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BLUE - GREEN ALGAL SURVEY OF LOWER CLICKER QUARRY

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SUMMARY

1. A survey of the blue-green algae in Lower Clicker Quarry was carried out to assess the possible impact of pumping quarry water into the river Seaton.

2. The principal blue-green alga dominating the phytoplankton biomass was Oscillatoria.

3. The quarry water was isothermal on the survey date and Oscillatoria filaments were distributed fairly homogenously through the water column.

4. Densities of Oscillatoria on the survey date were two orders of magnitude lower than the NRA trigger limit for potentially toxic blooms.

5. The mean surface chlorophyll-a concentration was 2.6 $\mu g / l$. This is several orders of magnitude lower than bloom concentrations of chlorophyll-a.

6. It is not anticipated that pumping water from Lower Clicker Quarry to the R. Seaton between March and April 1991 will have any adverse environmental effect as a result of the algal community within the water body. Should de-watering be required after this period, a repeat algological survey will be required before any pumping activities take place.

CONTENTS

1. INTRODUCTION

Lower Clicker Quarry (NGR: SX288613 and Fig. 1) was created for the extraction of dolerite used for roadstone and rail ballast. It was quarried up until 1970 and has been filled with water since 1973. The quarry covers an area of about 3.5 ha, has a volume of approximately 50 million gallons and has a maximum depth of about 15 m (A. Stewart, personal communication). Lower Clicker Quarry has a history of potentially toxic blue-green algal blooms since the vesting of the National Rivers Authority (NRA) in 1989. Surface samples have been taken by the NRA on a number of occasions but no sample has been submitted for toxicity testing.

If the quarry is de-watered the water will be pumped into the River Seaton. The River Seaton was classified as National Water Council (NWC) Class 2 in 1989 as a result of high concentrations of total copper, ammonia and high BOD values. It has a River Quality Objective (RQO) of Class 1A.

The present study was commissioned by the Highways Laboratory of Cornwall County Council and forms part of an application for an NRA consent to de-water the quarry.

The aim of the survey was to assess densities of potentially toxic blue-green algae in the quarry and to make comments on whether densities would affect the designated uses of the River Seaton if the water was pumped into it.

2. METHODS

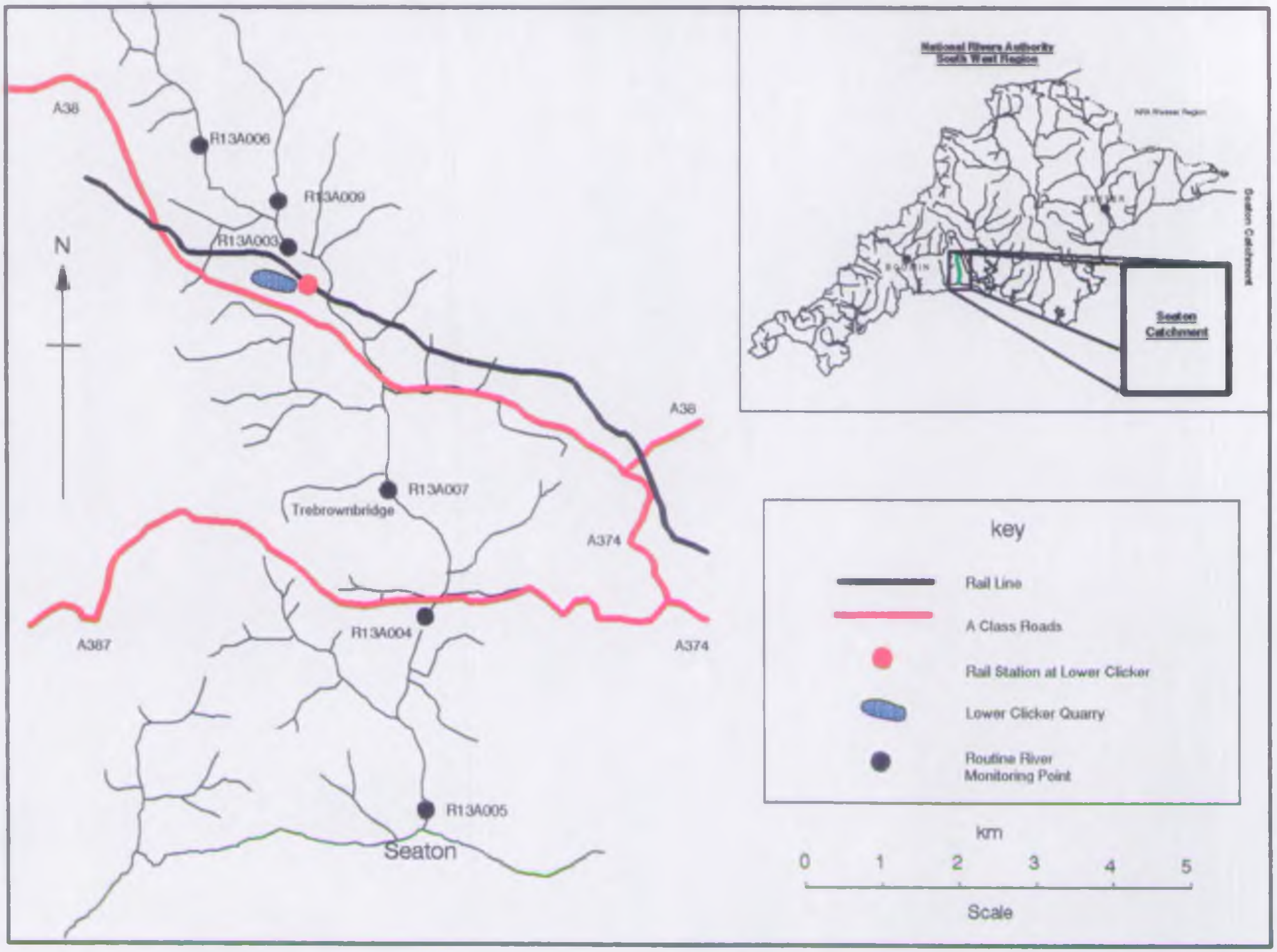
A field survey was conducted on 5th February 1991. A standard Secchi disc was used to determine water clarity. Samples from the water column were taken from a site in the middle of the quarry using a 1 litre standard water sampler (BDH); eleven samples were collected at one metre depths from the surface to 10 m inclusive. Water temperatures at each depth were recorded with a thermocouple. Samples were stored at 4 °C in the dark until analysis. A plankton net (mesh aperture 53 μm) was towed for approximately 100 m to concentrate plankton for identification; this sample was also used to assess qualitative estimates of abundance. Five 1 litre surface samples were taken for chlorophyll-a analysis.

In the laboratory each of the depth samples were divided into two halves; one aliquot was filtered onto a Sartorius 0.45 μm nitrocellulose filter and the other aliquot was preserved with Lugol's iodine and stored for future analysis. The 500 ml aliquot collected on the filter was scanned under a low power microscope and filaments of Oscillatoria (identified as the major blue-green alga from the concentrated tow net sample) were counted (detection limit = 2 filaments /l). Ten Oscillatoria filaments were selected randomly from each of the eleven filters and were measured using a micrometer eye piece to the nearest 5μm.

Chlorophyll-a concentration was analysed by South West Water Services plc using a methanol extraction, and measuring the absorbance of the extracted pigment spectrophotometrically.

Mean daily gauged flows for the River Seaton from the years 1973-1990 have been obtained from the Hydrometric section of the NRA South West.

Fig. 1 Seaton Catchment



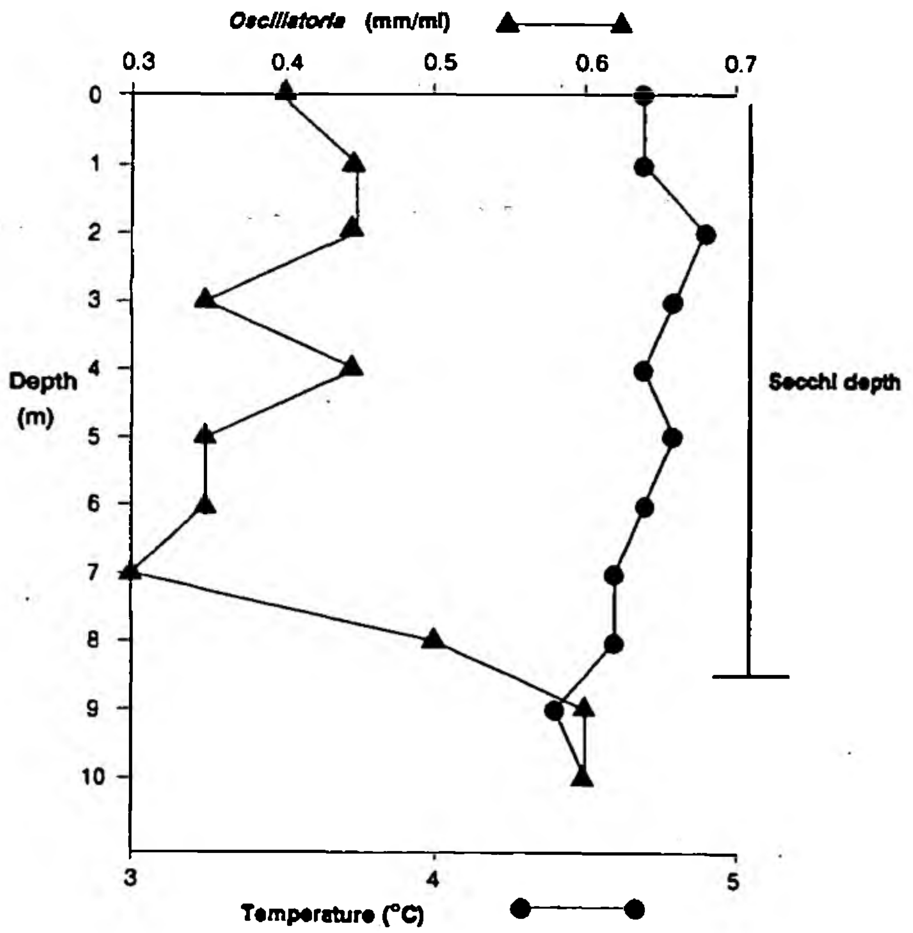
3. RESULTS

The surface phytoplankton, sampled by tow net, was dominated by the blue-green alga Oscillatoria argardhii. Other dominant taxa present are listed in Table 1.

Table 1. Dominant taxa identified from concentrated tow net sample. Relative abundances range from 1 (occasional) to 5 (very abundant).

	Taxa	Relative abundance
Phytoplankton	Oscillatoria argardhii Botryococcus braunii Pediastrum boryanum Cosmarium sp.	5 2 2 1
Zooplankton Rotifers Copepods	 Keratella sp. Daphnia sp.	 5 2

Fig. 2 Temperature and Oscillatoria filaments through the water column on 05/02/91.



The numbers of Oscillatoria filaments have been converted to filament length per ml as filament length varied by more than an order of magnitude. Filament length gives a more precise estimate of their abundance. The transformation of filament number to filament length was carried out using data from measured filament lengths from randomly selected filaments on each filter (see Methods). A summary of these lengths is given in Table 2. The number of Oscillatoria filaments per ml has also been included in the table as these are the units used by the NRA in their standard methodology and to enable comparisons with Fig. 2.

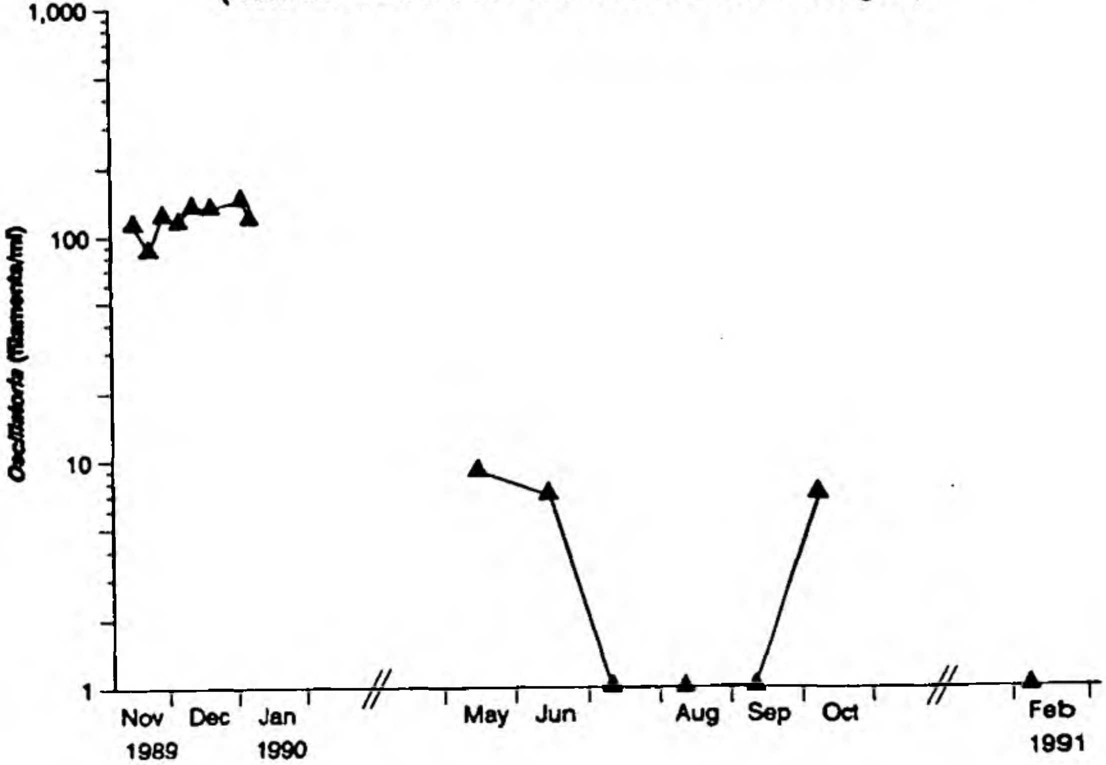
Table 2. Mean filament length and number of Oscillatoria filaments per ml through the water column.

Depth (m)	mean filament length (μm)	standard deviation (μm)	Oscillatoria filaments / ml
surface	4440	2482	0.088
1	6626	3912	0.068
2	4888	2664	0.090
3	3160	3717	0.110
4	4244	3158	0.102
5	4188	3628	0.086
6	4020	3292	0.084
7	3412	1051	0.080
8	6740	3424	0.076
9	6876	3953	0.094
10	7310	3337	0.078

The water was isothermal with no major difference in water temperature (and therefore water density) throughout the column. This suggests that the whole water column is well mixed and thus it would be expected that Oscillatoria densities would be evenly distributed with depth. This was in fact the case, with filament length per ml not varying by more than a factor of two. The water column is quite clear with the Secchi depth extending 8.5 m down the water column; this reflects the low abundance of phytoplankton present. Another indicator of the low biomass of phytoplankton was the low concentrations of chlorophyll-a. The five surface samples had a mean chlorophyll-a concentration of 2.6 μg /l with a standard deviation of 0.07 μg /l. Chlorophyll-a concentrations in waters with blooms may reach 200-500 mg /l, ie more than five orders of magnitude higher than concentrations recorded in the quarry.

It is difficult to assess the changes in the population of Oscillatoria with time, because previous samples collected by the NRA were obtained from the edge of the quarry and are therefore not strictly comparable with data collected in this survey.

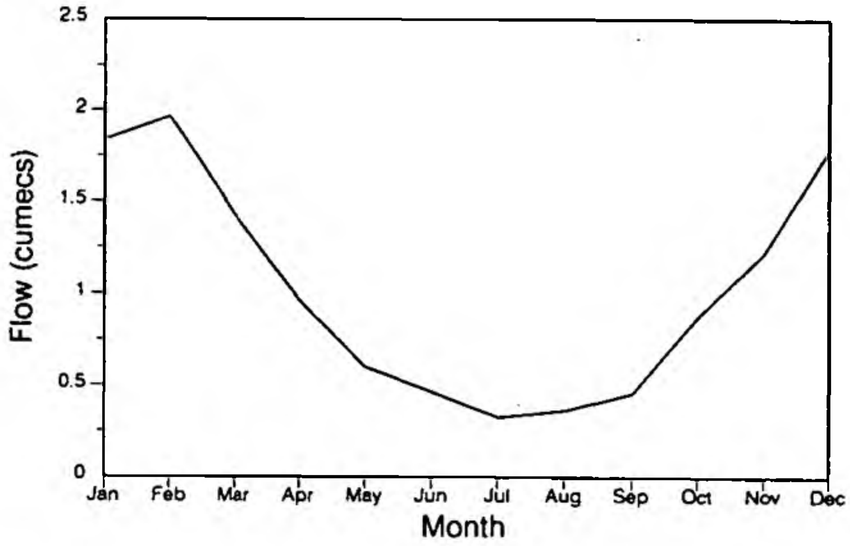
Fig. 3 Surface densities of Oscillatoria filaments in 1989, 1990 and 1991. (Note the units are not the same as those in Fig. 1.)



The densities in the winter of 1989/1990 were about an order of magnitude higher than in the summer of 1990 and in winter 1990/1991 (this survey) densities were very low.

Mean daily gauged flow of the River Seaton are given in Fig. 4. Data for the period 1973-90 are presented. The units are cumecs (= cubic metres per second).

Fig. 4 Mean daily gauged flow 1973-1990 at Trebrownbridge on the River Seaton



The river flow is generally greatest in January and February and thus it is during this period that greatest dilution would be available for any discharge.

4. DISCUSSION

The biomass of Oscillatoria in the quarry on the survey date was low. Oscillatoria is a gas vacuolate blue-green alga considered by NRA as potentially toxic; no information is available regarding toxicity. Any toxic effects would be negligible at the densities present in this survey.

The NRA trigger limit for alerting owners of potentially toxic blooms is twelve filaments per ml. Mean densities in the quarry were 0.09 filaments per ml, ie more than two orders of magnitude less than the trigger limit. At present there are no blue-green algal problems in the quarry. If the quarry was de-watered immediately the impact from potentially toxic blue-green algae in the River Seaton would be negligible.

Since any de-watering activity is unlikely to occur within the next few weeks, a prediction has been made on the consequences of delaying the action. Any predictions based on so few samples is inevitably speculative; nevertheless, an understanding of the organism involved helps to make some helpful inferences from the data available.

Oscillatoria is often most abundant below surface waters. In many circumstances it will form dense layers in the metalimnion of a stratified water body. Under these conditions a surface bloom will not be apparent and only by sampling at different depths through the water column are these subsurface blooms detectable. There is some evidence that this was the case in the quarry. Fig. 3 shows that surface Oscillatoria densities were low in the summer of 1990. It is then that a thermocline is expected to form in the quarry and it is possible that, during this period, most of the Oscillatoria were in the metalimnion. Surface samples would not collect these filaments. In the autumn, when water temperatures fall and storms stir up the water, complete mixing of the water column occurs (autumn overturn); the separate layers which existed in the summer are broken down and any filaments which had concentrated at depth will now circulate in the whole water column. Many of the filaments will be detectable in surface samples. Indeed, in periods of calm after the autumn overturn the gas vacuoles in the cells may cause filaments to ascend, giving rise to surface blooms. Again, Fig. 3. shows that densities of Oscillatoria filaments in surface samples were relatively high in the autumn and winter of 1989-90.

The anomoly in Fig. 3. is the low densities recorded in the surface sample in February 1991. If the scenario above is an accurate reflection of the system in the quarry, we might expect surface densities to be two orders of magnitude higher, comparable, say, to January 1990. With so few data available it is not possible to explain the apparent anomoly. The winter of 1989-90 was certainly milder than the current winter and perhaps Oscillatoria was still able to grow, all-be-it slowly, in 1989-90. The colder winter this year may have reduced growth rates leading to a net loss of filaments from the water column. Other possibilites include an increase in grazing by zooplankton in 1991 compared with 1990. Rotifers were very abundant in the surface tow net sample and these may account for reduced filament numbers.

To indicate how quickly the phytoplankton biomass in the quarry can change, a few simple calculations based on doubling times of the organisms have been made. Based on the data in Fig. 3. the doubling time of the population from 21/11/89 to 5/12/89 was thirty days. No water temperatures are available for this period, but in January 1991 the mean temperature of five Cornish reservoirs was 5.0 °C; water temperatures in the quarry are unlikely to be very much different from this. Assuming a Q10 of 2, a 10 °C rise in temperature would reduce the doubling time of the population by half. Thus at 15 °C the doubling time may be 15 days and at 25 °C about a week. In optimum conditions, therefore, a population of 0.09 filaments/ml (current density in quarry) could rise to NRA trigger levels in seven weeks. At 15 °C the time to reach the trigger limit would be fourteen weeks. It must be emphasized that these times are based solely from three samples and the error may be high; nevertheless published values of doubling times of Oscillatoria (eg Reynolds, 1984) are similar, so the numbers probably represent reasonable "ball park" figures.

Clearly, water temperatures are not going to rise to 25 °C in a matter of weeks, but it should be borne in mind that the plankton density and assemblage can change quite quickly, and any de-watering of the quarry should go ahead in the next few weeks if algological concerns are considered important. Once water temperature and day length begin to increase significantly, the results of this survey are unlikely to be applicable.

Nothing is known of the toxicity of Oscillatoria. If its biomass increases it may become a hazard for any de-watering activity. Little is known about the toxicity of blooms though studies have shown that a bloom which is toxic on one particular day may not be toxic the next (NRA report, 1990). Other studies reveal that more toxic material is released when cells of toxic strains are broken up compared to intact cells. It is likely that most of the filaments would break up when transferred from the standing water of the quarry to the turbulent flowing water of the river; thus any effects from cellular toxins is likely to be increased.

If the Oscillatoria is non-toxic, the only detrimental effects of high biomass entering the river is its effect on the biological oxygen demand (BOD) when it dies and decays. De-watering the quarry should therefore be regulated so that the dilution of the river prevents a significant increase in BOD.

5. CONCLUSIONS

1. Dewatering activity should be carried out when algal biomass is low.

2. Densities of blue-green algae recorded during a survey on 05/05/91 were very low.

3. The most likely period of low blue-green algal density in Lower Clicker Quarry is during the summer period although sub-surface blooms may occur at this time.

4. Flow in the River Seaton is generally highest in the winter when greatest dilution will be available for any detrimental effects from the quality of Lower Clicker water.

6. RECOMMENDATIONS

1. De-watering the quarry should not be restricted for any algological reason if carried out between 05/02/91 and 30/04/91.

2. If de-watering is delayed for any significant length of time (from the beginning of May 1991), a brief repeat survey should be conducted to ensure water quality is acceptable for discharge to the River Seaton.

   - Action by Freshwater Scientist

7. REFERENCES

National Rivers Authority (1990): Toxic blue-green algae. Water Quality Series No.2. NRA, London.

Reynolds, C.S. (1984). The ecology of freshwater phytoplankton. Cambridge University Press, Cambridge.