# LOWESWATER:

# WATER QUALITY MONITORING 2012

# REPORT NUMBER 002-LCP-WCRT

**ANDREW SHAW**

LOWESWATER CARE PROGRAMME
WEST CUMBRIA RIVERS TRUST
THE OLD SAWMILL
THIRLMERE
KESWICK
CUMBRIA, CA12 4TQ

DECEMBER 2013

# LOWESWATER:

# WATER QUALITY MONITORING 2012

## CONTENTS

# LOWESWATER:

# WATER QUALITY MONITORING 2012

## SUMMARY

Loweswater, one of the smaller and more picturesque lakes in the English Lake District, was once an excellent brown trout (*Salmo trutta*) fishery, but with the impact of agricultural practices and domestic input from the catchment over many years the water quality has declined and the lake has suffered seasonal blooms of potentially toxic blue-green algae, greatly diminished fish populations and a proliferation of phantom midge larvae (*Chaoborus)* in open water.

During 2012, the lake's water quality was monitored through evaluation of chemical data on water samples taken on a monthly basis and by enumeration and identification of the lake's phytoplankton populations, also on a monthly basis, and the results were compared to data gathered in 2011, when the lake's trophic status was classified as mesotrophic.

The results of the 2012 monitoring programme indicate that Loweswater should continue to be classified as mesotrophic under the OECD scheme and close to being of good ecological status under the Water Framework Directive.

# 1. INTRODUCTION

## *Background*

Loweswater is a small lake of 0.64 $km^2$, which lies within the north-west boundary of the Lake District National Park, 3º 21' W and 54º 35' N.

The Loweswater catchment area includes 371 ha of open fells, 273 ha of in-bye land (grassland) and 130 ha of woodland. The lake has a maximum depth of 16 metres and a volume of 5.4 million cubic metres[1] of water, a long retention time (or residence time) with a mean of 199 days, and is the thirteenth largest of the Lake District lakes (Fryer, 1991). There are several inflow streams to the lake, the four main ones being Dub Beck at the northern end of the lake, Holme Beck and Black Beck on the western side, and Crabtree Beck on the eastern side. There is one outflow, also named Dub Beck, which flows into Park Beck and then into the north end of Crummock Water close to that lake's outflow, the River Cocker.

## *Water quality*

A comprehensive review of the chemical data from surveys, carried out since 1984, showed that over the 20 years since 1984 concentrations of total phosphorus (TP) in Loweswater increased and that over fifteen years phytoplankton chlorophyll *a* levels (a quantitative measure of the amount of algae in the water) rose, with the result that the lake's trophic status was classified as 'close to the mesotrophic-eutrophic boundary' (see Report number 001-LCP-WCRT, 2011).

One clear indicator of deteriorating water quality has been the regular incidence of potentially toxic blue-green algal (cyanobacterial) blooms on the lake, and the decline in the lake's water quality has also brought about other changes to the aquatic community, including greatly

[1] One cubic metre is approximately 220 gallons.

diminished fish populations (Shaw, 2009) and a proliferation of phantom midge larvae (*Chaoborus)* in open water, possibly competing with the fish for available food (Winfield, 2008).

During 2011 and again in 2012, the lake's water quality was monitored through evaluation of the Environment Agency's chemical data on water samples taken on a monthly basis and by enumeration and identification of the lake's phytoplankton populations, also on a monthly basis. In addition, in 2012, the water quality of Dub Beck at Waterend was also monitored through evaluation of water samples taken regularly through the year. The EU Water Framework Directive includes phytoplankton as an important element to be used in the assessment of the ecological status of a lake; its ecological significance is determined by the fact that its productivity indicators are also indicators of the trophic status of water bodies (Cheshmedjiev et al., 2010; Pasztaleniec and Poniewozik, 2010). The results of the water quality monitoring programme of Loweswater for 2011 indicated that the lake should be classified as mesotrophic, an improvement on previous years, and that under the Water Framework Directive the lake was also close to being classified as of good ecological status (see Report Number 001-LCP-WCRT, 2011).

The purpose of this document is to:

- Report the results of the water quality monitoring programme of Loweswater in 2012 and compare them with those of 2011.
- Using the results of the 2012 water quality monitoring programme, determine the trophic status of the Loweswater using OECD guidelines and determine the lake's ecological status under the EU Water Framework Directive.

# 2. METHODS

## 2. 1 Sample collection

***Lake***

Using a small electrically powered dinghy, staff from Environment Agency collected five-metre integrated mid-lake water samples from Loweswater on a monthly basis. The samples were stored in one-litre plastic containers and labelled with the sample number and date. On each occasion, one litre of water was retained by the Environment Agency for analysis at their Starcross Laboratory in Exeter, Devon and another litre given to the author for subsequent processing for enumeration and identification of algal populations.

***Dub Beck***

At regular intervals throughout the year, one litre samples were collected from Dub Beck at Waterend (one of the main inflows to the lake) near the footbridge at NY 1170 2245 and retained by the Environment Agency for analysis at their Starcross Laboratory in Exeter, Devon.

## 2.2 Water quality monitoring

***Lake***

At the point of sampling, the Environment Agency measured water transparency with the aid of a Secchi disc. The black and white painted metal disc, 30 cm in diameter, was lowered into the water and the depth at which it disappeared from view noted from the calibrated rope. Also, using a YSI Professional Plus handheld multiparameter meter, they measured the Water temperature, pH, Oxygen concentration and Conductivity (all measurements at a depth of 25 - 30 cm). In addition, the Starcross Laboratory analysed each water sample for a wide range of variables, including: Alkalinity, Total Phosphorus, Soluble Reactive Phosphorus, Chlorophyll *a*, and Total Nitrogen.

***Dub Beck at Waterend***

At the point of sampling, using a YSI Professional Plus handheld multiparameter meter, staff of the Environment Agency, measured the Water temperature, pH, Oxygen concentration and Conductivity.  In addition, the Starcross Laboratory analysed each water sample for Soluble Reactive Phosphorus and Total Nitrogen.

## 2.3 Phytoplankton identification and enumeration

***Preserving water samples***

Lugol's iodine solution[2] was added to the water samples at the rate of 4 - 5ml / litre in order to preserve the algae and increase their rate of sedimentation during subsequent processing.

***Concentrating samples***

Sub samples of 300 ml of the iodine-preserved water samples were concentrated to 5 ml (i.e. a factor of x60) by a two-stage sedimentation procedure, in order to make counts more practicable.

***Microscopy***

Each concentrated 5ml sample was mixed well and a known volume transferred to a Lund counting chamber and the algae were identified and counted microscopically.  The algae were viewed under phase contrast and / or darkfield illumination at magnifications of x125 or x500 and 100 random fields were evaluated for each water sample.  All counts were made at x125 magnification and recorded on data sheets.

## 2.4 Algal bloom monitoring

During the year, local residents and frequent visitors to Loweswater were encouraged to record and report on their observations on the occurrence, extent and severity of algal blooms in the lake.

---

[2] A solution of potassium iodide and iodine in distilled water with the addition of acetic acid.

# 3. RESULTS

## 3.1 Water quality monitoring - Loweswater

### *Alkalinity and pH*

Alkalinity (acid buffering capacity) varied between 180 µeq / L in January and 240 µeq / L in September (see Figure 1), with an annual mean of 214 µeq / L compared with 198 µeq / L in 2011.

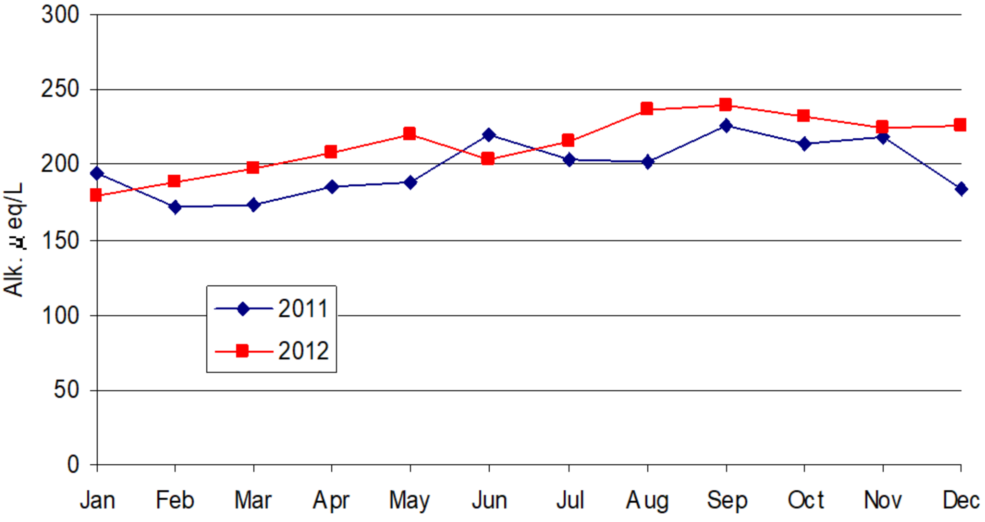


**Figure 1.** *Seasonal changes in Alkalinity in Loweswater, 2012 and 2011.*

This elevated 2012 value is significant as it is above 200 µeq / L and prompts a new calculation on the status of the lake in terms of the EU Water Framework Directive (WFD). The quality levels that define status are not given in absolute terms, but are calculated from formulae given in the 2010 Directions; this calculation involves the mean depth of the lake (Loweswater is classified as shallow), its altitude and its alkalinity.

The lowest pH recorded was in October at pH 6.39 and the highest in April at pH 8.1, see Figure 2; the annual mean value was pH 7 compared with pH 7.4 in 2011.

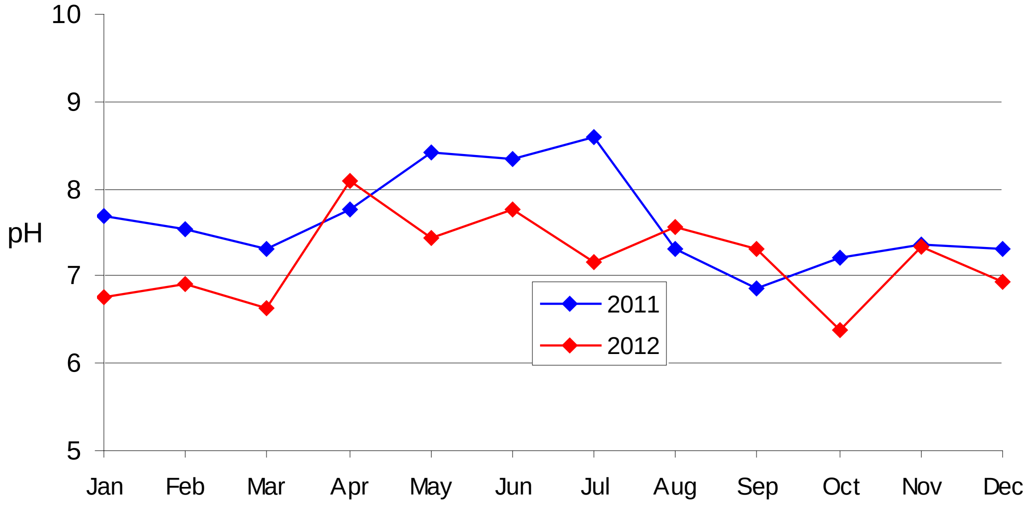


**Figure 2.** *Seasonal variation in pH values in Loweswater, 2012 and 2011.*

***Water temperature***

The lowest surface water temperature recorded was in February at 4.3 °C and the highest in May at 18.9 °C (see Figure 3), with an annual mean of 10.6 °C, the same as 2011.

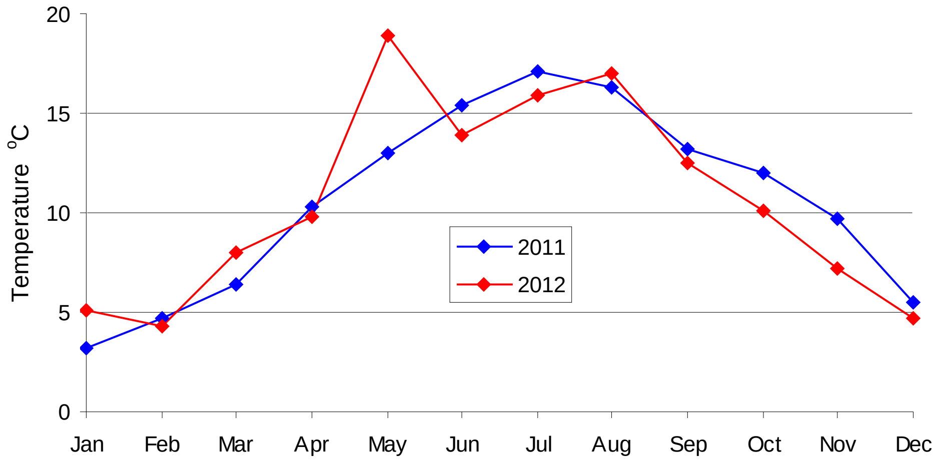


**Figure 3.** *Seasonal variation in surface water temperature in Loweswater, 2012 and 2011.*

***Conductivity***

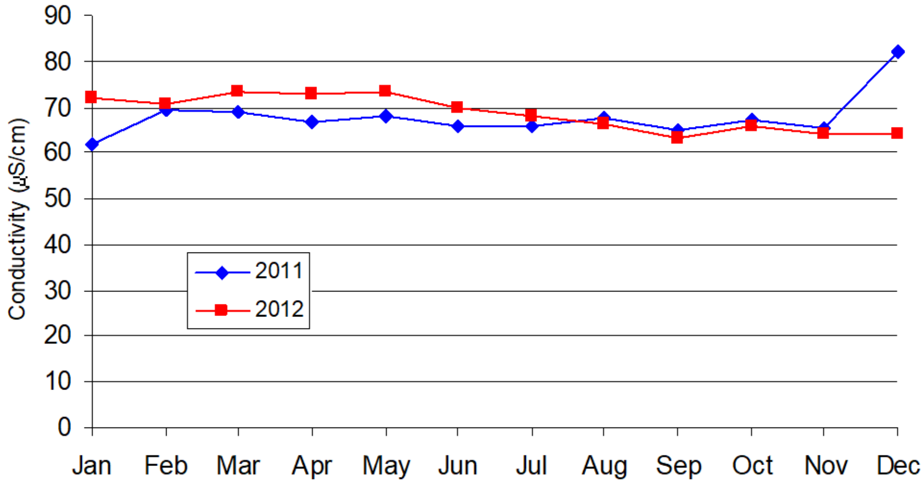


**Figure 4.** *Seasonal changes in conductivity in Loweswater, 2012 and 2011.*

Conductivity, a measure of the water's ionic activity and content, expressed as micro Siemens per centimetre (µS / cm), ranged from 63.2 µS / cm in September to 73.2 µS / cm in March (see Figure 4), with an annual mean of 69 µS / cm, slightly higher than the annual mean of 2011 at 68 µS / cm.

***Oxygen concentration***

The lowest oxygen concentration recorded was in September at 84.1% and the highest in May at 108% (see Figure 5); the annual mean concentration was 96%, slightly lower than the annual mean of 2011 at 99%. However, measurements were taken near the surface where the water would be expected to be well oxygenated. A more important consideration is the level of oxygen depletion at depth as, from early to mid-summer to early autumn, the lake water is thermally stratified, i.e. warmer surface water (the epilimnion) overlies, but hardly mixes with, colder bottom water (hypolimnion), the oxygen depletion at depth being caused by the decomposition of organic material produced in the upper layers of the lake. Unfortunately, no measurements were recorded at depth in 2012.

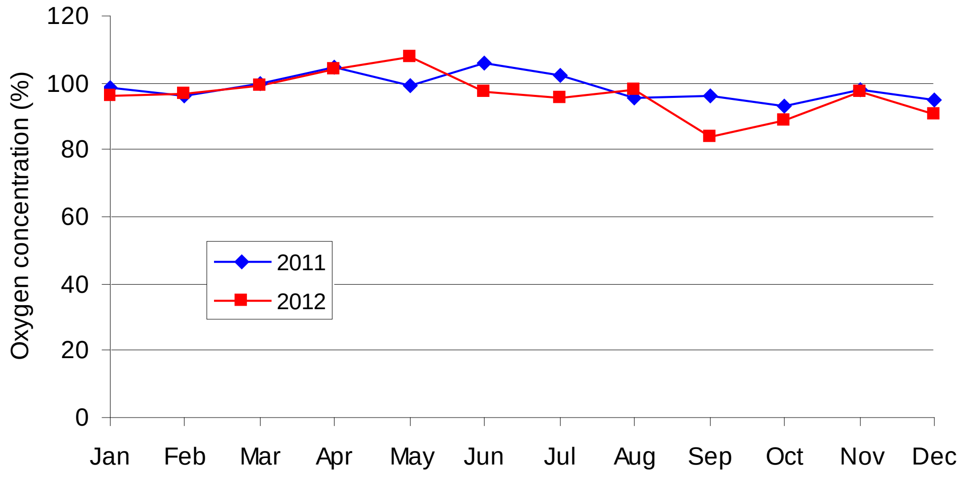


**Figure 5.** *Seasonal variation in surface oxygen concentrations (%) in Loweswater, 2012 and 2011.*

***Soluble Reactive Phosphorus (SRP)***

The SRP concentrations given for February, April, May and August were < 1.0 µg / L (? below detection levels) and so these have been plotted at 0.5 µg / L; there were no data for December. The maximum concentration was in November at 4.3 µg / L (see Figure 6); the annual mean concentration was 1.7 µg / L, higher than in 2011 at 1.2 µg / L.

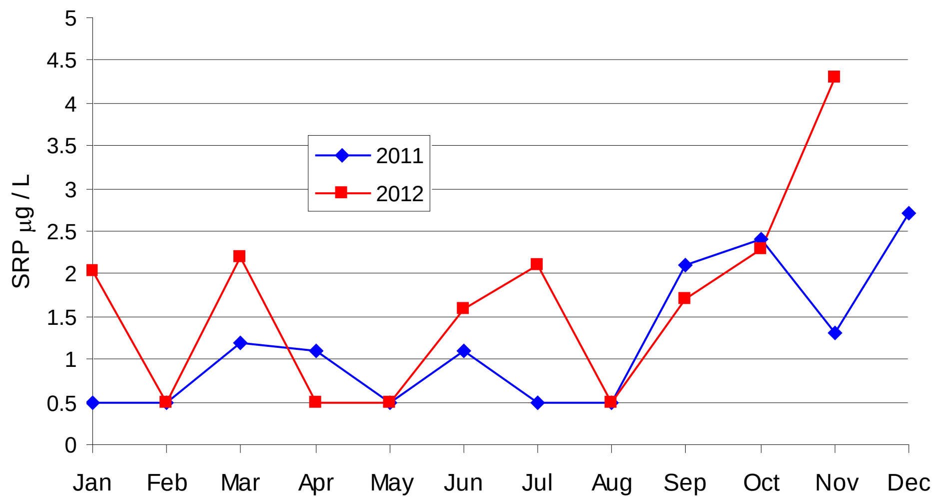


**Figure 6.** *Seasonal variation in concentrations of SRP in Loweswater, 2012 and 2011.*

Phosphate is the main nutrient controlling phytoplankton production in Loweswater and as SRP is readily available to phytoplankton, concentrations can change rapidly in response to supply and demand and tend to be very low throughout the growing season. As a result, SRP is less reliable as an indicator of the trophic state of a lake than total phosphorus (Maberly et al., 2006).

***Nitrate- nitrogen***

Concentrations of nitrate-nitrogen (NO3-N) ranged from 270 µg / L in August to 670 µg / L in October and November (see Figure 7), with an annual mean of 493 µg / L, higher than in 2011 at 474 µg / L.

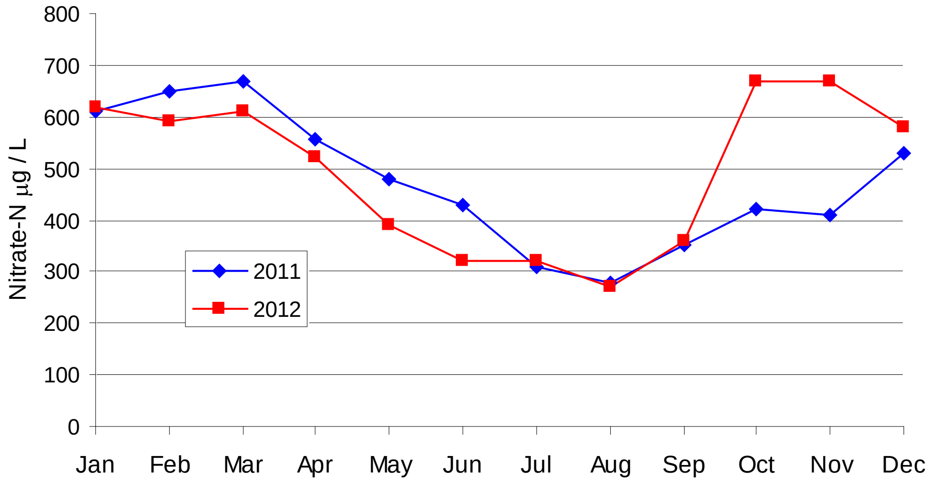


**Figure 7.** *Seasonal variation in concentrations of nitrate-nitrogen in Loweswater, 2012 and 2011.*

Maberly et al. (2006) reported a highly significant and strong tendency for summer and autumn concentrations of nitrate to decline. This, they suggest, is caused by processes within the lake consistent with increasing productivity caused by increasing availability of phosphorus, which in turn increases the demand for nitrogen.

***Total phosphorus (TP), Phytoplankton chlorophyll* a *and depth of Secchi disc***

As phytoplankton production is governed by the availability of phosphorus, there is close correlation between TP and phytoplankton chlorophyll *a* concentrations; there is also an inverse correlation between phytoplankton chlorophyll *a* concentration and depth of Secchi disc readings.  For these reasons these three parameters are considered together.

The minimum TP concentration was in September at 10.9 µg / L, and the maximum in November at 16.2 µg / L (see Figure 8), although there were similar levels of between 15.2 to 15.8 µg / L in June July and August; the annual mean concentration was 13.2, a little higher than in 2011 at 12.4 µg /L.

Phytoplankton chlorophyll *a* concentrations varied between 1.9 µg /L in July and 13.3 µg /L in August (see Figure 9); the annual mean concentration was 6.05 µg /L, very slightly less than in 2011 at 6.2 µg /L.

The minimum depth of Secchi disc was in September at 2.4 metres and the maximum in May at 5.6 metres (see Figure 10), the deepest reading recorded since June 2007 at 6 metres; the annual mean was 3.41 metres, very slightly lower than in 2011 at 3.44 metres.

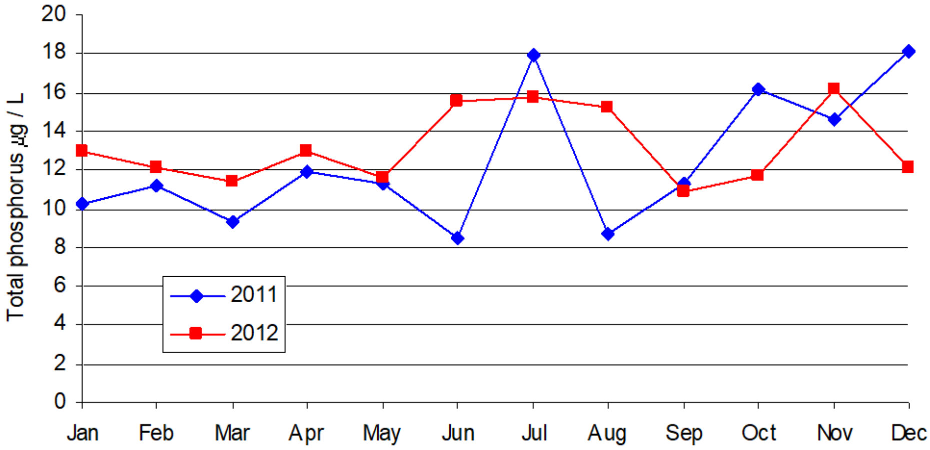


**Figure 8.** *Seasonal variation in concentrations of total phosphorus in Loweswater, 2012 and 2011.*

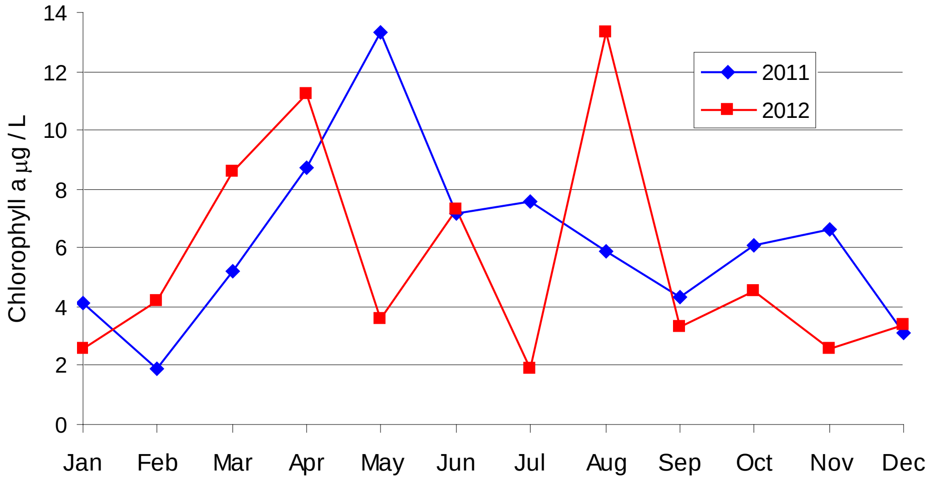


**Figure 9.** *Seasonal variation in concentrations of phytoplankton chlorophyll a in Loweswater, 2012 and 2011.*

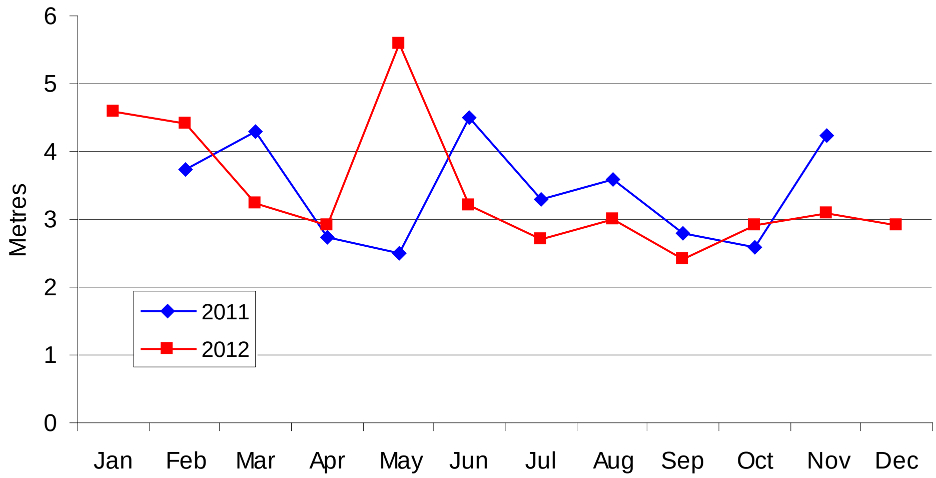


**Figure 10.** *Seasonal changes in depth of Secchi disc in Loweswater, 2012 and 2011.*

## 3.2 Water quality monitoring – Dub Beck at Waterend

***pH***

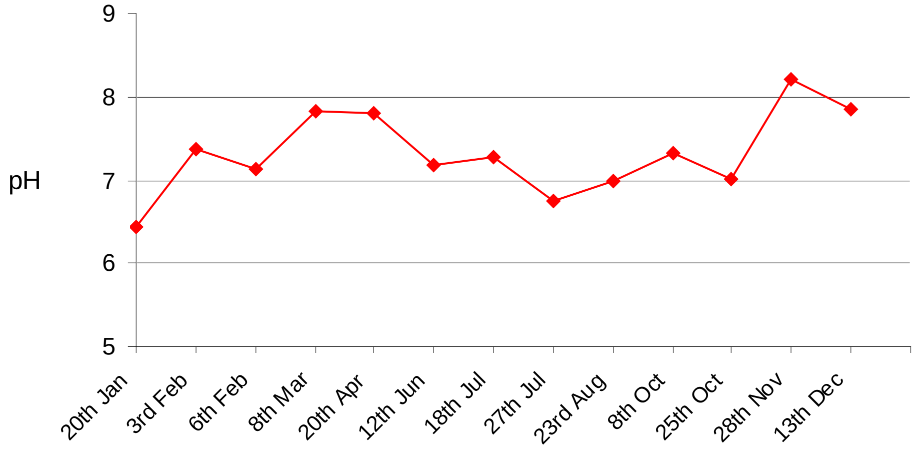


**Figure 11.** *Seasonal variation in pH values in Dub Beck, Waterend, 2012.*

The lowest pH recorded was in January at pH 6.43 and the highest in November at pH 8.21, see Figure 11; the annual mean value was pH 7.6 (the lake was pH 7).

***Water Temperature***

The lowest water temperature recorded was in February at 2.8 °C and the highest in July at 13.6 °C (see Figure 12), with an annual mean of 8.3 °C, compared to the lake's at 10.6 °C.

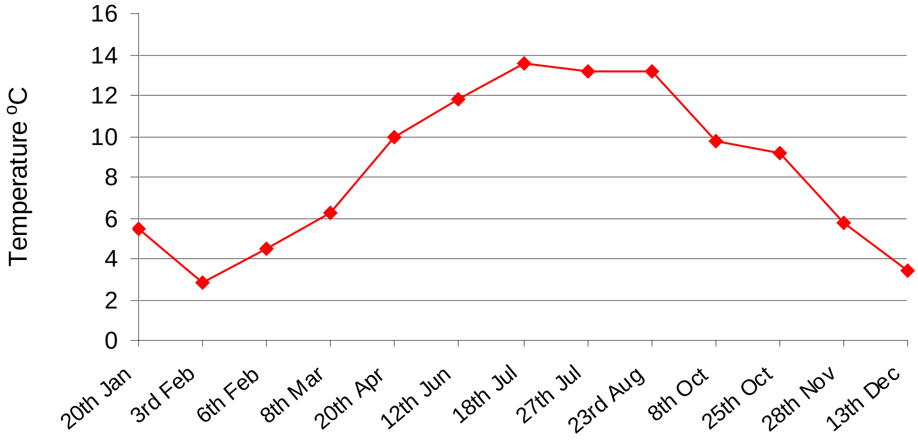


**Figure 12.** *Seasonal variation in water temperature in Dub Beck, Waterend, 2012.*

***Conductivity***

Conductivity, a measure of the water's ionic activity and content, expressed as micro Siemens per centimetre (µS / cm), ranged from 46.6 µS / cm in July to 109.9 µS / cm in February (see Figure 13), with an annual mean of 93 µS / cm, higher than the annual mean of the lake at 68.6 µS / cm. For 10 of the 13 measurements recorded in 2012, conductivity ranged between 94.7 and 109.9 5µS / cm; it is possible that the particularly low reading of 46.6 µS / cm in July was not adjusted for temperature, but even if a temperature correction to 25°C were to be applied the level would still be no more than 60 µS / cm, well below the readings for the rest of the year.

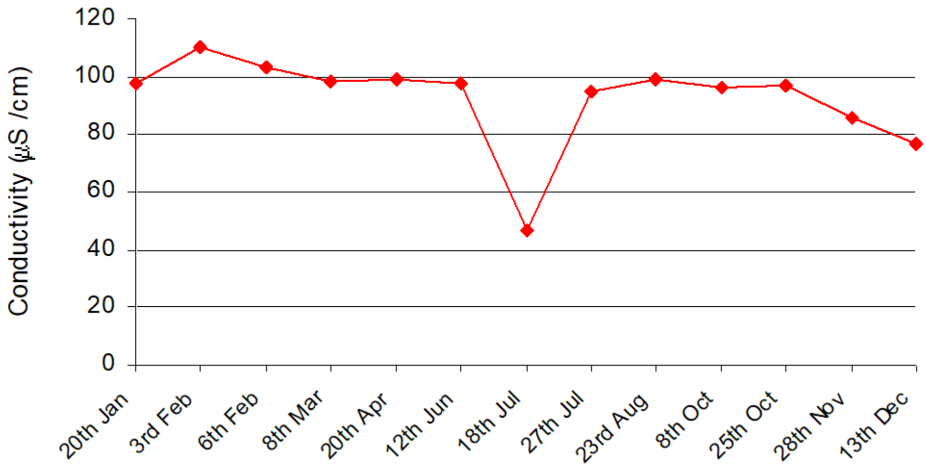


**Figure 13.** *Seasonal variation in conductivity in Dub Beck, Waterend, 2012.*

***Oxygen concentration***

The lowest oxygen concentration recorded was in July at 85.1% and the highest in February at 103.4% (see Figure 14). The annual mean concentration was 99%, slightly higher than the lake at 96%; however, the beck would be expected to be well oxygenated given that it is fed by turbulent flows of water from the fells.

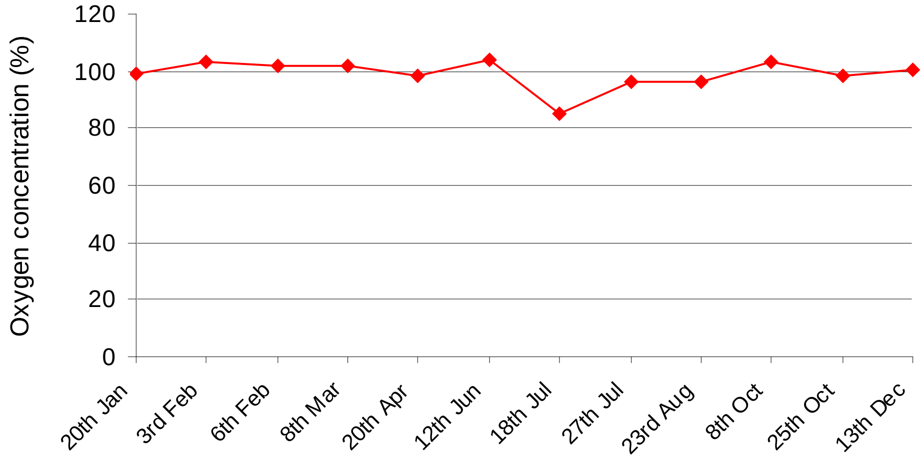


**Figure 14.** *Seasonal variation in Oxygen concentrations in Dub Beck, Waterend, 2012.*

***Nitrate-nitrogen***

The annual mean concentration of nitrate-nitrogen was 638 µg / L, higher than in the lake at 493 µg / L and with much greater seasonal variability, i.e. from 109 µg / L in March to 986 µg / L on 6th February; however, three days earlier, on 3rd February, the level was almost as low as in March at 128 µg / L (see Figure 15).

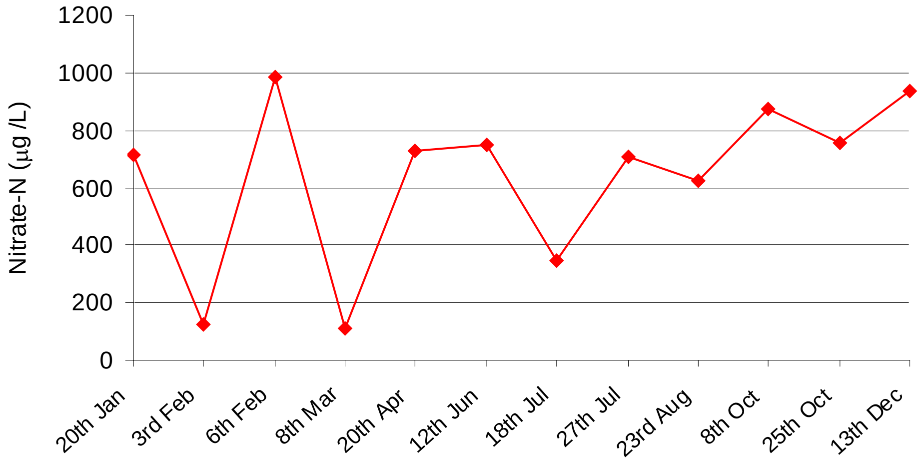


**Figure 15.** *Seasonal variation in concentrations of nitrate-nitrogen in Dub Beck, Waterend, 2012.*

***Soluble Reactive Phosphorus (SRP)***

Eleven of the measurements for SRP taken throughout 2012 were recorded as < 2 µg / L; the twelfth measurement taken on 18 July was recorded as 2.34 µg / L.

### 3.3 Microscopy and algal counts

A wide range of algae were identified and counted, falling broadly into the following phylogenetic groups: Chlorophytes (including Euglenophytes), Chrysophytes, Cryptophytes, Dinophytes, Diatoms and Cyanophytes (blue-green algae), although the latter are not true algae having features more in common with bacteria (Cyanobacteria).

Figures 16, 18, 20 and 21 show the populations of the various Loweswater algae identified in 2012 and their patterns of seasonal variation; Figures 17, 19, 22 and 23 show the 2011 patterns for comparison.

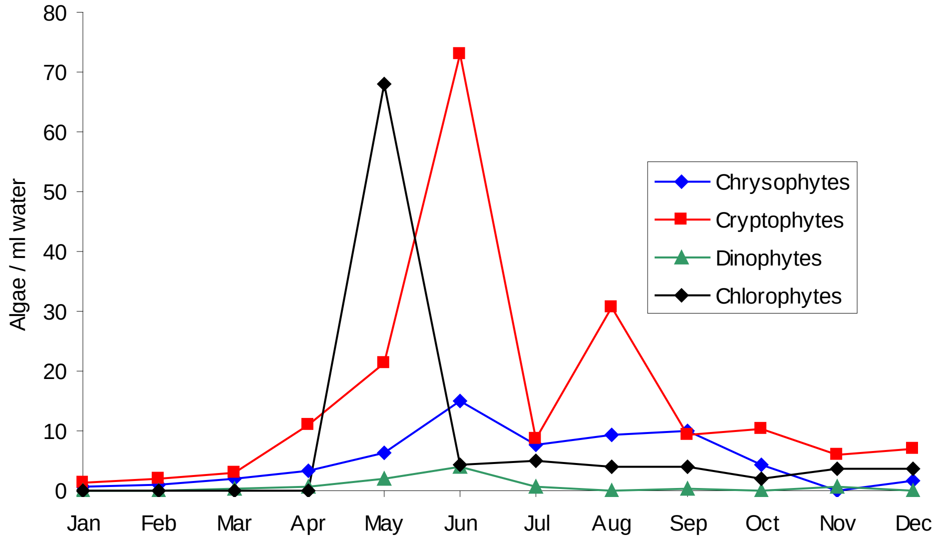


**Figure 16.** *Seasonal variation in Chlorophyte, Chrysophyte, Cryptophyte and Dinophyte populations observed in Loweswater – 2012.*

Cryptophytes were present all year round, with distinct peaks in June and August; Chlorophytes were present from April to December, with a sharp peak in May; with the exception of November, Chrysophytes were present all year, with peaks in June and September; Dinophyte were present in small numbers in seven months, with a small increase in June.

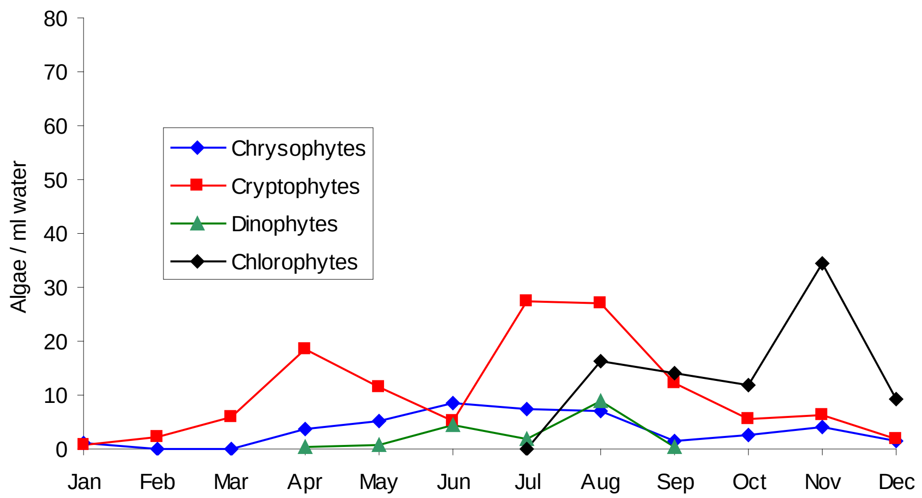


**Figure 17.** *Seasonal variation in Chlorophyte, Chrysophyte, Cryptophyte and Dinophyte populations observed in Loweswater – 2011.*

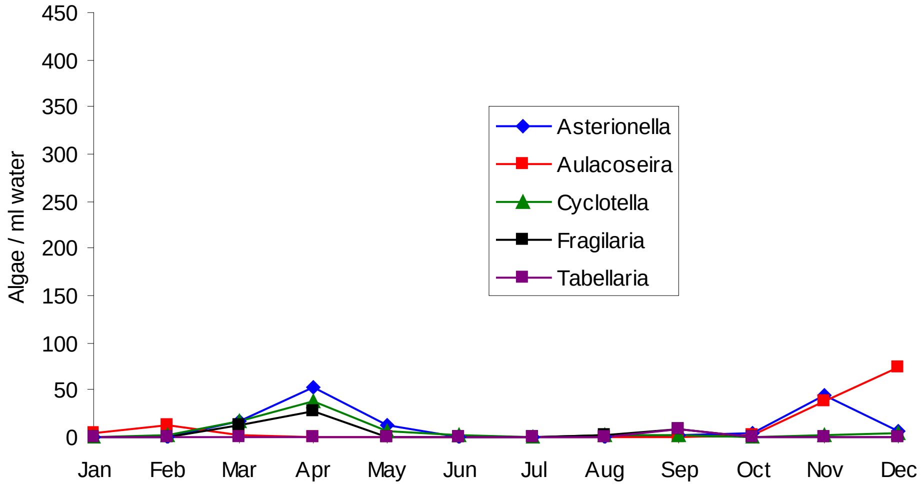


**Figure 18.** *Seasonal variation in diatom populations observed in Loweswater – 2012.*

Diatom counts were relatively low throughout 2012, but with minor increases in *Asterionella formosa*, in April and November, *Cylcotella* and *Fragilaria* in April, and *Aulacoseira* in November and December. The counts for *Asterionella formosa* showed a dramatic reduction compared to those of 2011 (see Figure 20), when they were abundant in April and May and to a lesser extent in March.

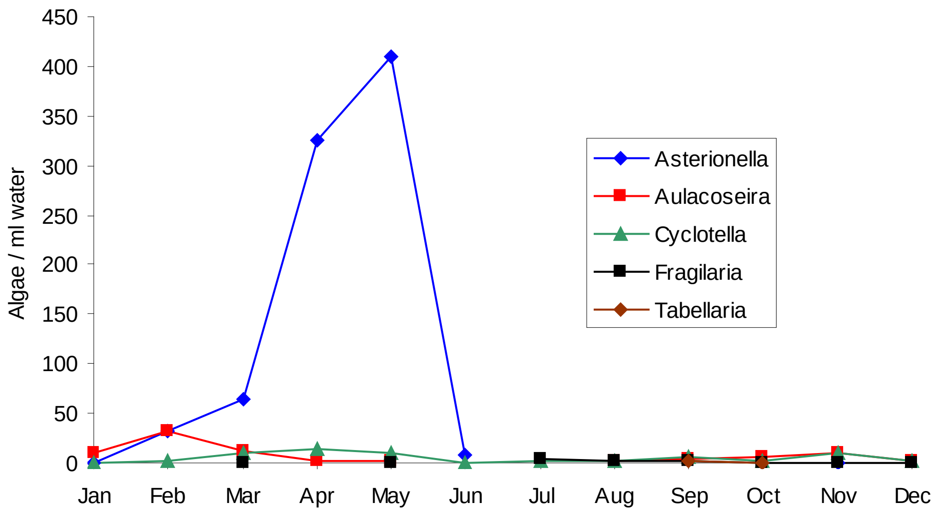


**Figure 19.** *Seasonal variation in diatom populations observed in Loweswater – 2011.*

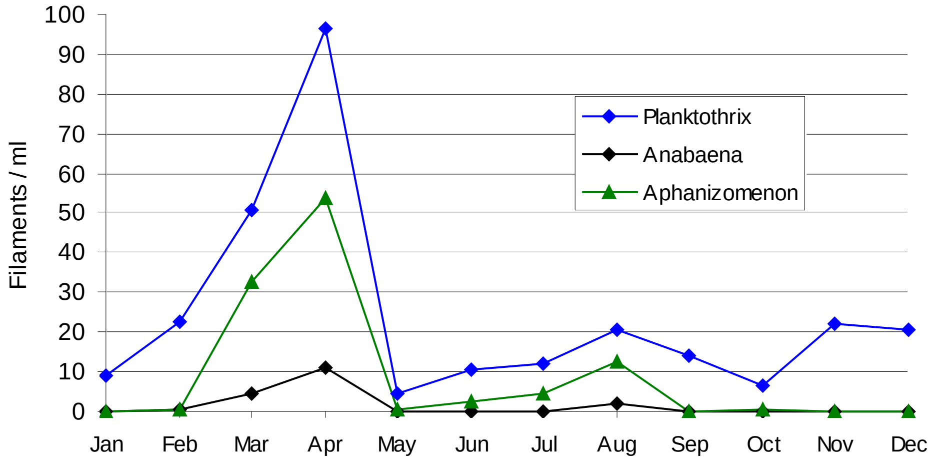


**Figure 20.** *Seasonal variations in filamentous cyanobacterial populations observed in Loweswater – 2012.*

The filamentous *Planktothrix mougeotii*, was present all year, but with *Aphanizomenon* and *Anabaena* was most abundant in early summer. The colonial *Snowella* was more dominant in July and August and to a lesser extent *Woronichinia naegeliana* and *Planktothrix mougeotii* in November and December (see Figures 20 and 21). This pattern of seasonal variation in cyanobacteria was in marked contrast to 2011, when the filamentous *Planktothrix mougeotii* was much less prominent and with a lower early summer count; the colonial *Woronichinia naegeliana*, on the other hand, was present throughout 2011, with a particularly sharp peak in July (see Figures 22 and 23 on the next page).

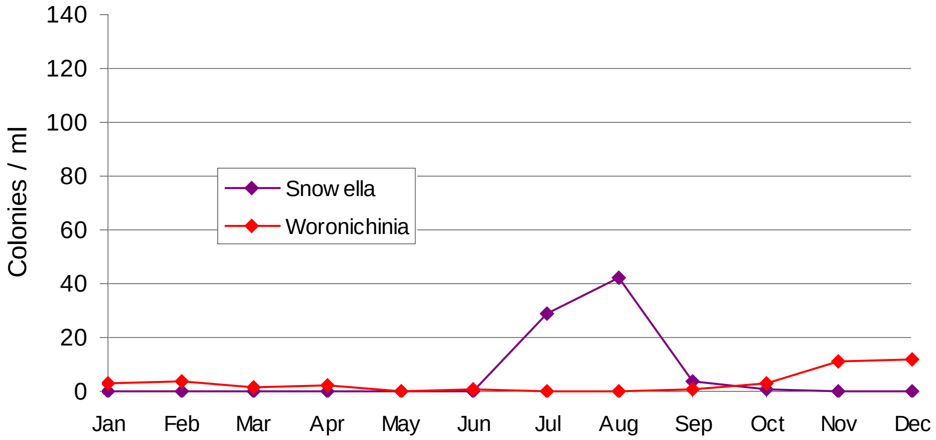


**Figure 21.** *Seasonal variations in colonial cyanobacterial populations observed in Loweswater – 2012.*

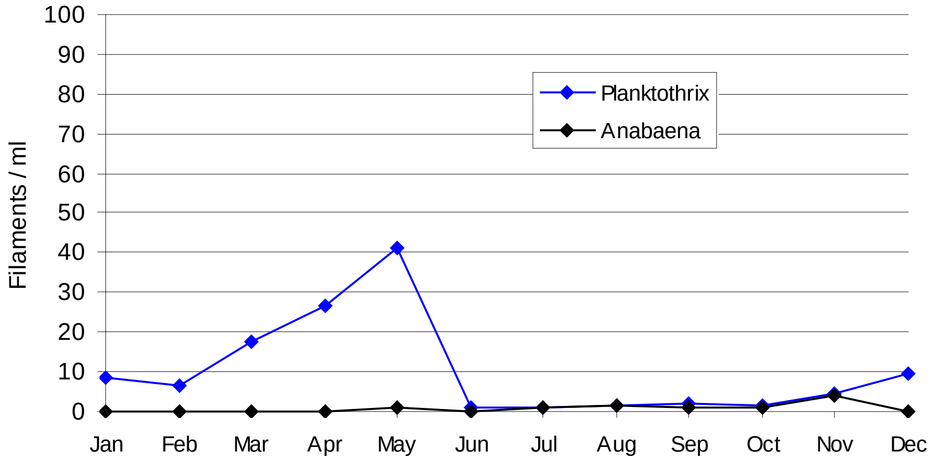


**Figure 22.** *Seasonal variations in filamentous cyanobacterial populations observed in Loweswater – 2011.*

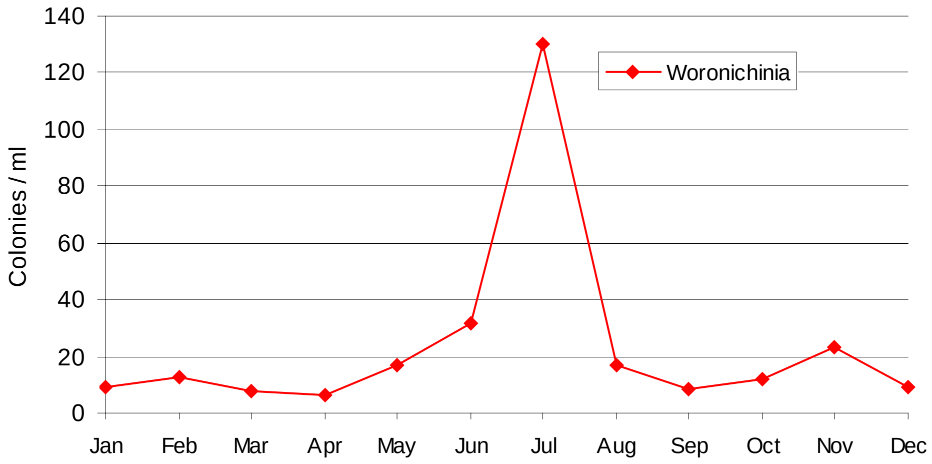


**Figure 23.** *Seasonal variations in colonial cyanobacterial populations observed in Loweswater – 2011.*

## 3.4 Algal bloom monitoring

Observations by local residents on the incidence and nature of algal blooms in Loweswater, during 2012, are recorded in the table below.

| Date | Nature of event |
|---|---|
| Jan 2012 | Bloom, Waterend |
| 16.04.2012 | Grey bloom |
| 23.04.2012 | Green swatches |
| 14.05.2012 | Bloom |
| 16.06.2012 | Foam near exit to lake |
| 27.08.2012 | Smallish area of blue green algae washed against the shore |
| 22.09.2012 | Bloom near bothey |
| 06.10.2012 | Swirly patterns of blooms |
| 08.10.2012 | Thick *'emerald soup'* was visible from the shore alongside the road; stretched several metres out into the lake, about 4 metres from Crabtree beck to the far end of the lake |
| 15.11.2012 | Bloom along shore near Watergate |

Unfortunately, there were rather a small number of observations and many didn't record the precise area of the lake that was affected.

## 4. DISCUSSION

Although the water quality monitoring programme was based on single point sampling, i.e. a monthly mid-lake sample, the results of a one day trial conducted on behalf of the Environment Agency, indicated that, at 0.5 metres, Loweswater was fairly uniform in temperature, pH, conductivity and dissolved oxygen. On 01 November 2011, YSI Hydrodata Ltd used an Ecomapper (an autonomous underwater vehicle) to survey the water quality and bathymetry of Loweswater; the results indicated that the lake's temperature range was10.7 to 10.9 °C, pH 7.05 to 7.1, conductivity 68 to 70 µS / cm and dissolved oxygen 94 to 97 %. The exceptions were that at the northern end of the lake, near the inflow from Dub Beck, the temperature was slightly lower at 10.2 °C; pH was slightly lower at 6.97 and conductivity higher at 75 µS / cm and that at the southern end near the outflow pH was slightly higher at 7.14. The lake was also shown to be uniform, at 0.5metres, in the distribution of chlorophyll and blue-green algae (phycocyanin) (YSI Hydrodata, 2012).

From the results of the water quality analysis and algal counts during 2012, certain correlations and patterns emerge and these are highlighted and discussed briefly in the next paragraphs.

The **pH** varied between 7.2 and 8.6. The seasonal elevated values, commencing in April at pH 8.1, result from the photosynthesising action of algal blooms, which increase the water pH, particularly in slow moving waters (Loweswater has a long residence time of about 200 days). The second highest **phytoplankton chlorophyll *a*** concentration of 11.1 µg /L was also in April, corresponding with a time of highest **algal counts**, including mainly the filamentous cyanobacteria, the diatom assemblage and Cryptophytes; a 'grey bloom' and 'green swatches' were observed in the lake on 16 and 23 April, respectively. The highest **phytoplankton chlorophyll *a*** concentration of 13.3 µg /L in August corresponded with high counts of

***Cryptophytes*** and the colonial blue-green ***Snowella***; on 27 August '*blue-green algae'* were observed, '*washed against the shore'*. However, the extensive '*thick emerald soup'* observed in October is difficult to explain, given that at that time of the year **phytoplankton chlorophyll *a*** and algal counts were relatively low.

In general, there is an inverse correlation between **phytoplankton chlorophyll *a*** and **depth of Secchi disc** values and in April the **depth of Secchi disc** reading was low at 2.9 metres and low in September at 2.4 metres. However, **phytoplankton chlorophyll *a*** concentration is not the only factor determining water transparency; heavy rainfall has the potential to wash large amounts of suspended solids into a water body, which may also lower **depth of Secchi disc** readings. Local records show that in August and September 2012 Loweswater had high levels of rainfall, i.e. 228 mm and 237 mm, respectively (see weather records in Appendix 1); the average August and September rainfall levels for Loweswater are 136.3 mm and 146.9 mm, respectively (Pers. Comm. Spencer, 2012).

The form of phosphorus that is readily available to phytoplankton is **soluble reactive phosphorus** (**SRP**) the concentration of which can change rapidly in response to supply and demand and therefore is considered to be less reliable as an indicator of the trophic state of a lake than **total phosphorus (TP).** There were relatively high levels of **TP** in June, July and August, i.e. between 15.2 to 15.8 µg / L coinciding with the summer decline in **nitrate** concentrations, which Maberly et al. (2006) suggest is caused by processes within the lake and is consistent with increased phytoplankton productivity caused by increased availability of phosphorus which, in turn, increases the demand for nitrogen. The 2012 results reflect this observation with peak counts for *Snowella* in August, the summer peak of 15.8 µg /L **TP,** in July and a decline in **nitrate** concentrations to 270 µg /L in August. Increased phytoplankton production in summer, when the lake undergoes thermal stratification, can lead to greater depletion of oxygen at depth, which leads to a reduction in the redox potential of the surface sediment resulting in trapped phosphorus (as phosphates) being released into the hypolimnion, with subsequent diffusion of dissolved phosphate into the water column (Mortimer, 1941; 1942).

Using OECD guidelines (1982), the trophic status of a water body may be classified using data on three of the variables discussed above, i.e. **TP**, **phytoplankton chlorophyll *a*** and **depth of Secchi disc**, as shown in Table 1, below:

**Table 1.** ***Trophic categories based on five limnological variables***

| **Trophic category** | **Mean Total Phosphorus (µg / l)** | **Mean Choro. *a* (µg / l)** | **Maximum Choro. *a* (µg / l)** | **Mean Secchi depth (m)** | **Minimum Secchi depth (m)** |
|---|---|---|---|---|---|
| **Ultra-oligotrophic** | < 4 | < 1 | < 2.5 | > 12 | > 6 |
| **Oligotrophic** | 4 - 10 | 1 - 2.5 | 2.5 - 8 | 12 - 6 | 6 - 3 |
| **Mesotrophic** | 10 - 35 | 2.5 - 8 | 8 - 25 | 6 - 3 | 3 - 1.5 |
| **Eutrophic** | 35 - 100 | 8 - 25 | 25 - 75 | 3 - 1.5 | 1.5 - 0.7 |
| **Hypertrophic** | > 100 | > 25 | > 75 | < 1.5 | < 0.7 |

Using these guidelines, data from Centre Ecology and Hydrology (CEH) in 2010 indicated that Loweswater classified as being on the mesotrophic / eutrophic boundary. Data from the water quality monitoring programme in 2011, however, indicated an improvement and the lake's trophic state, based on these data, was mesotrophic. The results of the 2012 monitoring programme confirm the 2011 result, although there was a slight increase in annual mean TP and small reductions in annual mean Secchi depth and annual minimum Secchi depth readings (see Table 2, on the next page).

**Table 2.** ***Assessment of the trophic state of Loweswater from 2010 to 2012, using five variables.***

| | | Mean Total Phosphorus (µg / L) | Mean Chloro. *a* (µg / L) | Maximum Chloro. *a* (µg / L) | Mean Secchi depth (m) | Minimum Secchi depth (m) |
|---|---|---|---|---|---|---|
| **CEH data** | **2010** | **14.75** | **11.7** | **19.2** | **2.8** | **1.9** |
| **Environment Agency data** | **2011** | **12.44** | **6.17** | **13.3** | **3.44** | **2.5** |
| **Environment Agency data** | **2012** | **13.2** | **6.05** | **13.3** | **3.41** | **2.4** |

Oligotrophic (yellow) Mesotrophic (green) Eutrophic (pink)

Of particular interest from a legal standpoint is the status of the lake in terms of the EU Water Framework Directive (WFD). Water quality standards under the WFD are established in The River Basin Districts Typology, Standards and Groundwater threshold values (Water Framework Directive) (England and Wales) Directions 2010. The WFD categorises rivers and lakes into five levels of 'ecological status', i.e. poor, moderate, good, high and bad, the main objective of the WFD being that water bodies should achieve 'good ecological status' by a specified date, normally 2015 (but relaxed to 2027 for Loweswater). The two WFD parameters of particular interest for the lake's ecological status are total phosphorus and phytoplankton chlorophyll *a*. The quality levels that define status are not given in absolute terms, but are calculated from formulae given in the 2010 Directions; this calculation involves the mean depth of the lake (Loweswater is classified as shallow), its altitude and its alkalinity (Loweswater is low). The calculated boundary levels for TP and phytoplankton chlorophyll *a* for Loweswater are given in Table 3 on the next page.

**Table 3.** ***WFD boundary levels for total phosphorus and phytoplankton chlorophyll a for Loweswater***

| ***WFD Status*** | **High** | **Good** | **Moderate** | **Poor** | **Bad** |
|---|---|---|---|---|---|
| ***Parameter (µg/L)*** | | | | | |
| **Total phosphorus** | <8.06 | 8.06 - 12.22 | 12.49 - 24.45 | 24.45 - 48.9 | >48.9 |
| **Phytoplankton chloro. *a*** | <4.5 | 4.5 - 7.7 | 7.92 - 15.5 | 15.5 - 46.9 | >46.9 |

**Note:** *The TP level is the annual arithmetic mean, whereas the phytoplankton chlorophyll* a *level is the annual geometric mean (as required by WFD), both usually judged over 12 samples.*

The mean levels for Loweswater in 2012 were 13.2 µg/L for TP and 4.6 µg/L for phytoplankton chlorophyll *a* (lower than the level given in Table 2 as that value is the arithmetic mean). On the basis of phytoplankton chlorophyll *a*, the lake quality is thus 'good', but is within the 'moderate' quality range for TP.

## 5. CONCLUSIONS

- The results of the water quality monitoring programme of Loweswater for 2012 indicate that the lake continues to be classified as mesotrophic and that under the Water Framework Directive the lake is also close to being classified as of good ecological status.

- Enumeration and identification of algal populations indicate that filamentous cyanobacteria were more abundant in 2012 than in 2011, but that colonial forms of cyanobacteria were less abundant.

**REFERENCES**

Cheshmedjiev, S., Belkinova, D., Mladenov, R., Dimitrova-Dyulgerova, I. and Gecheva, G. (2010). Phytoplankton based assessment of the ecological status and ecological potential of lake types in Bulgaria. *Biotechnology & Biotechnological Equipment,* 24, 2.

Fryer, G. (1991). *A natural history of the lakes, tarns and streams of the English Lake District.* The Freshwater Biological Association, The Ferry House, Far Sawry, Ambleside, Cumbria.

Maberly, S., Norton, L., May, L., De Ville, M., Elliott, A, Thackeray, S., Groben, R., and Carse, F. (2006). *An investigation into the potential impacts of farming practices on Loweswater.* A report to the Rural Development Service and the National Trust (funded through the Rural Enterprise Scheme). Report Number: LA/C02707/4 Centre for Ecology & Hydrology, Lancaster University.

Mortimer C.H. (1941). The exchange of dissolved substances between mud and water in lakes. I. *Journal of Ecology,* 29: 280-329.

Mortimer C.H. (1942). The exchange of dissolved substances between mud and water in lakes. II. *Journal of Ecology,* 30: 147-201.

Pasztaleniec, A. and Poniewozik, M. (2010). Phytoplankton based assessment of the ecological status of four shallow lakes (Eastern Poland) according to Water Framework Directive – a comparison of approaches. *Limnologica - Ecology and Management of Inland Waters.* 40, 3, Pages 251–259.

Pers. Comm. Spencer (2012). Rainfall records of Loweswater, 1984 to 2012, supplied by Neil Spencer, Iredale Place Cottage, Loweswater, Cumbria.

Report Number 001-LCP-WCRT, 2011. *Loweswater: Water quality monitoring 2011.*

Shaw, A. (2009). *The decline of the Loweswater fish community: contributory factors and events.* A dissertation submitted in partial fulfilment of the degree of M.A. in Lake District studies, University of Lancaster.

Winfield, I. J., Fletcher, J. M., James, J. B. and Thackeray, S. J. (2008). *A first look at Loweswater's fish population*. Centre for Ecology and Hydrology, Lancaster, UK. A Powerpoint presentation to Loweswater Care Project Meeting, Loweswater Village Hall, 11 September 2008.

YSI Hydrodata (2012). *Loweswater Lake Bathymetry and Water Quality Survey*. A report to the Environment Agency on a survey carried out on 01 November 2011, report number: 179001112011.

## APPENDIX 1.

## RAINFALL FIGURES FOR LOWESWATER YEAR 2012

## IREDALE PLACE COTTAGE, LOWESWATER

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sept | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Rainfall (mm)** | 159.5 | 89.9 | 44.2 | 78.9 | 73.7 | 227.7 | 156.4 | 228 | 237 | 197.1 | 241.9 | 164.9 |
| **Mean (over 29 years)** | 153.9 | 121.9 | 123.8 | 89.6 | 85.8 | 98.8 | 111.3 | 136.3 | 146.9 | 187 | 172 | 174.4 |