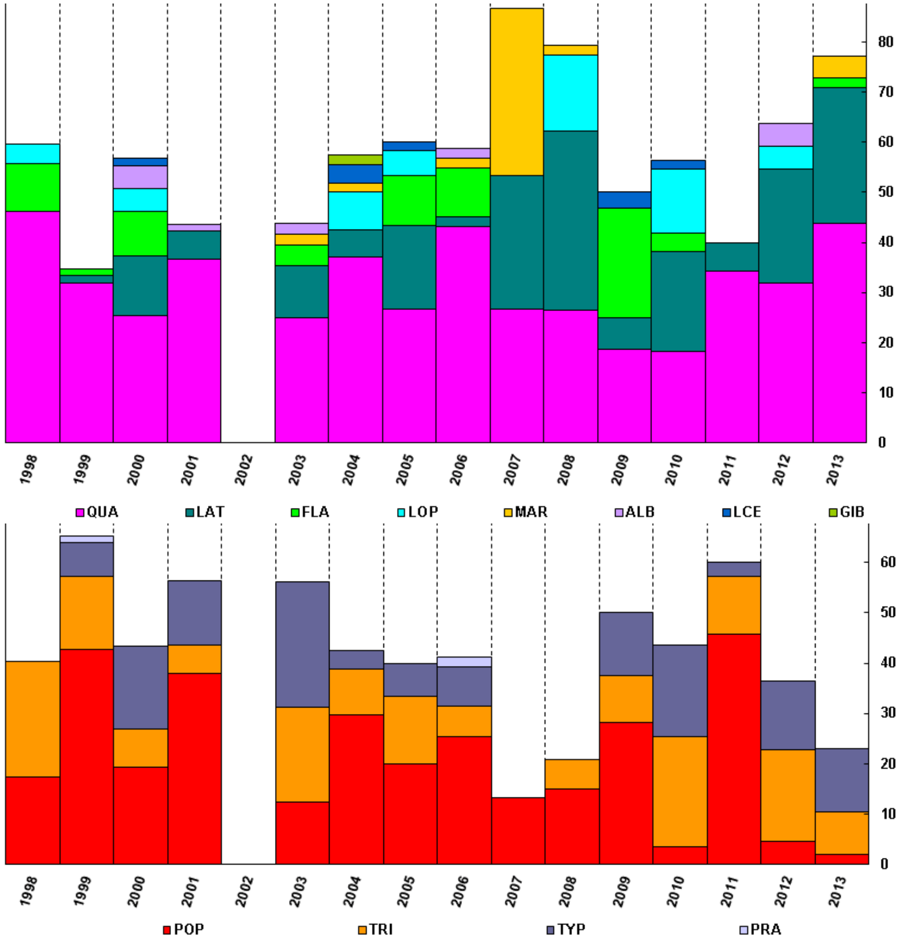
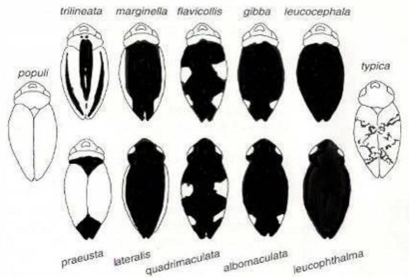


Figure 42: Proportions of different colour morphs of *Philaenus spumarius* separated into melanic, above, and non-melanic, below, over the period 1998-2013. Data missing for 2002.

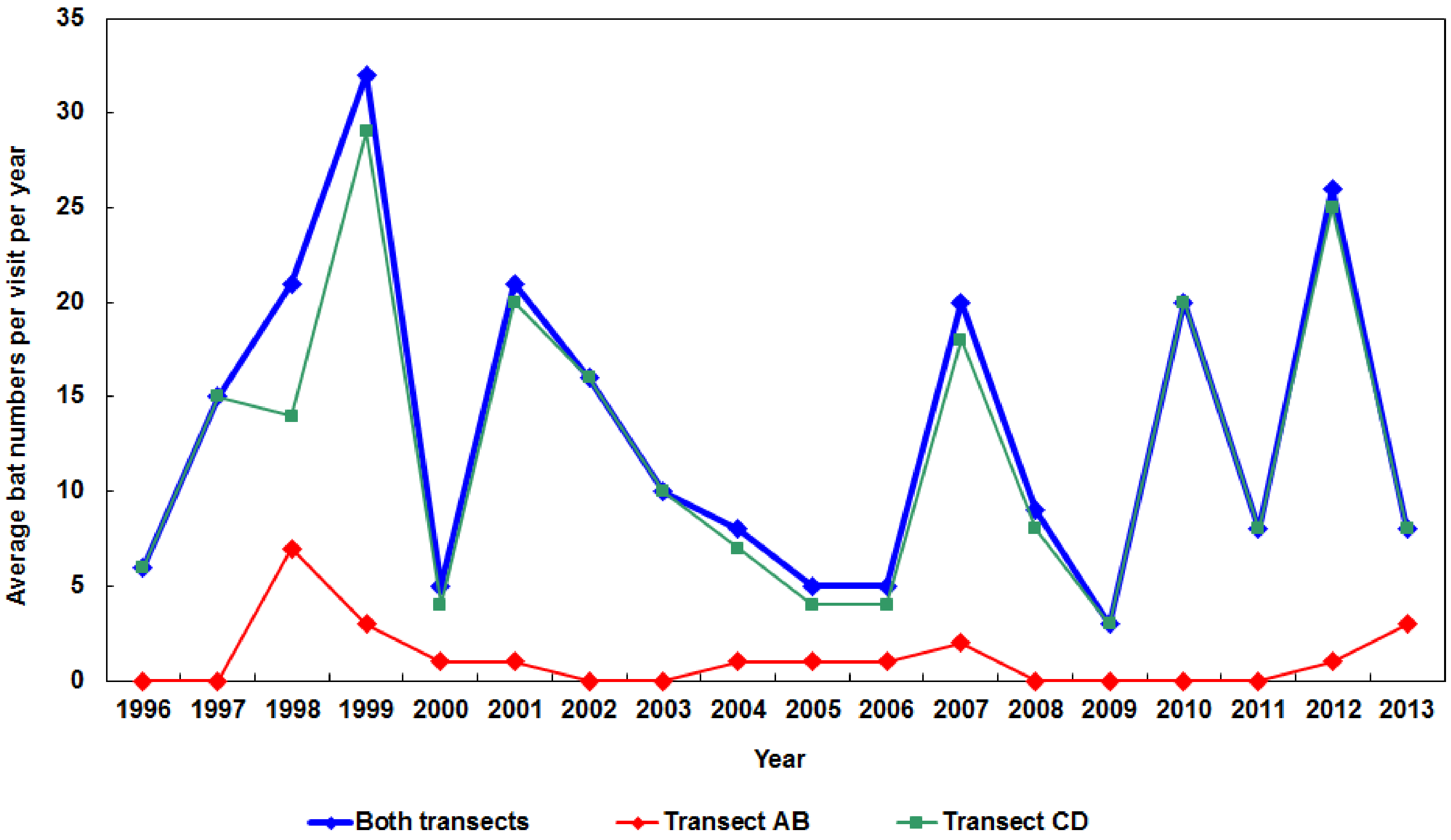
Key: Names and abbreviations of colour morphs found on the ECN site.

Abbrev.	Full name	Melanic/non-melanic
ALB	*albomaculata*	MELAN
FLA	*flavicollis*	MELAN
GIB	*gibba*	MELAN
LAT	*lateralis*	MELAN
LCE	*leucocephala*	MELAN
LOP	*leucopthalma*	MELAN
MAR	*marginella*	MELAN
POP	*populi*	NON-M
PRA	*praeusta*	NON-M
QUA	*quadrimaculata*	MELAN
TRI	*trilineata*	NON-M
TYP	*typica*	NON-M



Colour morphs of *Philaenus spumarius*.

Bats (BA)



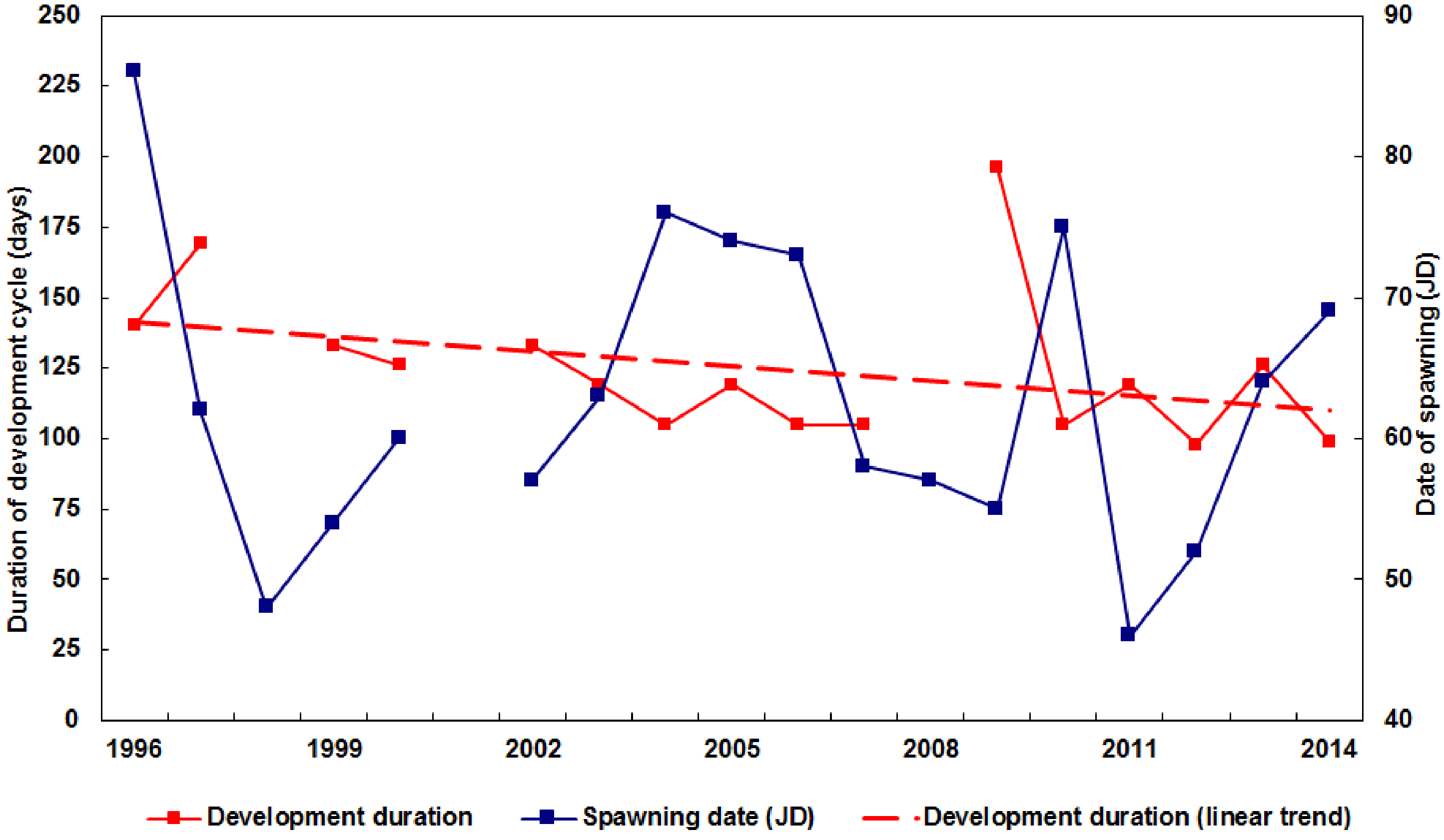
Bats:

Bat numbers at high altitude sites are particularly sensitive to even slightly extended periods of spring and summer rainfall, when females need daily food for young. Work done on Moor House ECN site (Rob Rose, pers. comm.) has indicated a bimodal activity curve for upland bats, where it is speculated female bats move to lower and drier sites during mid-summer after the birth of young.

The current protocol appears to fail to record the first of these periods of activity on Snowdon, and only catches part of the second one. The number of bat transects undertaken on Snowdon per year has, therefore, been increased from 4 to 7 since 2012

Figure 43: Mean number of bats per transect per year 1996 – 2013.

Frog spawn (BF)



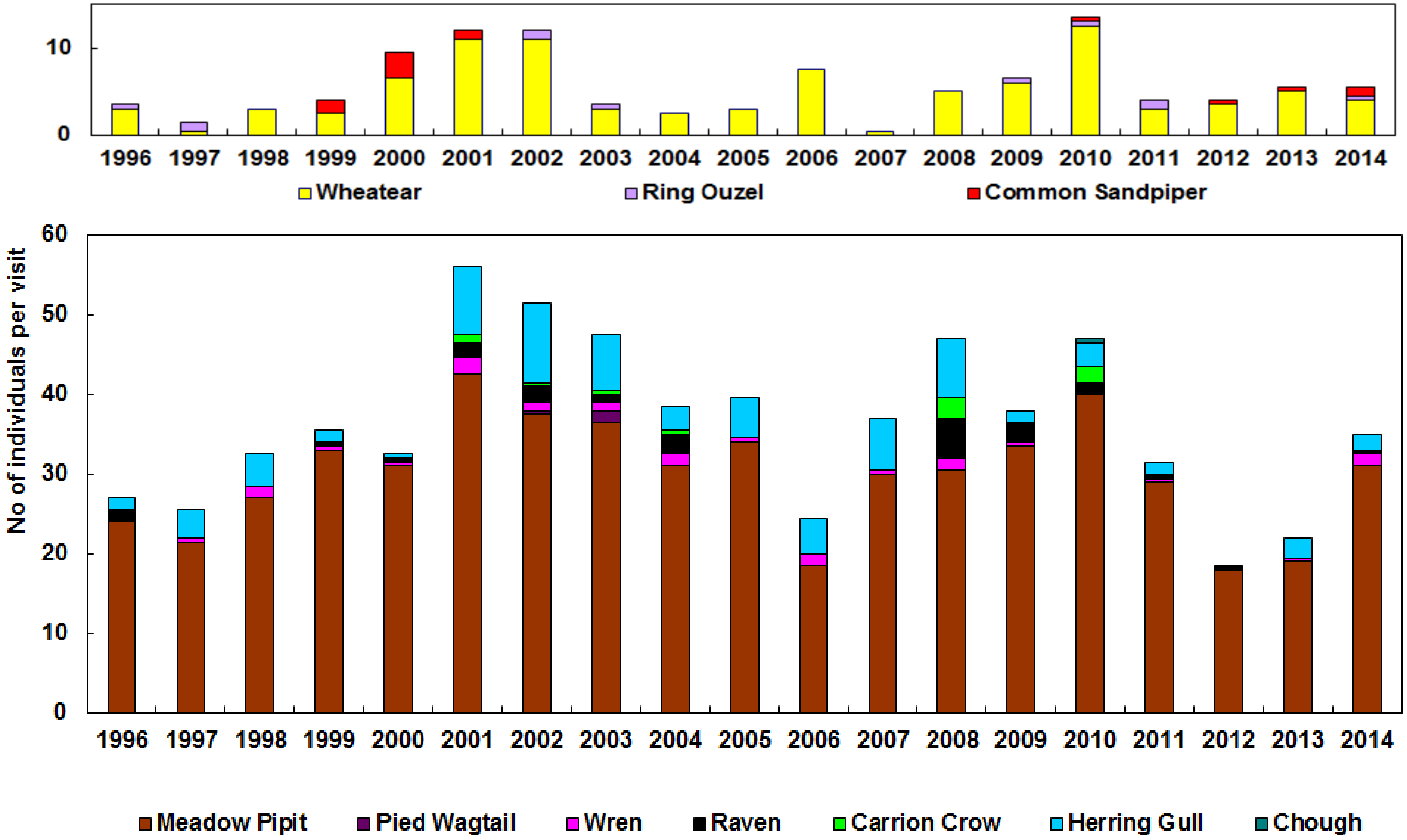
Frogs:

Frog spawning dates can be quite variable depending on late winter and early spring conditions. Late frosts or snowfall can produce mass mortality if spawning happens too early as happened in 1998 and 2008.

Duration of the period from spawning to metamorphosis is much less variable and shows a significant trend ($p < 0.01$) towards shorter development times. The period in 2014 was the 2nd shortest since recording started in 1996.

Figure 44: Changes in development duration (spawning to adult metamorphosis) and spawning dates from 1996-2012 for Frog Pond 1.

Breeding Birds (BB)



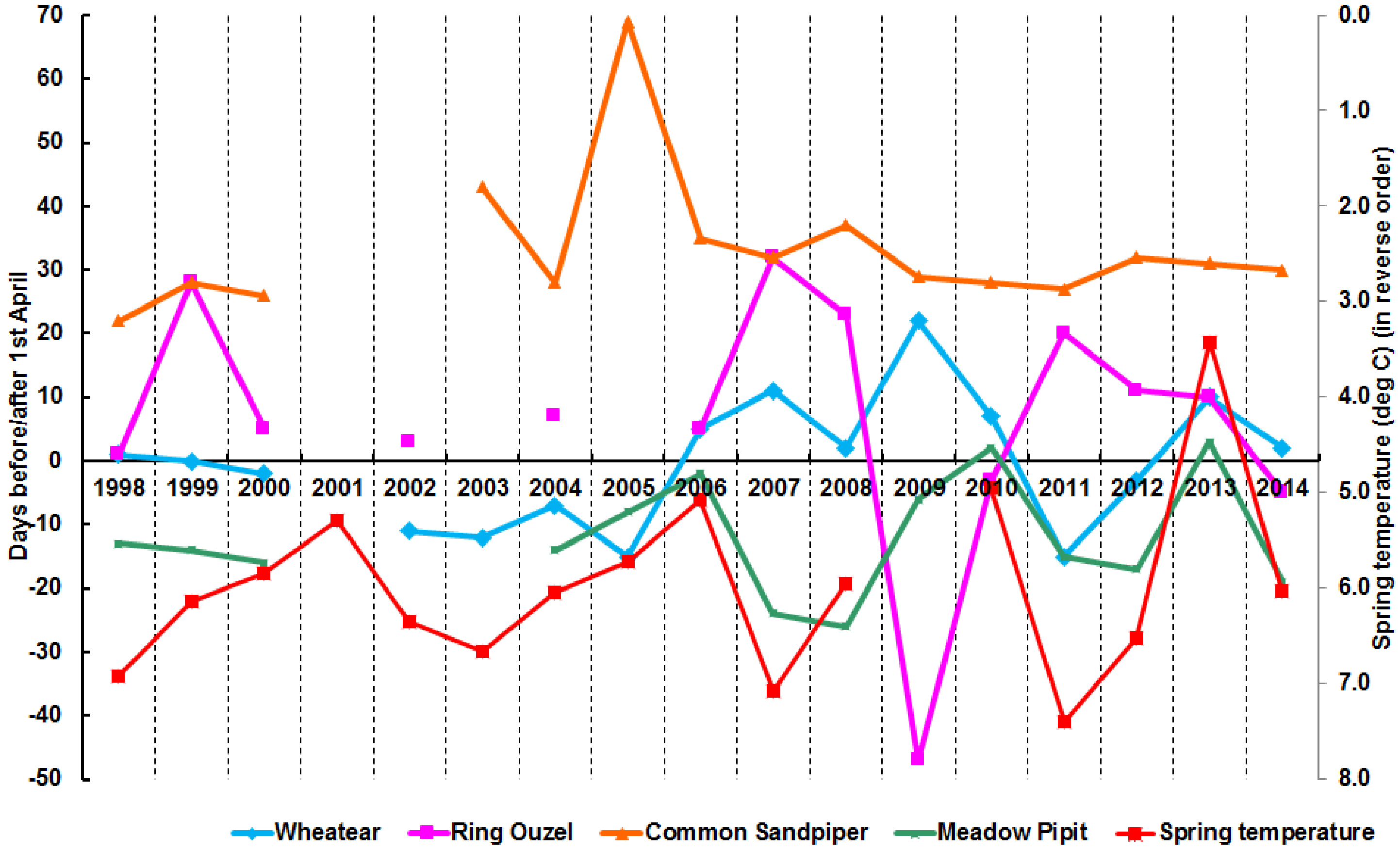
Birds:

The numbers of the different species recorded using the Breeding Bird Survey methodology do not show any significant trend over the recording period.

Meadow Pipits, the dominant small passerines on the site, appears to show a cyclic abundance curve, with minima in 1997 and 2006. The abundances of the long-distance migrants Wheatear, Ring Ouzel and Common Sandpiper also seem to follow this cyclic pattern, perhaps indicating that the origin is in the environmental conditions on the ECN site.

Figure 45: Numbers of bird species recorded on BBS survey over the period 1996 – 2014. Long range migrants, above, and shorter range migrants below.

Phenology - Breeding Birds



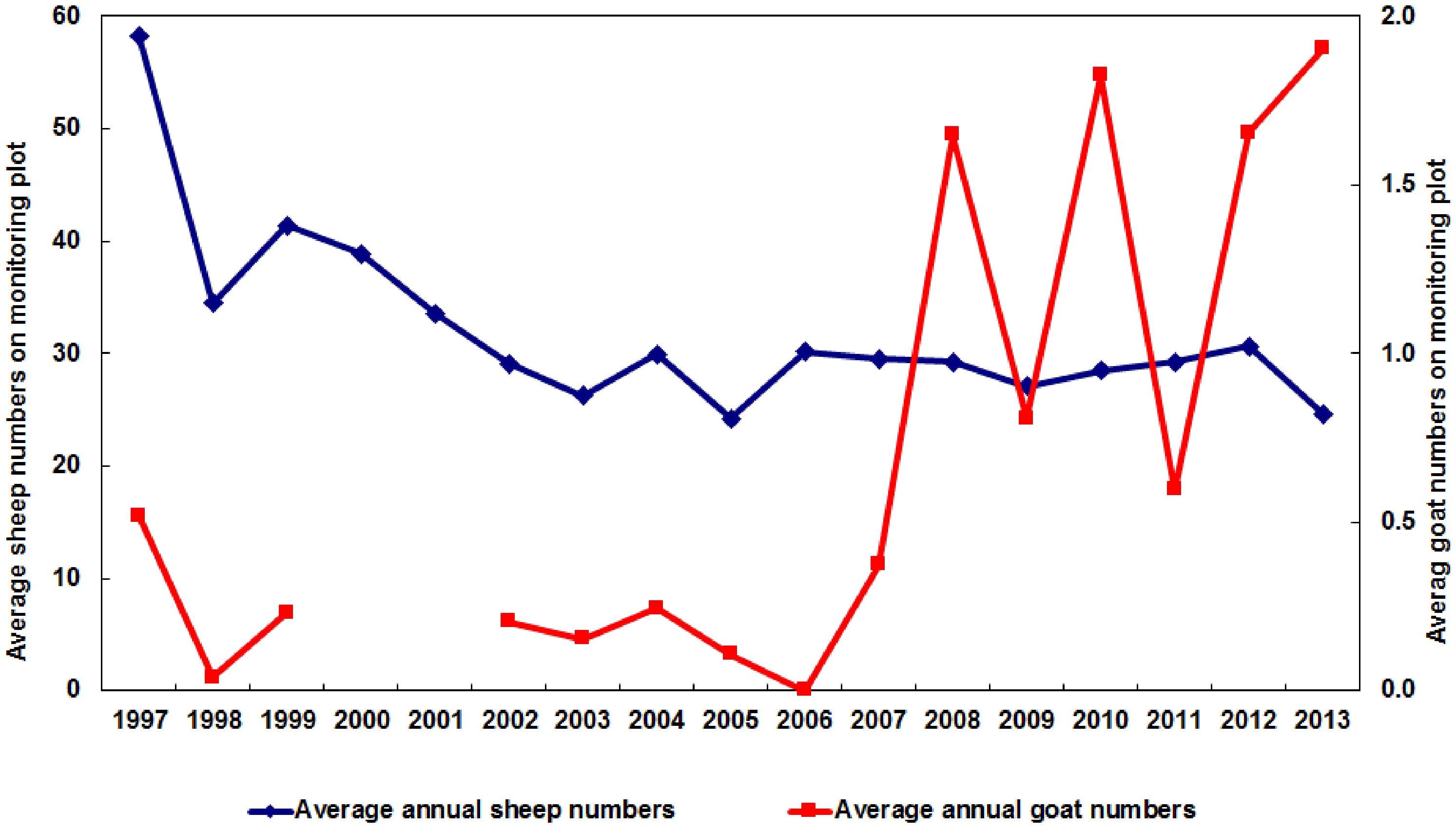
Bird returns:

There is little real change in the dates of return of the species shown in the figure.

The timing of return of the short-distance migrant the Meadow Pipit is probably determined by weather conditions in North Wales, in particular temperature. This is shown by the late arrivals in 2006, 2010 and 2013 when snow melt was late. The long-distance migrants by contrast show little correlation with local temperatures and timing is probably dictated by changes in weather across the whole of Europe and North Africa.

Figure 46: Changes in the timing of bird returns 1999-2012.

Land use & site management (LU) – sheep and goat numbers



Stock numbers:

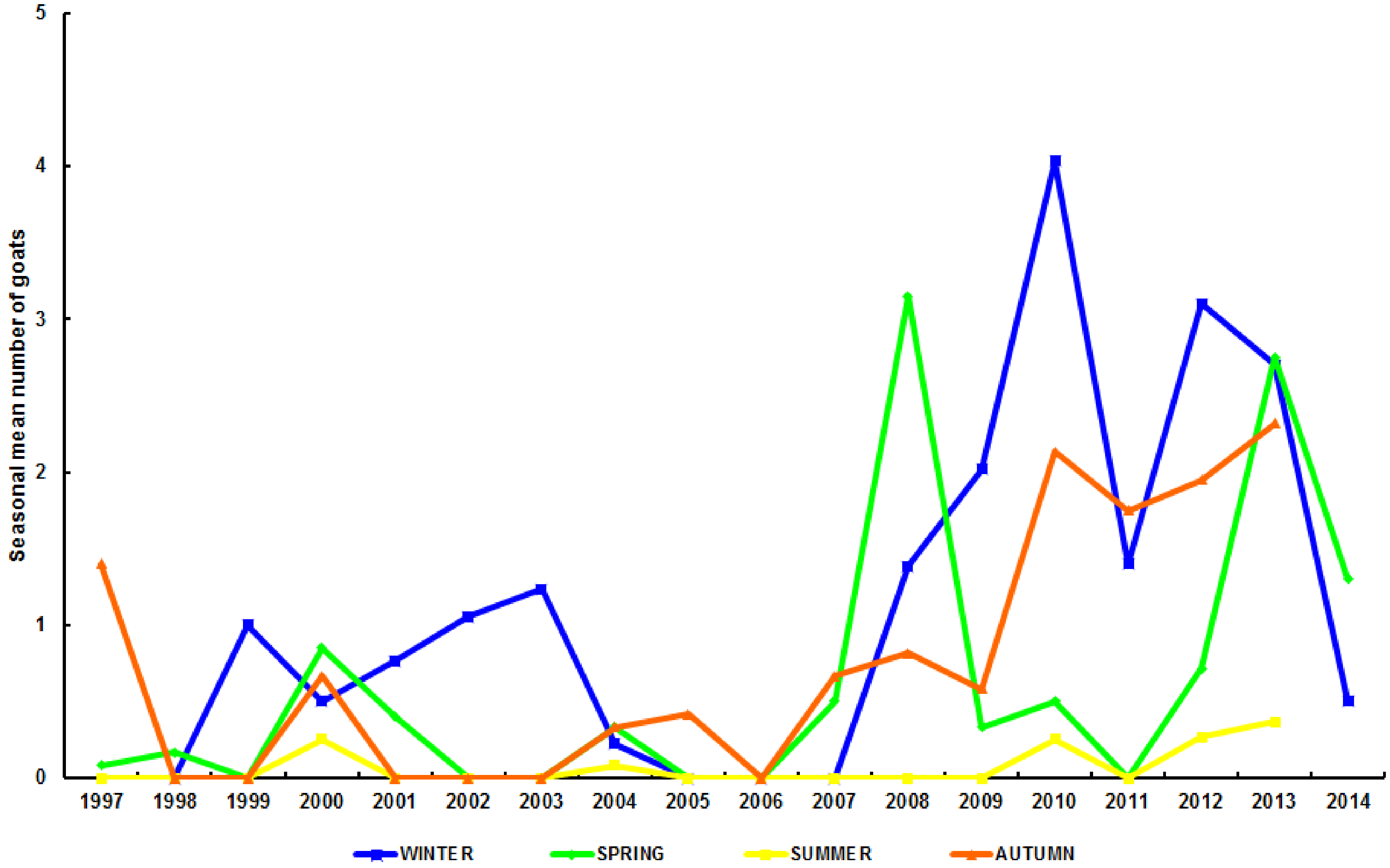
Sheep numbers fell sharply in the late-1990s and have continued at around 50% of the numbers in 1997.

The increasing trend in goat numbers is significant, but there is much variation in the numbers counted on the sampling site reflecting the localized grazing preferences of different groups of goats.

A small herd of about 25 Welsh Black cattle were introduced by the tenant farmer to the site during the summers since 2009, but have been removed in 2013 due to adverse interactions with walkers.

Figure 47: Average annual sheep and goat numbers on the ECN sheep monitoring plot.

Land use & site management (LU) – Seasonal goat numbers



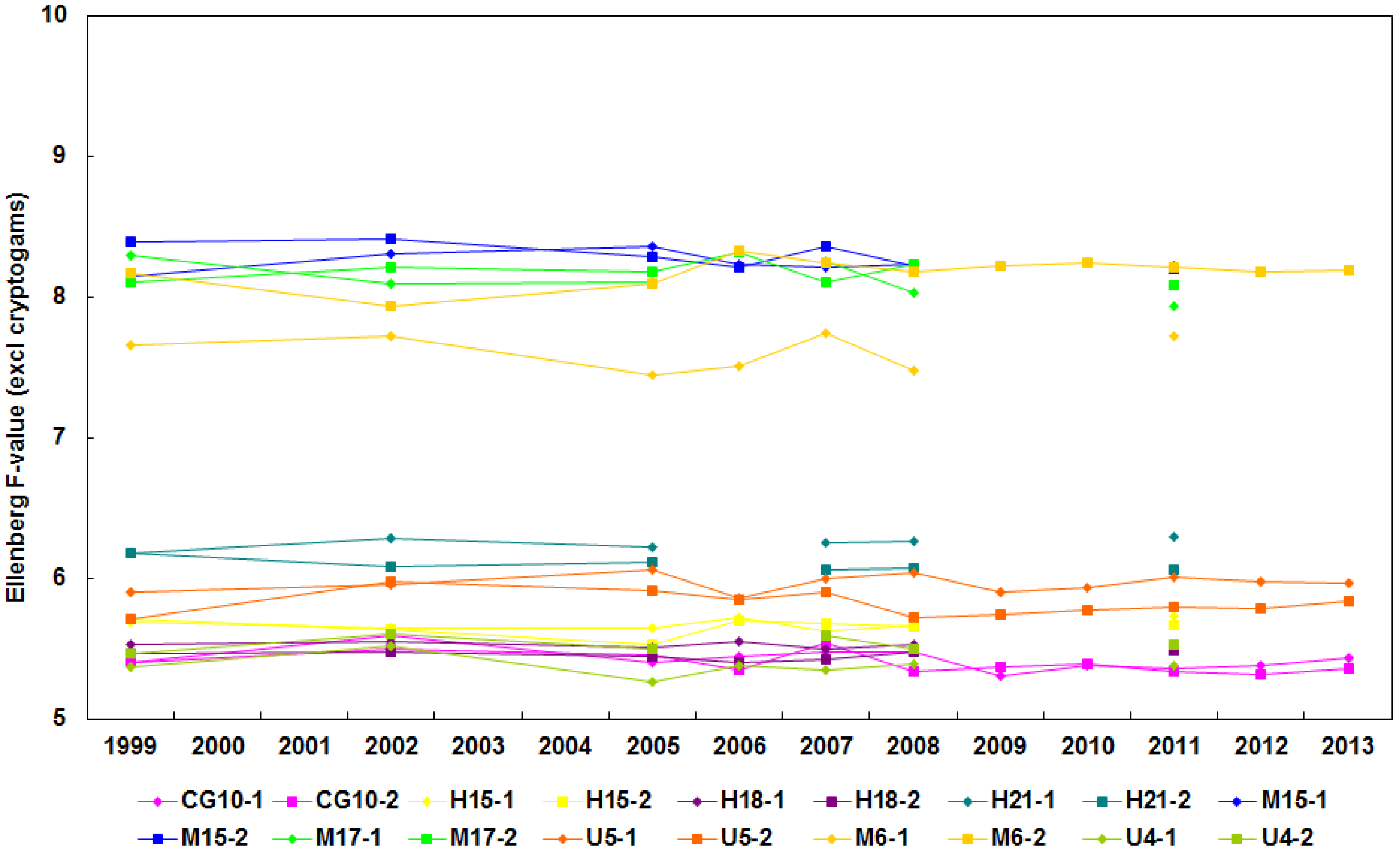
Goats:

Goats are also monitored in more detail over a wider area than sheep with recorded numbers having increasing particularly since 2006. The increase is seen in all seasons except summer, which may be due to groups of goats using higher level grazing beyond the ECN sampling area.

Low winter numbers in the area in 2013/14 are probably due to the persistent heavy rain.

Figure 48: Seasonal goat numbers on monitoring plot area, 1997-2014.

Fine-grain vegetation (VF)

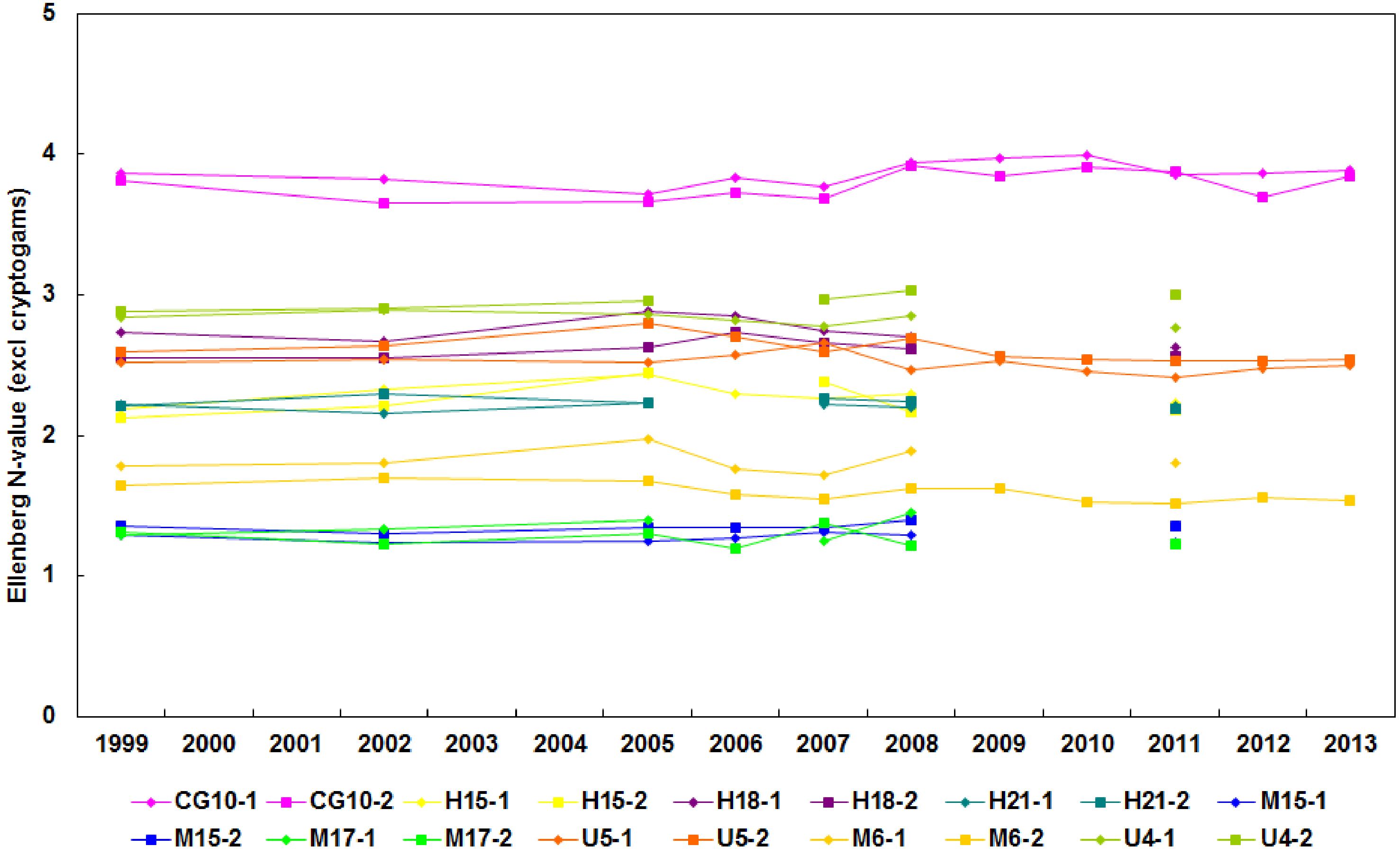


F indicator value:

Hill's modified Ellenberg indicator value for F (moisture) (Hill *et al.* 1999) clearly separates wet heath, flush and bog habitats (NVC M15, M6 and M17) from the remaining heath and grassland habitats on the site. None of the trends shown here, however, are statistically significant.

Figure 49: Weighted mean Hill's modified Ellenberg indicator value F (moisture) for the vascular plant layers of VF plots 1999-2013. Plot names use National Vegetation Classification (NVC) codes (Rodwell, 1991-2000).

Fine-grain vegetation (VF)



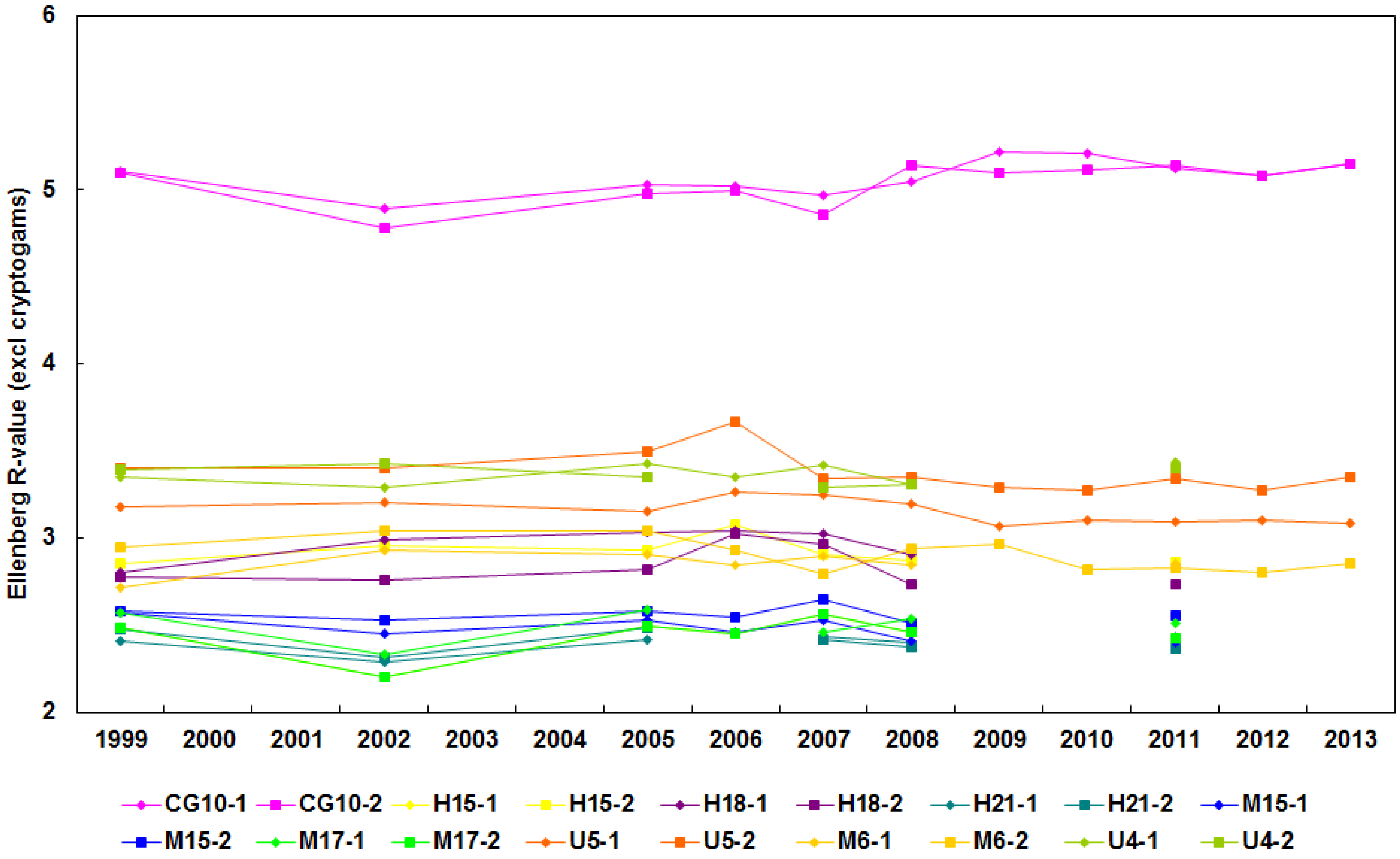
N indicator value:

There are no significant trends in Hill's modified Ellenberg indicator value N (nutrient).

Calcareous grassland (CG10), the most heavily grazed habitat on the site, is clearly separated from other habitats. The wettest habitats with the lowest grazing intensity, flush (M6), wet heath (M15) and blanket bog (M17), have the lowest value of the indicator value indicating their extreme infertility.

Figure 50: Weighted mean Hill's modified Ellenberg indicator value N (Nutrient or Nitrogen) for the vascular plant layers of VF plots 1999-2013. Plot names use National Vegetation Classification (NVC) codes (Rodwell, 1991-2000).

Fine-grain vegetation (VF)

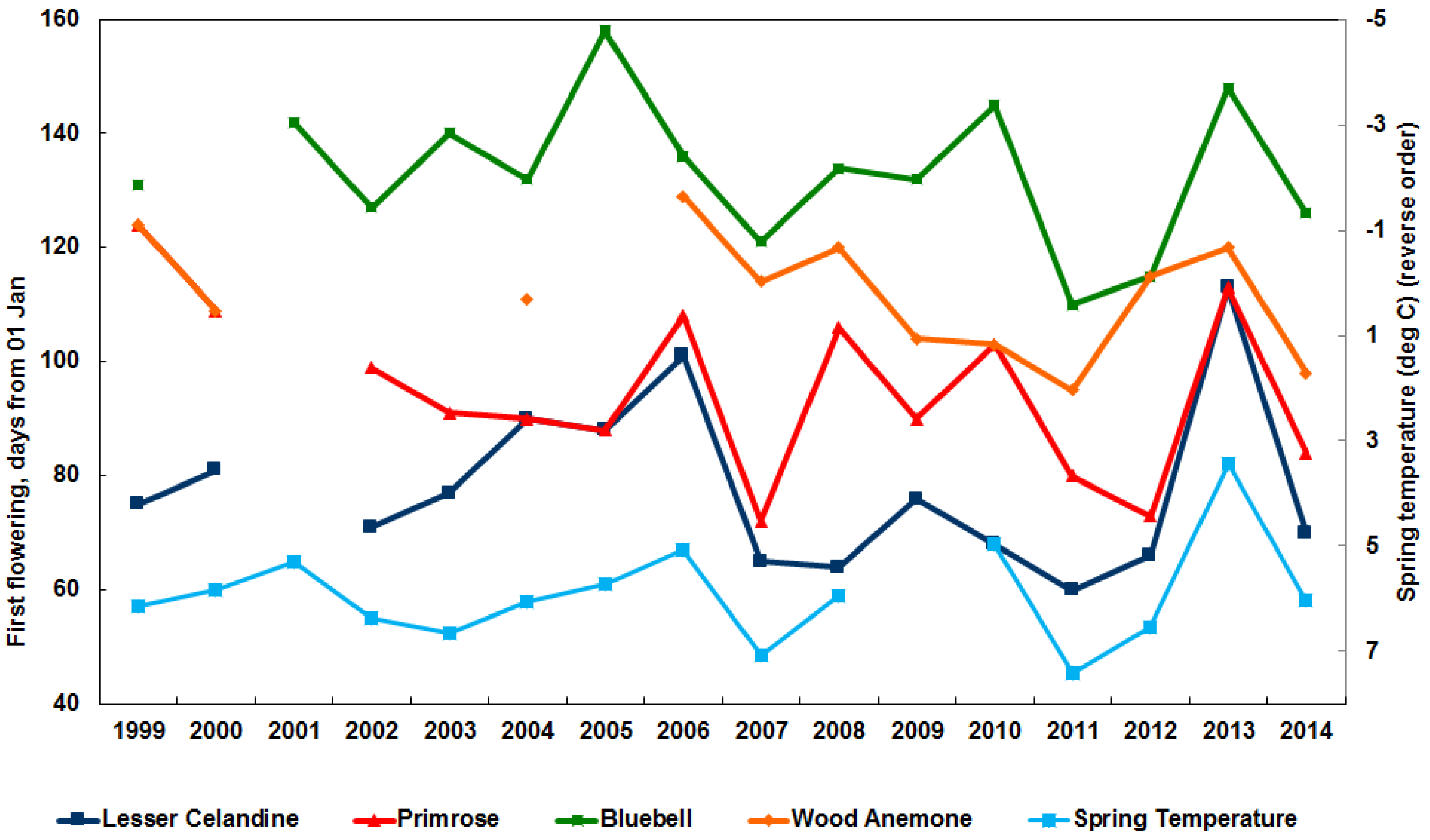


R index:

Hill's modified Ellenberg indicator value R (reaction) is correlated with soil acidity. The only significant change seen is with the calcareous grassland plots (CG10) after 2002 which show a slight steady increase ($p < 0.05$). This fits with increases in soil solution pH in calcareous grassland (Figure 24).

Figure 51: Weighted mean Hill's modified Ellenberg indicator value R (Reaction or Acidity) for the vascular plant layers of VF plots 1999-2013. Plot names use National Vegetation Classification (NVC) codes (Rodwell, 1991-2000).

Phenology – Vascular plants – Woodland species first flowering



Phenology:

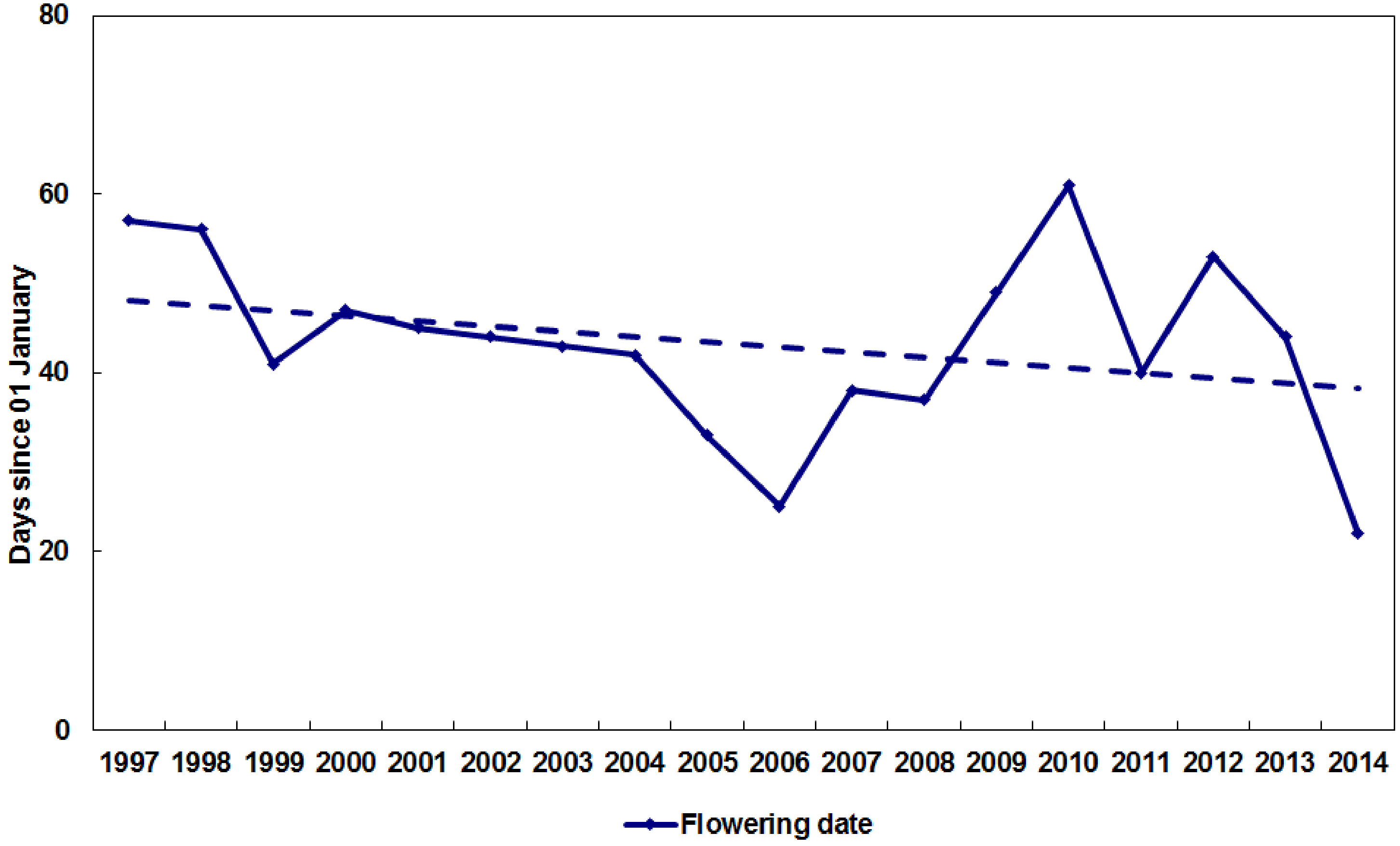
Of the 81 species currently monitored, a number of nominally woodland species have been monitored since 1999. Four of the commonest of these appear to show more or less parallel trends towards earlier flowering, but only that for *Primula vulgaris* (Primrose) is significant.

The Snowdon trends match UK trends for these species from data collated by the UK Phenology Network (http://www.naturescalendar.org.uk/)

Timing of first flowering is in part determined by average spring temperature.

Figure 52: Changes in the timing of first flowering of the woodland species Lesser Celandine (*Ranunculus ficaria*), Bluebell (*Hyacinthoides non-scripta*), Primrose (*Primula vulgaris*) and Wood Anemone (*Anemone nemorosa*), in relation to mean spring temperature, on the ECN site over the period 1999-2014.

Phenology – Vascular plants- Purple saxifrage (*Saxifraga oppositifolia*) first flowering

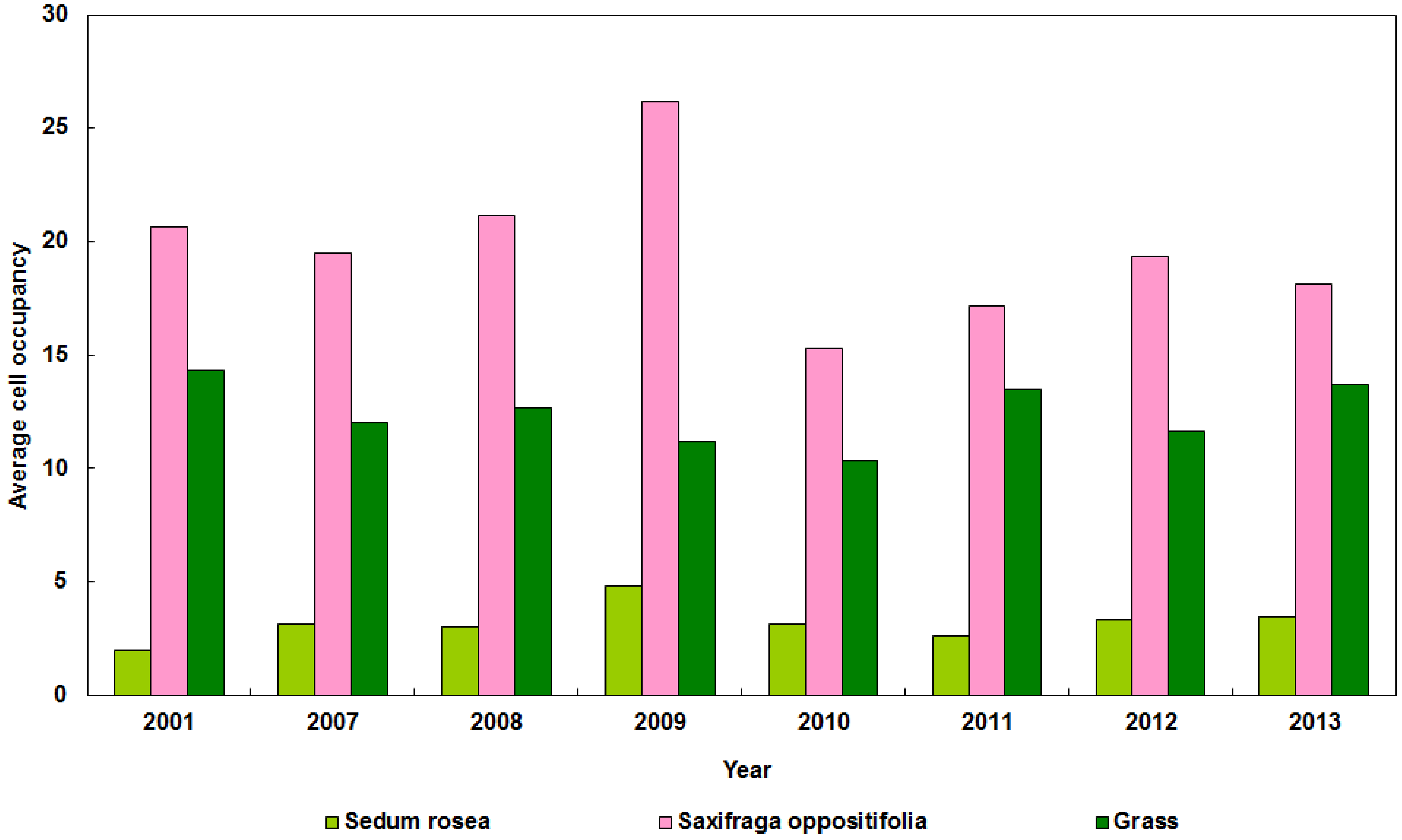


Purple saxifrage:

Purple saxifrage (*Saxifraga oppositifolia*), an arctic-alpine species occurring on the ECN site, has a very early flowering period. Over the period 1997-2008, first flowering dates had generally been getting earlier, but from 2009-13 later flowering occurred due to colder winters. After the very mild winter in 2014, however, the first flowering was the earliest yet recorded.

Figure 53: Purple Saxifrage (*Saxifraga oppositifolia*) date of first flowering on all sites over the period 1997-2014.

Arctic-alpines

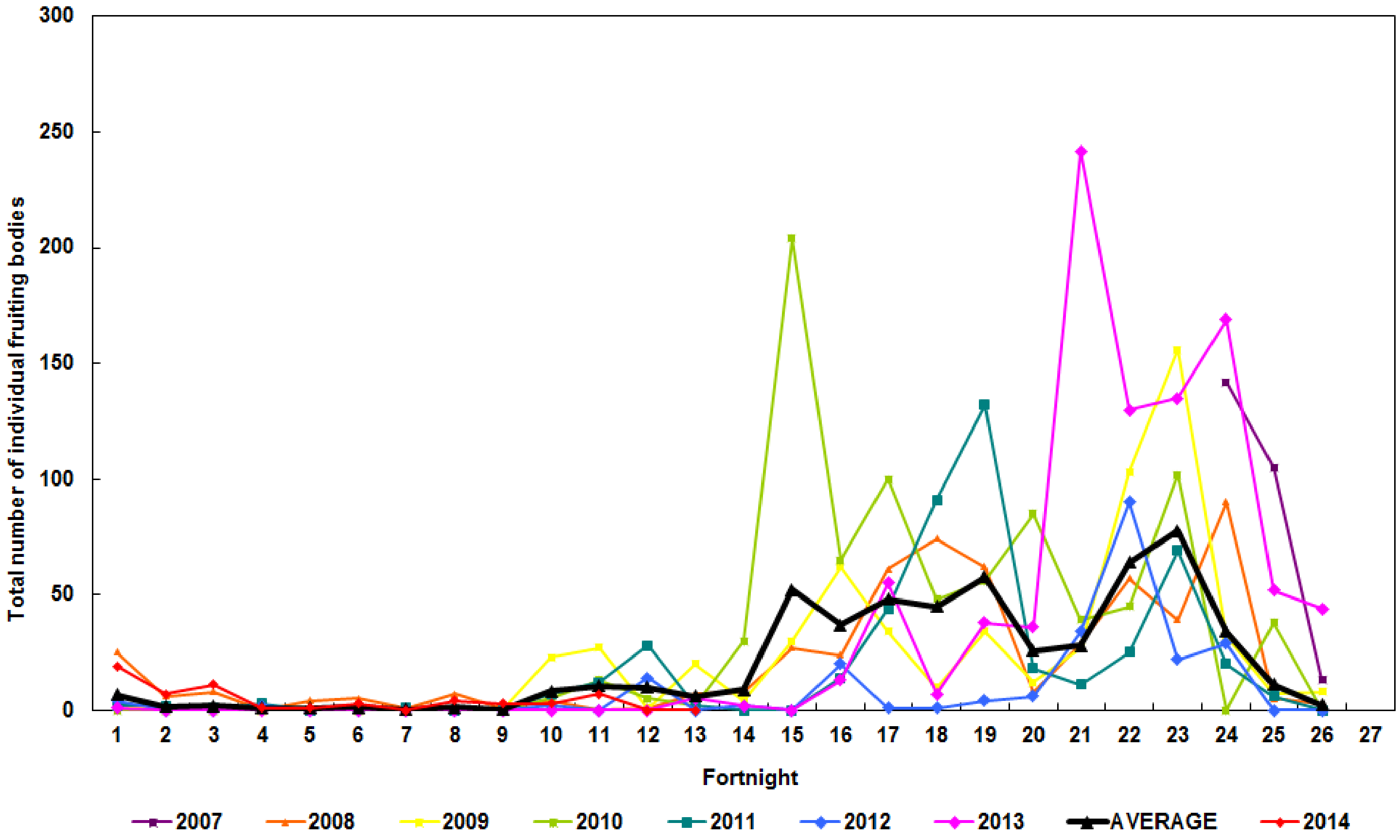


Arctic-alpines:

Arctic-alpine plant species, found on cliffs on the ECN site are relict species surviving since the last Ice Age. Monitoring is a non-ECN protocol which has been carried out since 2001. Every three years, all the plots are re-recorded while in the intervening years, a subset of 6 plots, shown here, on Diffwys are recorded. None of the changes shown here, however, are significant. The next full recording of all plots will take place in the summer of 2014.

Figure 54: Changes in cell occupancy of sampling quadrats observed for the arctic-alpines Roseroot (*Sedum rosea*) and Purple saxifrage (*Saxifraga oppositifolia*) recorded in quadrats on Diffwys (n=6).

Fungi



Fungi:

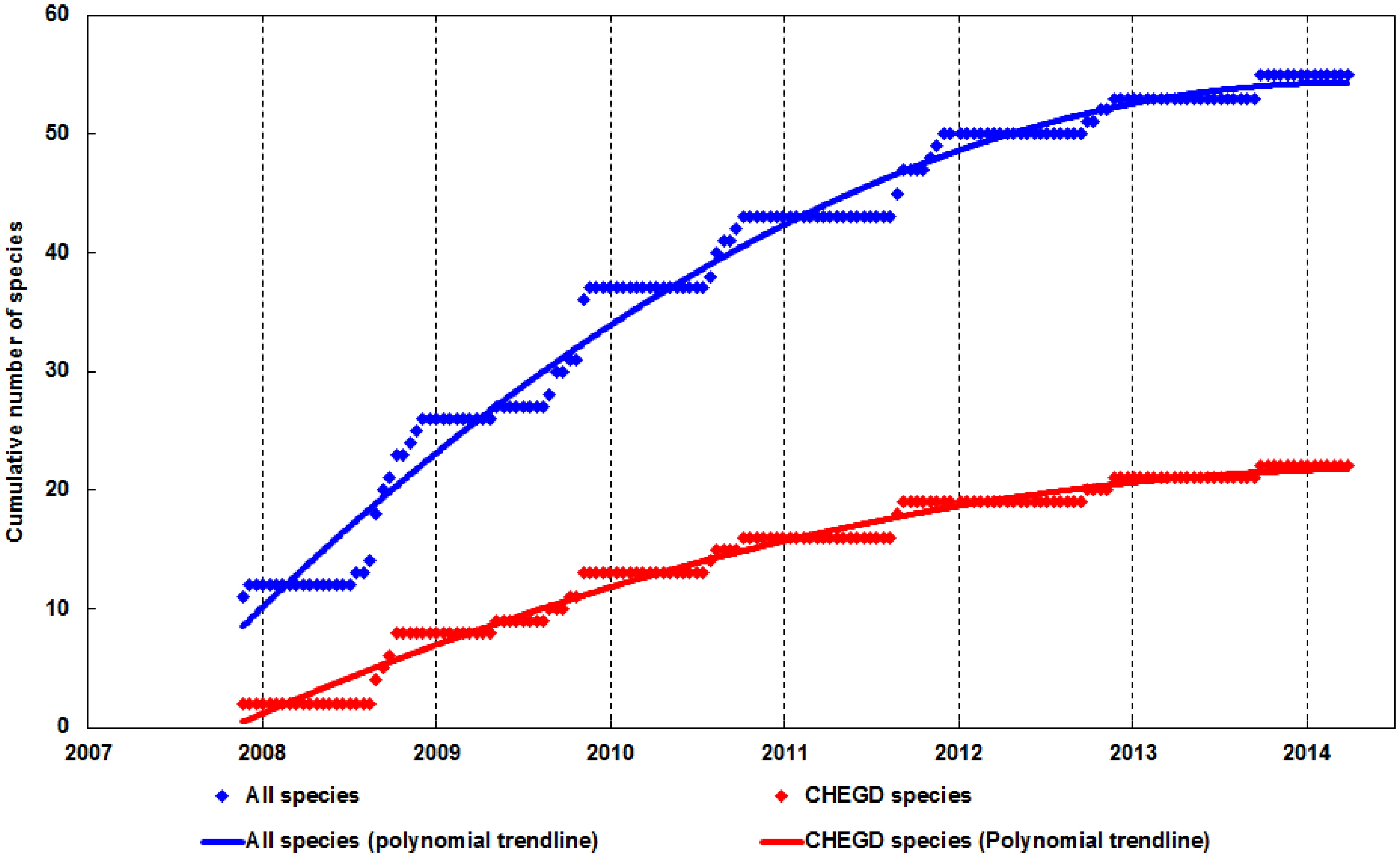
Fungi monitoring is a non-ECN protocol and recording is carried out fortnightly throughout the year, with identification of difficult genera carried out by a local mycological expert.

Fruiting varies quite considerably from year-to-year, both in intensity and timing. 2013 was the most productive year since recording started, following after the least productive year in 2012.

The intensity of continuous recording on the ECN site is unique in the UK. The count data provides an insight into the triggers for fruiting in the mycoflora on the site.

Figure 55: Log number of individuals and number of species recorded at fortnightly intervals within the ECN fungus sampling area over the period 2007 - 2013.

Fungi



Fungi:

The number of species recorded has continued to increase each year since recording began in late 2007, although the rate of increase has slowed somewhat in the last 2 years.

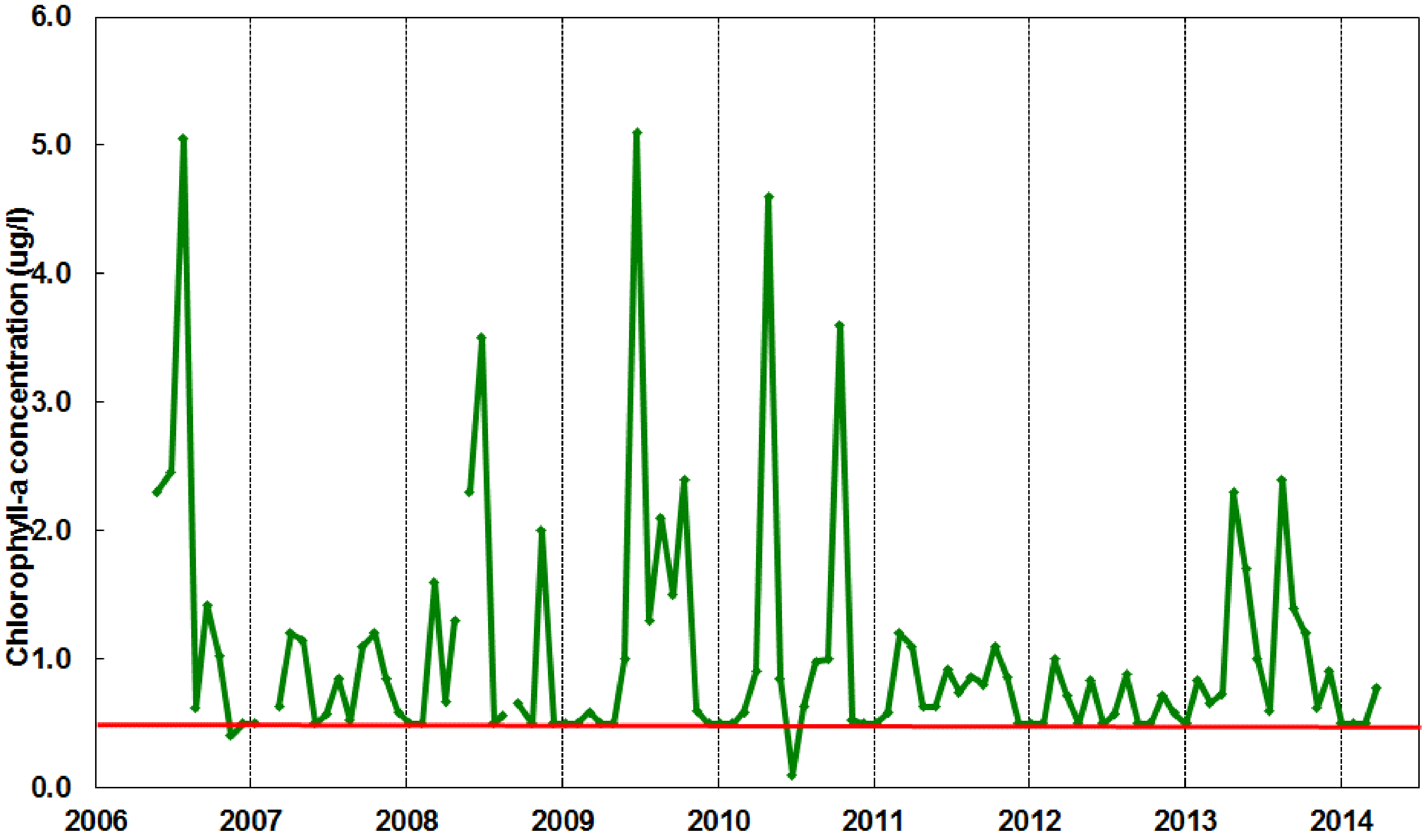
CHEGD species, comprise the **C**lavariaceae, ***H****ygrocybe* species, ***E****ntoloma species*, **G**eoglossaceae and ***D****ermoloma* species which are indicators of unimproved acid grassland (Griffiths *et al.* 2006).

30 soil cores were taken by Gareth Griffiths, University of Aberystwyth, in 2014 with a view to using the species counts to help with barcoding the mycoflora present on the site.

Figure 56: Cumulative numbers of species and CHEGD species recorded at fortnightly intervals within the ECN fungus sampling plot over the period 2007 - 2013.

3.9 Data summary biological variables – Freshwater

Phytoplankton (FPP) – Chlorophyll-a



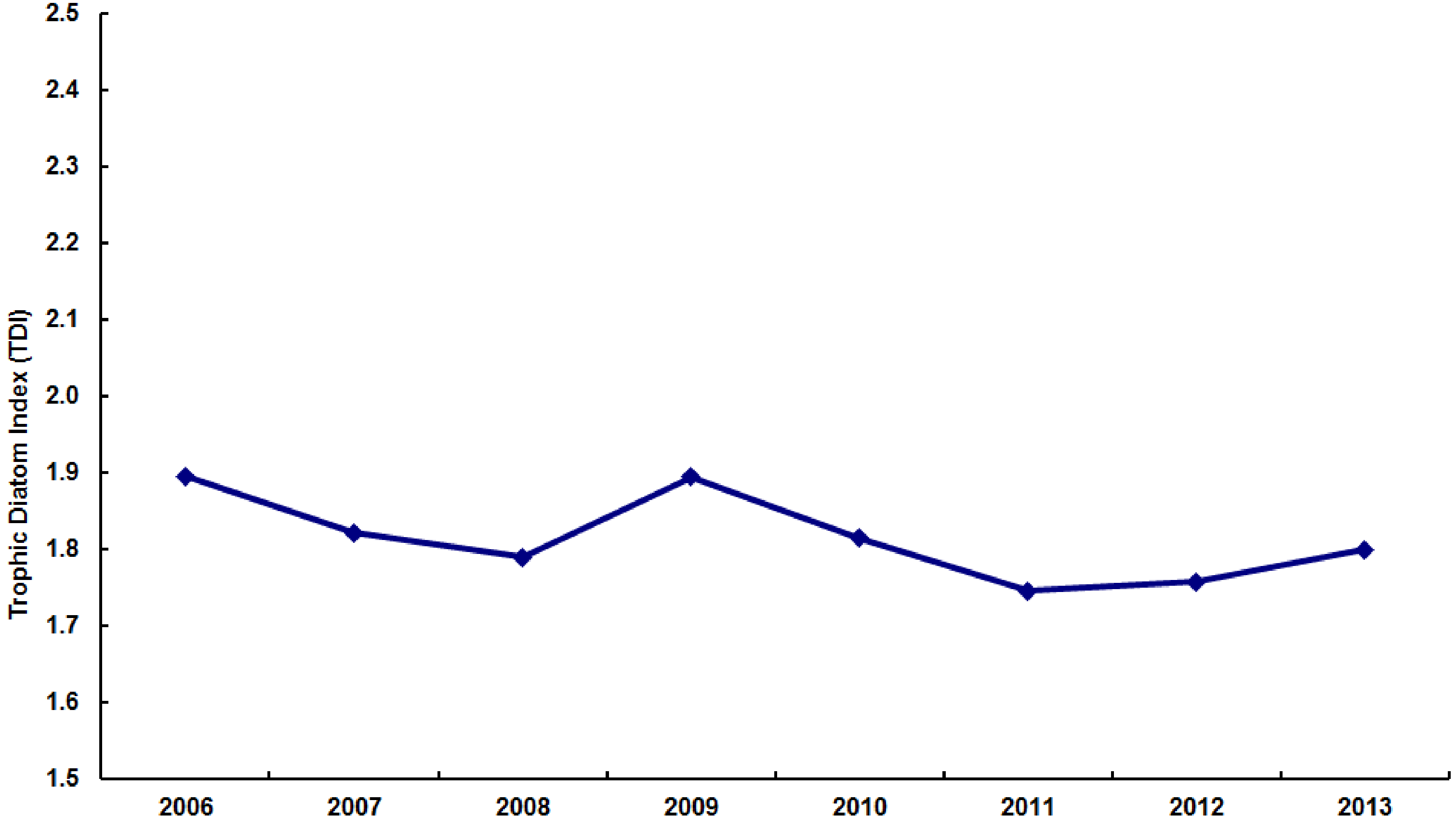
Chlorophyll-a:

Nant Teyrn is the outlet stream for Llyn Teyrn which means the chlorophyll-*a* results reflect changes in Llyn Teyrn as well.

Low Chlorophyll-a values are evident all through 2007, 2011 and 2012, with the latter year being particularly low. 2011 and 2012 were also years with poor summers and persistent cloudy conditions. By contrast, the warmer and sunnier summer of 2013 is reflected in higher values.

Figure 57: Chlorophyll-*a* concentration from Nant Teyrn, 2006 - 2013, horizontal line shows the detectable limit at 0.50 µg.l^{-1}.

Epilithic Diatoms (FDT) - Trophic Diatom Index



Epilithic diatoms:

The Trophic Diatom Index (TDI) was developed to assess the level of eutrophication in running water using benthic diatoms (Kelly *et al.* 2001, 2007).

There is no significant trend over the short recording period (8 years), and the average TDI of for Nant Teyrn is 1.81, typical of a low-nutrient watercourse.

Figure 58: Trophic Diatom Index averaged from 3 locations in Nant Teyrn, 2006 – 2013.

Aquatic Macrophytes (FMA)

Species	Year	2006	2007	2008	2009	2010	2011	2012	2013
Marsupella emarginata		IV	IV	IV	IV	IV	V	IV	II
Nardia compressa		V	IV	IV	V	V	V	V	V
Unidentified Green algae		V	V	IV	V	IV	IV	IV	IV
Pellia epiphylla		IV	IV	IV	III	III	IV	IV	V
Lobelia dortmanna		II	II	II	II	I	I	I	I
Racomitrium aciculare		III	III	III	II	III	III	III	II
Carex rostrata		II	II	I	II	I	II	I	II
Potamogeton polygonifolius		II	I	II	II	II	II	II	III
Batrachospermom turfosum			IV	V	V	IV	V	V	IV
Sphagnum compactum		V							
Sphagnum tenellum		II							
Molinia caerulea		V	III	I	I	I	I	IV	I
Narthecium ossifragum		IV	II	III	II	III	IV	IV	IV
Juncus bulbosus		IV	II	III	II	II	II	I	III
Viola palustris		IV	II	II	III	IV	V	V	V
Sphagnum denticulatum			III	III	II	IV	IV	IV	V
Cladopodiella fluitans			IV	III	I	III	II	III	II
Ephebe lanata			I	III	IV	IV	IV	IV	IV
Sphagnum palustre			II	II	IV	II	III	II	II
Unidentified Brown algae				II	IV	V	V	V	V
Scapania undulata			II		II		I	II	
Juncus acutiflorus			I	I	I	I	I	I	I
Cephalozia bicuspidata			I						
Calypogeia fissa			I						
Sphagnum inundatum			I	I				I	I
Carex nigra			I	I				I	
Campylopus atrovirens					I				
Juncus effusus					I				
Cephaloziella sp.					I		I		
Bryum alpinum						I		I	
Blindia acuta							I		
Calypogeia sp.							I		
Unidentified Red Algae							I		
Hyocomium armoricum							I	I	I
Andreaea rothii falcata							I	I	
Unidentified Yellow Algae								II	I
Carex echinata								I	
Andreaea rupestris								I	III
Carex demissa							I	I	II
Carex panicea							I	I	II
Agrostis canina									I
Eriophorum angustifolium									I
Trichophorum cespitosum									I
Bare rock		V	V	V	V	V	V	V	V

Macrophytes:

The bulk of the species observed are typical of upland streams flowing through peat or over mildly acidic igneous rocks.

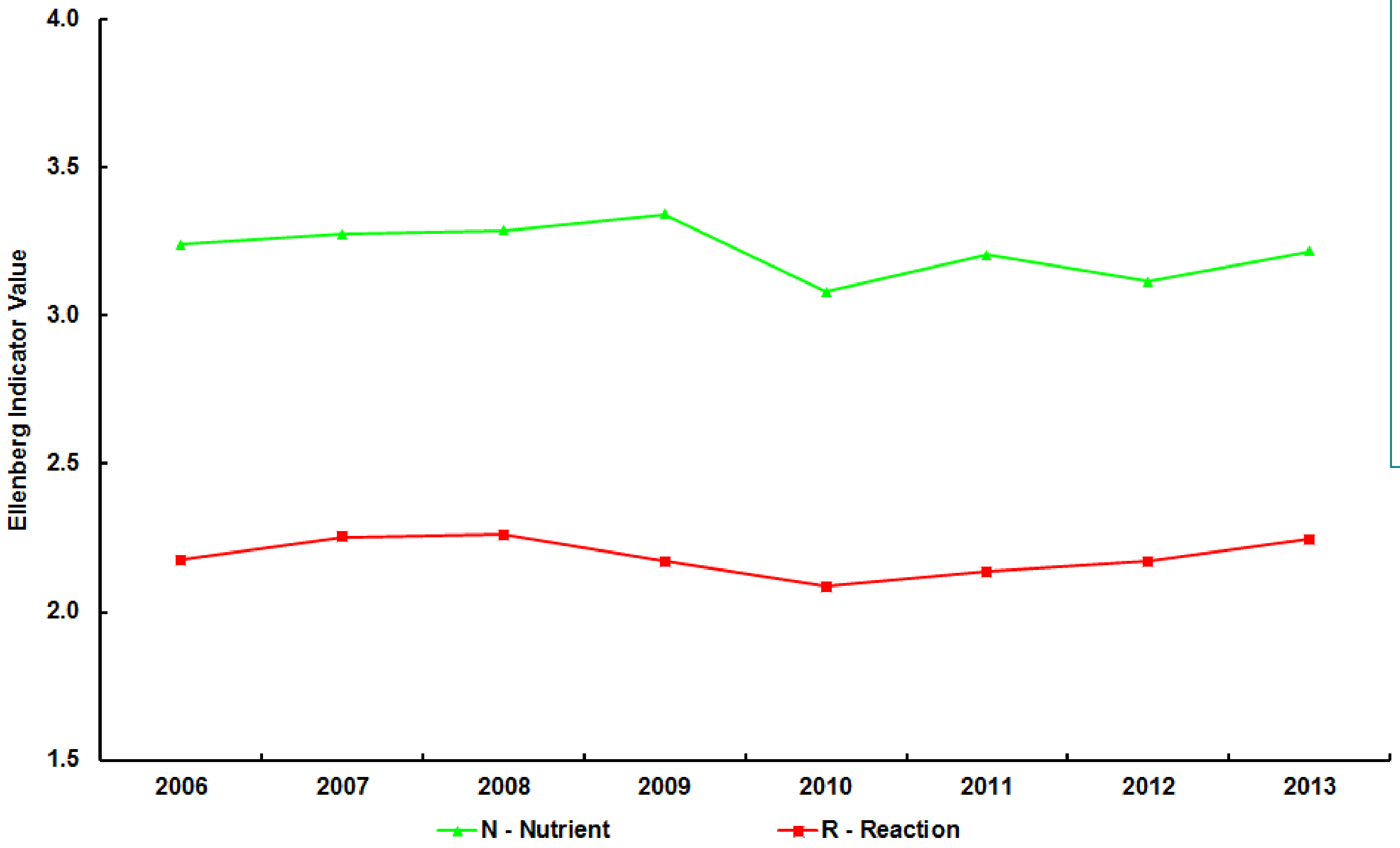
The upper and lower sections of the sampled length are different in character, the upper being a deep slower-flowing channel cut through peat, while the lower is faster flowing, has very thin peaty soils and abundant large boulders.

Little change is visible over such a short span of time. It is possible that the presence, in 2011, of *Blindia acuta* and *Carex demissa* (Common Yellow Sedge), both of which normally occur in more base-rich habitats, indicate the start of a change, but it is too early to say. There has been a slight reduction in frequency of *Lobelia dortmanna* (Water Lobelia) and an increase in *Potamogeton polygonifolus* (Bog Pondweed) in the higher peaty section of the stream.

The difference between 2006 and later years is due to different recorders. A number of species in 2006 e.g. *Sphagnum compactum* and *S. tenellum* are probably misidentifications.

Table 7: Results from macrophyte surveys in Nant Teyrn 2006-2013. Abbreviations: I 1-20% frequency, II 21-40%, III 41-60%, IV 61-80%, V 81-100%.

Aquatic Macrophytes (FMA) – Ellenberg Indicator Values



Macrophytes - Ellenberg Indicator Values:

Hill's modified Ellenberg indicator values can be calculated from the frequency data. Those for N (Nutrient) and R (Reaction) show no change over the short period of recording. The low level of the R indicator shows how acidic the stream vegetation in Nant Teyrn is, R=2 being ascribed to species occurring typically in conditions between acid and extremely acid (Hill et. al. 1999).

Figure 59: Weighted average Hill's Ellenberg Indicator Values for N - Nutrient and R - Reaction for Nant Teyrn, 2006 – 2013.

4. Forward look for 2014-15

In April 2013, the Countryside Council for Wales, the Environment Agency in Wales and the Forestry Commission in Wales were all joined together by statute to form a new environmental body, Natural Resources Wales. This merger could present some challenges to the future operation of the project, but there has been strong support for its continuation from Welsh Government.

The Environmental Change Network has now been in existence since 1992 and on the 12-13th May 2014 a symposium was held at Lancaster University entitled “20 years of ECN data”. Following on from this symposium, various groups will be producing papers derived from ECN data for a special issue of the journal Ecological Indicators due to be published in May 2016. Morecroft *et al*. (2009) was an initial analysis of the first 15 years of the network data and put the Snowdon site data in context, but it is intended that this analysis will be fully updated and extended to cover further protocols. A workshop was also held in Edinburgh in January 2014 to assess the feasibility of extending the approach taken by the Ecosystem Services paper by Dick *et al.* (2011) over the whole 20 year period that ECN has been operating.

There are a number of emerging issues which will involve the Snowdon ECN project over the next 12 months - these involve both policy and project delivery aspects. The current funding agreement for the running of the site comes to an end in April 2015 and a new funding agreement is currently under negotiation with Welsh Government. The current intention is to seek another 5 year funding period, however technical issues relating to the creation of NRW may mean a shorter term funding mechanism is put in place temporarily. As part of the negotiation process a business case has been drawn up for financial assessment by NRW and a partnership mandate application will shortly be written to seek agreement from NRW for an agreement with WG.

The key work delivery change which is expected to arise over the next 12 months results from the enhanced capacity of the new NRW laboratory at Llanelli to a point where it can handle dilute waters to the quality standards required for the ECN work. This will enable NRW to undertake water sample analysis internally. In preparation for this a laboratory transfer plan has been drawn up to ensure water standards are maintained and in order to prevent a step change in results due to differences in laboratory analytical approach. As part of this, an inter-laboratory quality assurance exercise has been developed involving the Upland Waters Monitoring Network with samples collected by CEH Bangor and comparable analysis to be undertaken by both the NRW Llanelli laboratory and the CEH Laboratory in Lancaster. When the NRW lab is ready for sample switching the inter-lab comparison exercise will be initiated.

5. Abbreviations

ANC	Acid Neutralizing Capacity
AO	Arctic Oscillation
AOT40	Accumulated dose over threshold concentration of 40ppb
AWS	Automatic Weather Station
CCU	Central Coordinating Unit
CCW	Countryside Council for Wales
CEH	Centre for Ecology ad Hydrology
DOC	Dissolved Organic Carbon
ECN	Environmental Change Network
IBP	International Biological Programme
NRW	Natural Resources Wales
NVC	National Vegetation Classification
RoTAP	Review of Transboundary Air Pollution
TDI	Trophic Diatom Index
UKEAP	UK Eutrophying and Acidifying atmospheric Pollution network
WG	Welsh Government
xSO_4	Non-marine sulphate

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Appendix 1 Trend statistics

The significance of the trends shown in this report have been tested using the non-parametric Mann-Kendall Trend Test in the package Kendall of the open-source statistical software R (R Development Core Team 2014).

Table 8: Physical variables

Protocol	Measurement	Dates	Last date	Trend	Mann-Kendall trend test		
					tau	n	1-tailed significance
MM	Maximum temp. residual (deg C)	1996-2013	2013		-0.059	18	n.s.
MM	Minimum temp. residual (deg C)	1996-2013	2013		-0.216	18	n.s.
MM	Temperature range residual (deg C)	1996-2013	2013		0.098	18	n.s.
MM	Mid-range temp. residual (deg C)	1996-2013	2013		-0.138	18	n.s.
MM	Grass min. temp. residual (deg C)	1996-2013	2013		0.229	18	n.s.
MM	Soil temp. residual (deg C)	1996-2013	2013		0.000	18	n.s.
MM	Manual rainfall residual (mm)	1996-2013	2013		0.033	18	n.s.
CL	Cloudiness	1996-2013	2013		0.281	18	n.s.
MA	Annual rainfall	1996-2013	2013		0.150	18	n.s.
MA	Mean temperature	1996-2013	2013		0.147	17	n.s.
MA	Maximum temperature	1996-2013	2013		0.085	18	n.s.
MA	Min temperature	1996-2013	2013		-0.176	17	n.s.
MA	Mean soil temperature	1996-2013	2013		0.209	16	n.s.
MA	Maximum soil temperature	1996-2013	2013		-0.037	17	n.s.
MA	Min soil temperature	1996-2013	2013		-0.083	16	n.s.
MA	High Temp days	1996-2013	2013		-0.134	18	n.s.
MA	High Temp days	1996-2013	2013		-0.128	17	n.s.
MA	Mean Spring temperature	1996-2013	2013		-0.074	17	n.s.
MA	Mean Summer temperature	1996-2013	2013		-0.007	18	n.s.
MA	Mean Autumn temperature	1996-2013	2013		0.250	18	n.s.
MA	Mean Winter temperature	1996-2014	2014		0.064	19	n.s.
MA	Spring Rainfall	1996-2013	2013		-0.137	18	n.s.
MA	Summer Rainfall	1996-2013	2013	upwards	0.322	19	*
MA	Autumn Rainfall	1996-2013	2013		0.006	19	n.s.
MA	Winter Rainfall	1996-2013	2013		0.088	19	n.s.
MA	Spring Raindays	1996-2013	2013		0.037	17	n.s.
MA	Summer Raindays	1996-2013	2013		0.303	16	n.s.
MA	Autumn Raindays	1996-2013	2013		0.008	16	n.s.
MA	Winter Raindays	1996-2014	2014		0.073	18	n.s.
SN	Date of last snowlie	1995-2014	2014		-0.064	20	n.s.

Table 9: Chemical variables

Protocol	Measurement	Dates	Last date	Trend	Mann-Kendall trend test		
					tau	n	1-tailed significance
AN	NO2	2002-2013	2013		0.121	14	n.s.
AS	SO2	2002-2013	2013	downwards	-0.485	12	*
OZ	Average spring ozone concentration	2000-2013	2013	downwards	-0.436	13	*
OZ	Ozone AOT40 May-June	2000-2013	2013		-0.231	13	n.s.
PC	pH Rain Water	1997-2013	2013	upwards	0.421	17	*
PC	SO4	1997-2013	2013	downwards	-0.702	17	***
PC	NO3 Rain Water	1997-2013	2013	downwards	-0.555	17	***
PC	NH4-N	1997-2013	2013		-0.258	17	n.s.
PC	PO4	1997-2013	2013		0.070	17	n.s.
PC	Cl	1997-2013	2013		-0.252	17	n.s.
PC	DOC	1997-2013	2013	downwards	-0.424	17	*
PC	Fe	1997-2013	2013		-0.033	17	n.s.
PC	Al	1997-2013	2013		-0.193	17	n.s.
WC	pH Stream Water	1997-2013	2013	upwards	0.539	17	**
WC	SO4	1997-2013	2013	downwards	-0.727	17	***
WC	NO3 Stream Water	1997-2013	2013	downwards	-0.799	17	***
WC	NH4-N	1997-2013	2013	downwards	-0.373	17	*
WC	PO4	1997-2013	2013	downwards	0.424	17	*
WC	Cl	1997-2013	2013		-0.303	17	n.s.
WC	DOC	1997-2013	2013	downwards	-0.421	17	*
WC	Fe	1997-2013	2013	downwards	-0.325	17	*
WC	Al	1997-2013	2013	downwards	-0.587	17	***
SSS	pH	1997-2013	2013	upwards	0.721	17	***
SSS	SO4	1997-2013	2013	downwards	-0.444	17	**
SSS	NO3-N	1997-2013	2013		-0.303	17	n.s.
SSS	NH4-N	1997-2013	2013	downwards	-0.637	17	***
SSS	PO4	1997-2013	2013	downwards	0.642	17	***
SSS	Cl	1997-2013	2013	downwards	-0.435	17	**
SSS	DOC	1997-2013	2013	downwards	-0.515	17	**
SSS	Fe	1997-2013	2013	downwards	-0.553	17	***
SSS	Al	1997-2013	2013		-0.180	17	n.s.
SSD	pH	1999-2013	2013	upwards	0.714	15	***
SSD	SO4	1999-2013	2013	downwards	-0.367	15	*
SSD	NO3-N	1999-2013	2013	downwards	-0.593	15	***
SSD	NH4-N	1999-2013	2013	downwards	-0.425	15	*
SSD	PO4	1999-2013	2013		-0.010	15	n.s.
SSD	Cl	1999-2013	2013	downwards	-0.333	15	*
SSD	DOC	1999-2013	2013	downwards	-0.555	15	**
SSD	Fe	1999-2013	2013		0.087	15	n.s.
SSD	Al	1999-2013	2013	downwards	-0.394	15	*
PC	xSO4	1997-2013	2013	downwards	-0.524	15	**
PC	NO3-N + NH4-N	1997-2013	2013	downwards	-0.574	15	**
PC	xSO4 + NO3-N + NH4-N	1997-2013	2013	downwards	-0.505	15	**
WC	ANC	1997-2013	2013		0.250	17	n.s.
FWC	Cu, Dissolved	2006-2013	2013	downwards	-0.643	8	*
FWC	Cu	2006-2013	2013			8	n.s.
FWC	Hg, Dissolved	2006-2013	2013			8	n.s.
FWC	Hg	2006-2013	2013	downwards	-0.681	8	*
FWC	SiO2 as Si	2006-2013	2013	upwards	0.764	8	**
FWC	Zn, Dissolved	2006-2013	2013		-0.429	8	n.s.
FWC	Zn	2006-2013	2013		-0.286	8	n.s.
FWC	Mn, Dissolved	2006-2013	2013		-0.286	8	n.s.
FWC	Mn	2006-2013	2013		-0.143	8	n.s.

Table 10: Biological variables

Protocol	Measurement	Dates	Last date	Trend	Mann-Kendall trend test		
					tau	n	1-tailed significance
BA	Bat numbers	1996-2013	2013		-0.133	18	n.s.
BB	Bird numbers	1997-2014	2014		0.000	19	n.s.
BF	Frog spawning date	1996-2014	2014		-0.066	18	n.s.
BF	Frog spawning,pool1,duration	1996-2014	2014	shorter	-0.467	16	**
IB	Av numbers per transect	1996-2013	2013		0.098	18	n.s.
IB	Shannon diversity	1996-2013	2013	downwards	-0.343	18	*
IG	No of Carabids	1999-2013	2013	downwards	-0.619	15	***
IG	No of Carabids	1999-2013	2013	downwards	-0.619	15	***
IG	No of Carabids,Transect A	1999-2013	2013	downwards	-0.600	15	***
IG	No of Carabids,Transect B	1999-2013	2013	downwards	-0.581	15	***
IG	No of Carabids,Transect C	1999-2013	2013	downwards	-0.390	15	*
IG	No of Carabids (excl Perostichus madidus)	1999-2013	2013	downwards	-0.498	15	**
IG	No of Pterostichus madidus	1999-2013	2013	downwards	-0.638	15	***
IG	Log no of carabids+1,All Transects	1999-2013	2013	downwards	-0.625	15	***
IG	Log no of carabids+1,Transect A	1999-2013	2013	downwards	-0.590	15	***
IG	Log no of carabids+1,Transect B	1999-2013	2013	downwards	-0.574	15	**
IG	Log no of carabids+1,Transect C	1999-2013	2013	downwards	-0.390	15	*
IA	No of spiders	2000-2014	2014		0.099	14	n.s.
IA	No of spiders,Transect A	2000-2014	2014		0.011	14	n.s.
IA	No of spiders,Transect B	2000-2014	2014		0.297	14	n.s.
IA	No of spiders,Transect C	2000-2014	2014		0.165	14	n.s.
IA	Log no of spiders+1, All Transects	2000-2013	2013		0.110	14	n.s.
IA	Log no of spiders+1,Transect A	2000-2013	2013		0.022	14	n.s.
IA	Log no of spiders+1,Transect B	2000-2013	2013		0.300	14	n.s.
IA	Log no of spiders+1,Transect C	2000-2013	2013		0.169	14	n.s.
VF	Ellenberg N,CG10	1999-2013	2013		0.299	11	n.s.
VF	Ellenberg R,CG10	1999-2013	2013		0.404	11	n.s.
VF	Ellenberg R,CG10	2002-2013	2013	upwards	0.539	10	*
LU	Sheep density	1997-2013	2013	downwards	-0.515	17	**
LU	Sheep Average numbers. Winter	1997-2013	2014	downwards	-0.353	18	*
LU	Sheep Average numbers. Spring	1997-2013	2014		-0.176	18	n.s.
LU	Sheep Average numbers. Summer	1997-2013	2013		0.206	17	n.s.
LU	Sheep Average numbers. Autumn	1997-2013	2013	downwards	-0.559	17	***
LU	Goat density	1997-2013	2013	upwards	0.382	17	*
LU	Goat Average numbers. Winter	1997-2013	2014	upwards	0.370	18	*
LU	Goat Average numbers. Spring	1997-2014	2014	upwards	0.333	18	*
LU	Goat Average numbers. Summer	1997-2013	2013	upwards	0.361	17	*
LU	Goat Average numbers. Autumn	1997-2013	2013	upwards	0.548	17	***
PH	Phenology, Anemone nemorosa	1999-2013	2013		-0.290	12	n.s.
PH	Phenology, Hyacinthoides non-scripta	1999-2013	2013		-0.134	15	n.s.
PH	Phenology, Primula vulgaris	1999-2013	2013	earlier	-0.345	15	*
PH	Phenology, Ranunculus ficaria	1999-2013	2013		-0.162	15	n.s.
PH	First recorded flower (Purple saxifrage)	1997-2014	2014		-0.262	18	n.s.
PH	Phenology - Bird return - Comm Sandpiper	1998-2014	2014		0.077	15	n.s.
PH	Phenology - Bird return - Meadow Pipit	1998-2014	2014		0.011	14	n.s.
PH	Phenology - Bird return - Ring Ouzel	1998-2014	2014		-0.133	14	n.s.
PH	Phenology - Bird return - Wheatear	1998-2014	2014		0.159	16	n.s.
FMA	Macrophytes - Ellenberg N	2006-2013	2013		-0.214	8	n.s.
FMA	Macrophytes - Ellenberg R	2006-2013	2013		-0.148	8	n.s.
FDT	Trophic Diatom Index	2006-2013	2013		-0.500	8	n.s.

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