FRESHWATER BIOLOGICAL ASSOCIATION

The Ferry House, Ambleside, Cumbria LA22 OLP

Report to North West Water

DISTURBING THE SEASON'S DUE :

PLANKTON PERIODICITY IN GRASMERE, 1987

by C.S. Reynolds

Project Leader	:	C.S. Reynolds
Date	:	April 1988
Report to	:	North West Water
FBA Ref No.	:	W1/207/6
TFS Project No.	:	T04008-2

1. Introduction

This short report continues a series of annual unpublished accounts to North West Water, describing the phytoplankton and certain associated water-quality criteria in Grasmere. The present report summarises the key events in the lake during 1987 and shows how the planktonic community responded. It will be argued that these responses have remained entirely consistent with previous deductions about the lake (Reynolds 1985; 1986; 1987; Reynolds & Lund, 1987), that is that weather and, especially, rainfall events dominate the dynamic behaviour of its plankton. The forward projection of its behaviour is briefly reassessed.

2. The Grasmere environment, 1987

So far as its weather was concerned, 1987 is generally regarded as having been a poor year, although the viewpoint of water suppliers and especially of those concerned with water quality in Grasmere will be one of rather less dissatisfaction. Popular perception also has it that the year's weather was distinguished by extremes of wind, rainfall intensity and low temperatures. However, the Meteorological Office (1988) has discounted any implicit abnormality over the year as a whole. Temporal changes in the thermal structure of larger lakes accommodate and integrate separate, small-scale weather events over longer periods of time (days to months) and they have been shown to be particularly sensitive to medium-term weather patterns. In this way, even such an incomplete time-series of observations as those made at Grasmere (summarised in Fig. 1a) fairly reflects the outstanding weather events of 1987:

- In mid-January, the lake froze during an exceptionally cold, dry spell. It remained ice-covered until mid-February when milder temperatures and heavy rain brought about rapid melting.
- After a wet start, April was unusually sunny and warm: the seasonal stratification became established at this time.
- The remainder of the spring was cool, dull and, in June, wet. The epilimnion remained cool and generally relatively deep (5-7 m).
- Late June and early July brought much warmer weather and near-surface stratification of the lake; maximum recorded temperature, 18.4 C.
- Cool, unsettled weather returned in late July and persisted until mid-August when there was a further warm spell.
- October was a very wet month; the deep depression of the 15th-16th which brought the infamous "great storm" to Southern Britain was weaker in the north and made little impact on the residual stratification in Grasmere.
- Cold weather in late November and early December brought about rapid convectional heat loss from the lake, which froze briefly, between 7-10 December. Very

mild but wet weather at the end of the month was such to raise the water temperature significantly.

Major flood events occurred in January, late March, mid-October and in December (Fig. 1b). No substantial drought periods obtained in summer.

Taken over the summer, the incidence of high winds was infrequent. The weakness of the stratification owed more to the small temperature differential through the column rather than to a high input of kinetic energy. This distinction accounts for the vertical extent of anoxia (maximum, to 6 m beneath the surface, which may be compared to corresponding values in a warm, dry summer like 1984 (6-7 m) and a cool windy one like 1985 (~16 m).

Nevertheless, there were few periods in which stable microstratification built up in the epilimnion so as to restrict the depth of wind- and convection-mixing to < 3 m (see Fig. 1c). Moreover, Fig. 1d shows it was only during the late spring and early summer, that the mixed layer did not extend 1.5 x the contemporaneous Secchi depth, a criterion of some selective import (Reynolds 1987; see also Reynolds et al. 1984).

The major nutrients monitored regularly - soluble reactive silicon (SRS), total phosphorus (TP) and the soluble reactive fraction (SRP) and dissolved inorganic nitrogen (DIN) were generally present in the amounts typical of the post-1982 years. Winter SRS levels (~ 2.0 mg l^{-1} as SiO_2) were depleted through spring and restored in the autumn, generally in accord with the pattern observed in many previous years (see Reynolds & Lund 1987). TP fluctuated within a range 12-46 μg l^{-1} as P, in line with a possibly significant increase in P-loadings since 1979. SRP continued to remain at levels implying phosphorus limitation of growth (< 10 μg P l^{-1}) for long periods of 1987, at least until the autumnal break down of stratification. Maximum DIN - levels were near typical (600-700 μg N l^{-1}) in the spring and in the autumnal 'recovery' period (400-500 μg N l^{-1}). The lowest DIN concentration recorded in summer (138 μg N l^{-1}: 1 Sept) was above the level (80-100 μg N l^{-1}) at which it would discriminate heavily in favour of nitrogen-fixing orgnaisms. Nutrient data are represented in Fig. 1(e) as phases in which the supposedly critical levels were encountered.

Neither grazing, nor the populations of zooplankton have been rigourously quantified so the representation in Fig. 1(f) is approximate, based upon the provisional quantifications of the zooplankton present, the size- and species-composition and in-house relationships to predict feeding rates (Thompson et al. 1982). Removal rates of > 0.3 d^{-1} are shown by solid bands; the hatching approximtes to an error margin but it serves to show more clearly the period of and build-up in grazing activity. Ciliates, like <u>Coleps</u> and Tintinnids, were the major grazers during April, there being even few rotifers (<u>Ascomorpha</u> sp.). A large population of <u>Daphnia hyalina</u> developed through May but apparently collapsed in June through starvation. Ciliates, including <u>Coleps</u> and <u>Nassula</u>, rotifers (especially <u>Keratella cochlearis</u>) and, finally, <u>Daphnia</u> dominated the September/October pulse.

3. The Phytoplankton

The variations in population (either up or down) of several of the commoner species in Grasmere during 1988 are illustrated in Fig. 1(g) through the use of semilog plot. Rather than simply catalogue individual species performances it is possibly more helpful to first compare phases of increase and decrease with the driving variables that are supposed to be operating. For instance, efficient flushing of the lake at the end of 1986 left only very small inocula. Inverse stratification and bright dry weather combined to produce a favourable environment under the ice for the growth of smaller nanoplanktonic forms and indeed Chlamydomonas, Chrysochromulina especially together with Rhodomonas, Chlorella and Ankistrodesmus increased strongly at this time.

Restoration of open-water circulation supported their growth less positively but added to the diversity of species increasing - which included Asterionella, Cyclorella, Tabellaria and Cryptomonas, all species common in Grasmere in spring. However, the onset of thermal stratification truncated the diatom growth period, when Asterionella, for example, had reached only 900 cells ml^{-1}.

The combination of thermal stratification with a relatively high-clarity phosphorus-deficient epilimnion, and heavy grazing intensity on the by-now abundant nanoplankton was, predictably, to select in favour of colonial chlorophyceae. The dominant form in the lake in late April was Gemellicystis neglecta which produced a population of over 2000 cells ml^{-1}.

Deeper mixing towards the end of May reverted selection towards diatoms and Cryptomonas; the late June stratification favoured Cryptomonas, Rhodomonas and Chlorella but the phase was short-lived. Epilimnetic deepening in July led to conditions ultimately favouring Asterionella growth: a population (3700 cells ml^{-1}), together with ~ 1000 Tabellaria ml^{-1} dominated the early August plankton until silicon exhaustion was evident.

Greater stability in mid-August promoted a resumption in growth of summer forms including Sphaerocystis, Gemellicystis, Paulschulzia and Dinobryon but it was Chlamydomonas (14000 cells ml^{-1}) and Cryptomonas (500 cells ml^{-1}) which dominated this phase. Grazing populations built up in response to the enhanced presence of food organisms.

The concluding autumnal phase follows the systematic falling temperatures, shortening days and increased depth of mixing, until flood displacements dominate the attrition processes. Dinobryon, Cryptomonas, and Tabellaria were the species longest able to maintain positive increase and were the prominent forms during October.

The outcome of these sequenced, event-led phases was to produce another variant of the basic Grasmere periodic cycle (cf. Reynolds & Lund 1987) but one nevertheless conforming (albeit weakly) to the 'classic' diacmic pattern, and deviating neither from typical mean Chlorophyll levels achieved (chl s: 14.2 $\pm$ 7.0; chl y 10.3 $\pm$ 8.1; cf. Table 1 of Reynolds & Lund 1987) nor in the extremes realized (maximum 25.1 μg chl.l^{-1}).

4. Concluding remarks

The behaviour of the phytoplankton of Grasmere may be considered to be generally typical for the lake and to conform with the behaviour of the same species elsewhere. Nevertheless, the 'norm' in Grasmere is one of short phases of species growth which generally denies to the selected species the opportunity to build up large populations and to the assemblage sufficient time to undergo full successional sequences and to achieve the stability, organisation and equitability characterizing mature ecosystems. This theme has been emphasised in previous reports (notably Reynolds 1986) and no apology is made for doing so again. It is difficult only to find new ways of giving the message. Some lines of John Milton (in Lycidas) express the situation most appositely.

I come to pluck your berries, harsh and crude...
... Shatter your leaves before the mellowing year.
Bitter constraint and sad occasion dear
Compels me to disturb your season's due.

This passage is, of course, the source of the title of this report.

At risk of an anticlimax, it is worth noting that apart from the implicit dangers to water quality in Grasmere that are posed by the probabilities of a fine, undisturbed summer, two other aspects need to be flagged: one is the apparent rise in the phosphorus levels reaching the lake (these are not likely to have any direct effect in most years but they increase the potential yield capacity of the phytoplankton to respond to a future opportunity for maximum growth); the other is ongoing tendency for oxygen to be depleted most rapidly in the layer 7-8 m, presumably as direct result of sewage loading at this depth.

5. Acknowledgment

I am grateful to my colleagues Derek Allonby (who collected most of the samples); Eric Rigg, Jean Lishman and Julie Corry (who performed most of the analyses); and to Julie Waterhouse who typed the report.

6. References

Meteorological Office (1988). Weather Report for the Year 1987. Meteorological Office, Bracknell.

Reynolds, C.S. (1985). Phytoplankton in Grasmere 1983/84. Unpublished report (W1/207/2) of the Freshwater Biological Association, Ambleside.

Reynolds, C.S. (1986). The phytoplankton of Grasmere: Ecological mismatch and the consequences of matching. Unpublished report (W1/207/3) of the Freshwater Biological Association, Ambleside.

Reynolds, C.S. (1987). The phytoplankton of Grasmere in 1986: adaptation and ecological space. Unpublished report (W1/207/4) of the Freshwater Biological Association, Ambleside.

Reynolds, C.S. & Lund, J.W.G. (1987). The phytoplankton of an enriched soft-water lake subject to intermittent hydraulic flushing (Grasmere, English Lake District). Unpublished report (W1/207/5) of the Freshwater Biological Association, Ambleside. Also in press in Freshwater Biology, 19.

Reynolds, C.S., Wiseman, S.W. & Clarke, M.J.O. (1984). Growth- and loss-rate responses of phytoplankton to intermittent artificial mixing and their potential application to the control of planktonic algal biomass. Journal of applied Ecology, 21, 11-39.

Thompson, J.M., Ferguson, A.J.D. & Reynolds, C.S. (1982). Natural filtration rates of zooplankton in a closed system: the derivation of a community grazing index. J. Plankton Res. 4: 545-560.

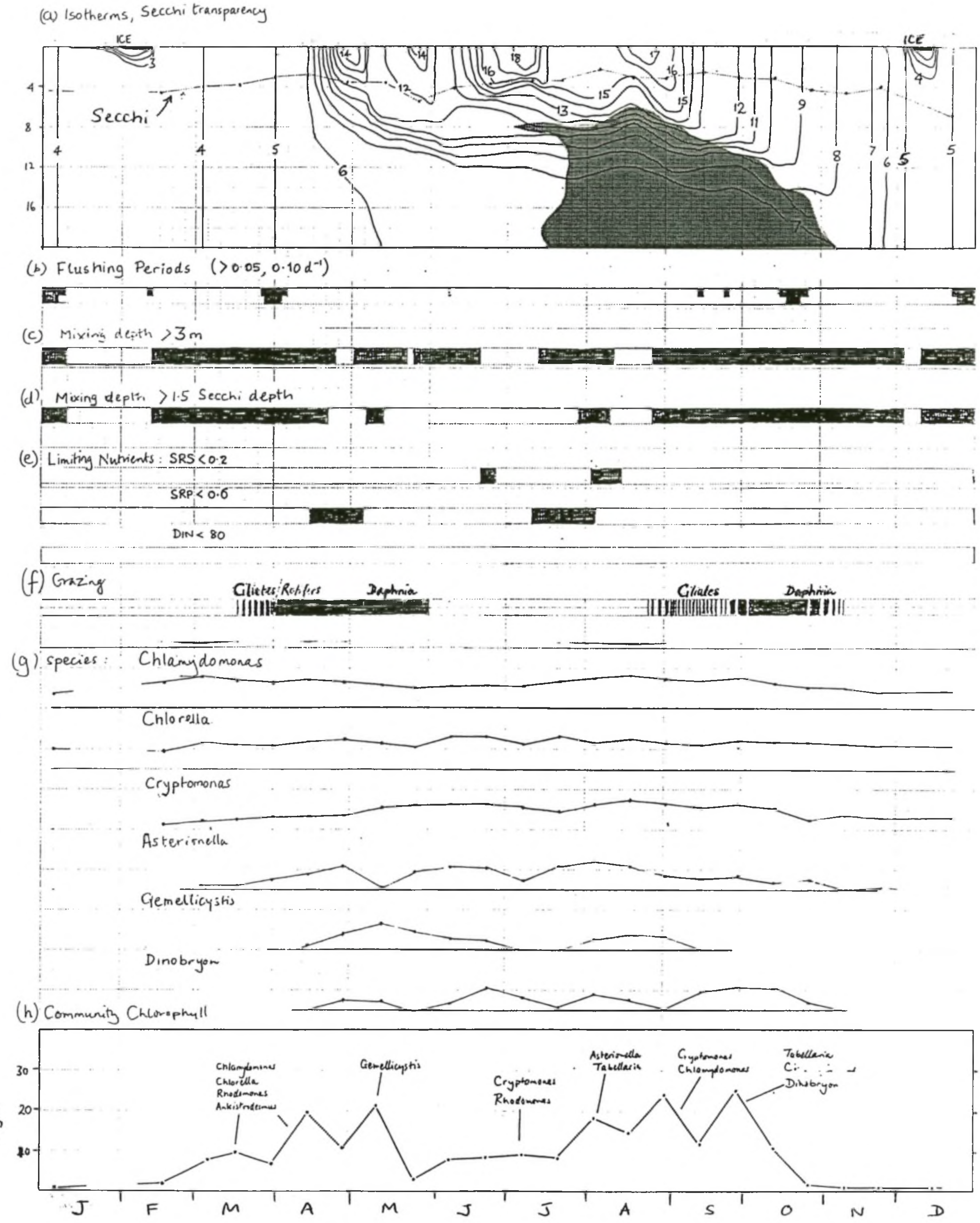

Figure 1. Grasmere, 1987: (a) Depth time distribution of isotherms, Secchi-disc transparency and 'anoxic' water (shaded area, [O_2 < 0.5 mg l^{-1}]); the periods of the year when: (b) flushing of the lake exceeds 5 and 10% day^{-1}; (c) mixing depth > 3 m and (d) > 1.5 Secchi depth; (e) soluble reactive silicon falls < 0.2 mg SiO_2 l^{-1}; soluble reactive phosphate < 0.6 µg P l^{-1}; and dissolved inorganic nitrogen < 80 g N l^{-1} (none); (f) grazing rate is ~ 0.3 d or more; (g) shows semilog plots of algal numbers for the named species; (h) shows fluctuations in the chlorophyll a content of the upper 5 m of the lake and the seasonal changes in its dominance.