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An Appraisal of Grazing by Zooplankton on Blue-Green Algal Blooms: A Case Study of Hollingworth Lake, Northwest, UK

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Abstract

The grazing of blue-green algae by zooplankton was assessed as an indicator to measure how many counts of blue-green algae could be minimised in Hollingworth Lake over a period of three months during the mid-summer months of 2004, when the water surface temperature increased to about 17°C. Previously, *Hollingworth* Lake which is a tourist attraction to UK locales, students and tourists alike, had a history of algal bloom formation with filaments of *Oscillatoria agardhii* and colonies of the diatom *Asterionella* sp. which contaminated the water and all living organisms there. As a result of this problem, a lake management team was constituted ,which devised various techniques that could mitigate future algal bloom formation. This work, however, provides an insight into the effects of the grazing animals of the lake on the reduction of blue-green algae and determines if this method is suitable for reducing eutrophication.

Keywords: Zooplankton, grazing, blue green algae, lake

Introduction

Grazing influences the succession of phytoplankton, which gradually changes from edible to inedible phytoplankton in the late summer (Reynolds 1984a). Therefore, algal dominance may shift in favour of blue-green dominance, leading to selective grazing (Samelie, 1992). Blooms of blue-green algae such as Microcystis, may be held in check through the removal of the smallest colonies by grazing.

Certain large blue green algae, particularly those with surface mucilage, may pass through the gut of zooplankton unharmed and when they are able to do this, they are further balanced by the acquisition of nutrients e.g. Phosphates from their host during passage. According to Reynolds, (1984a), diatoms are the major food source for herbivorous zooplankton; thus, grazing pressure is likely to affect their

population by changing their composition and numbers. Blue-greens are barely consumed except when there is no alternative source. They often release a lethal dose of toxins which reduces the number of zooplanktons population when ingested (Carmichael, 1994).

Also, some types of filamentous blue-green algae cannot be ingested by Cladocerans as their active filtration systems become choked due to the large size of the bluegreens (Dryden and Wright, 1987). The larger Cladoceran, Daphnia, however, is capable of ingesting some species of blue-green when compared to other species. The copepods are capable of consuming filamentous blue-greens without getting choked when compared with cladocerans. This is because they have both filtering and raptorial modes of feeding (Vanerploeg and Paffenhofer, 1985). Rotifers, on the other hand, are smaller in size and are unable to consume blue-greens but are capable of consuming other smaller minute algae (Boney, 1989).

The use of zooplankton grazing was investigated by Griffin and Rippingale (2001) to determine whether the resident zooplankton community was able to substantially reduce phytoplankton biomass through grazing, or whether high phytoplankton biomass effectively inhibited grazing. The experiment‟s results showed that there was a diversion to the consumption of other phytoplankton species. It also indicated that zooplankton grazing impact was negatively associated with high phytoplankton and low dissolved oxygen in bottom waters. Boon et al (1994) noted that the commonest zooplankters, calanoid copepods and rotifers, had very much less potential for controlling cyanobacterial blooms than do the large cladocerans. However, as much as the cladocerans can consume the toxin releasing blue-greens, detrimental effects of blue-greens on zooplankton have been documented.

Materials and Methods See sample lake area below

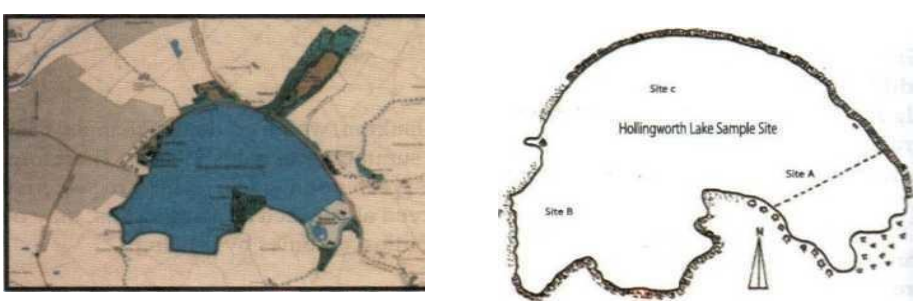


Fig. 1: Schematic Diagram of Hollingworth Lake Sample Sites

Collection of Samples

250ml was collected for phytoplankton counts 500ml
for chlorophyll analysis, and

- **Zooplankton**

250pm vertical trawl net samples were taken on the lake on each site to identify zooplankton species. The net was attached to a tape metre to measure the depth of the net lowered into the lake. When the sample was collected, it was segregated "to two: half of the zooplankton sample was placed in a universal tube and fixed with preservative, 4% formaldehyde. This preserved sample was used to identify and count the zooplankton, while the other sample was not fixed. This was used to measure the zooplankton biomass.

- **Phytoplankton**

A net of small mesh size of 53pm, used to trawl samples horizontally on the lake. The net was lowered gently and trawled at a boat speed. The horizontal trawl net simple was used to identify large phytoplankton (>50pm) and the sample was fixed with 4% formaldehyde to preserve the phytoplankton collected.

Phytoplankton and Zooplankton Biomass

- **Zooplankton Dry Weight**

Prior to the field sample collection, the GF/C Whatman filter papers were covered :n a foil paper and dried at 60°C for 24 hours in the oven. The filter papers were pre-weighed before filtration and the weights recorded. 100ml of the surface water -vas filtered through the pre-dried filter paper. The filter

papers containing the wet zooplankton were then oven-dried once again at 60°C for 24 hours, after which they were weighed. These gave the dry weight of the zooplankton. The difference between the filter paper and the zooplankton D/W was measured to give the actual zooplankton biomass.

The volume of the trawl was calculated as: depth x JIr^2
r = radius of the opening of the zooplankton net which was calculated to be 0.1535m d = depth through which the net was trawled.
Therefore, Weight of zooplankton (mg/1) = Weight/depth* $JIr^2$of net.

Chlorophyll-a

Phytoplankton biomass was measured as chlorophyll-a. This was carried out by filtering 500ml of collected water sample through a Whatman GF/C filter paper. The filter paper stored the chlorophyll-a, extracted in 10ml of 96% ethanol. The samples were stored in the dark for 20 hours at 4°C, a time sufficient for pigment extraction. The solution was centrifuged at 3300 revolutions per minute for 10 minutes. Following this, a 1ml aliquot of the supernatant was pipetted into a non-UVB 1ml quartz cuvette and measured with the aid of CECIL CE 20011

spectrophotometer at wavelengths of 665 and 750nm, to correct for turbidity. The chlorophyll-a concentration was estimated using standard procedures. Chlorophyll-a (p.g/1) =
VexfxA)/(Vs*l)
Ve= total volume of the solvent (ml) i.e. 10ml
Vs=total volume of the filtered sample (1) i.e. 0.51 L=
cell path length (1cm)
A=Absorbance at 665 and 750nm f
=
(L/specific extraction coefficient) x 1000
The specific extraction coefficient for chlorophyll-a in ethanol is 83.41/g/sm

Phytoplankton and Zooplankton Counts

Phytoplankton Counts

Polypropylene bottles containing the 250 ml lake water were fixed with 1% Lugols iodine. The addition of iodine assists the sedimentation of the phytoplankton and does not distort smaller and more delicate cells. The plastic bottle was dropped from a few centimetres twice and shaken. The process aids the collapse of the cell vacuoles and prevents the blue-green algae from floating.

The solution was then poured into 250ml cylindrical bottles and allowed to settle in a period of 72 hours. The time was consistent for all the samples collected. 225 ml of the surface water was siphoned leaving a ten-fold concentration of algae in the remaining 25ml.These plastic bottles were then stored in dark containers at 4°C prior to examination. To analyse the sample, 1 ml of the phytoplankton sample was placed on a sedgwick-rafter slide and covered with a cover slip. The phytoplankton was then identified using the identification keys of Bellinger (1992) and counted under the microscope at magnification of X40.

Numbers of organisms were calculated as follows:
(Number of phytoplankton/Number of squares counted) x 1000/ Concentration Factor.

• **Zooplankton Counts**

The identification and counts of zooplankton were carried out in a Petri dish under a light microscope. 1ml of the preserved sample was measured using a wide bore pipette. 1 ml sample of the zooplankton was diluted several times depending on the concentration of the zooplankton. The various types and groups were identified and segregated using the taxonomical keys of White (1999). These served as the counts for the zooplankton recorded.

The numbers of the zooplankton/m^3 were calculated as follows:
number of zooplankton counted (1ml) x Volume of sample x Dilution Factor/ Depth of trawl x Jlr^2 of net.

Results

Chlorophyll -a and Secchi depth

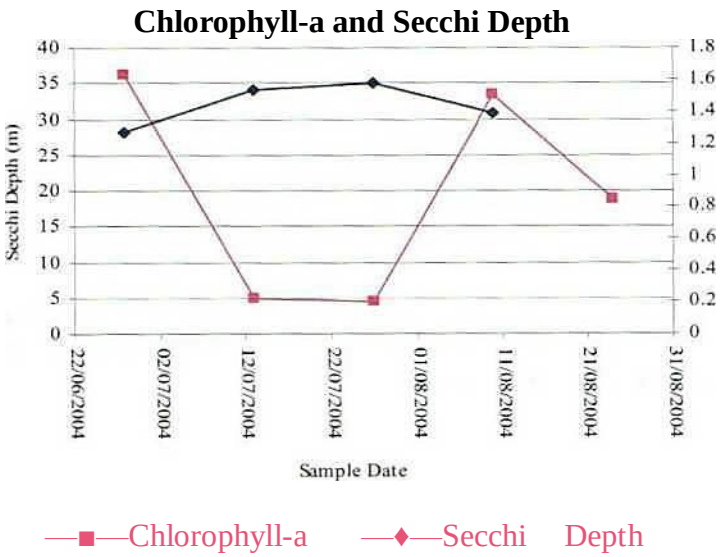
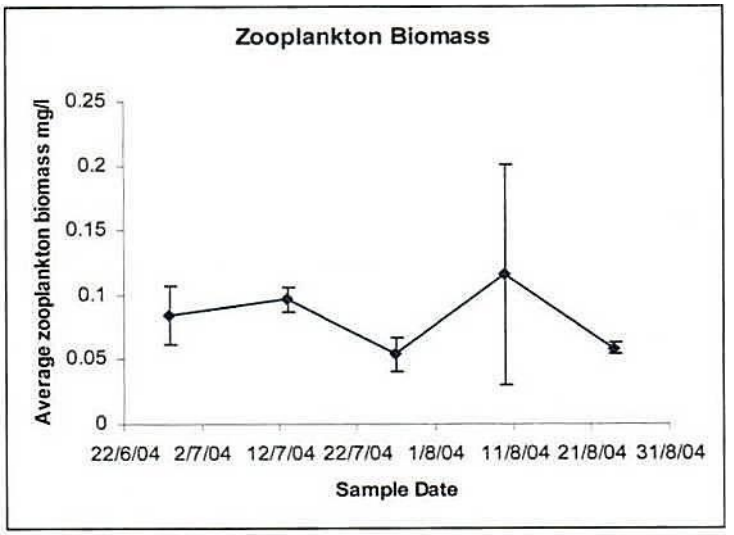


Fig. 2: Chlorophyll-a and Secchi Depth

The graph of Chlorophyll-a and Secchi depth indicates an inverse relationship between Chlorophyll-a and the depth. The Phytoplankton Biomass measured as Chlorophyll-a ranged from 4.27-36.01pg/l. The highest Chlorophyll-a concentration •vas recorded on the first sample date at the end of June with a concentration of 36.01 pg/1. The concentration decreased towards the end of August. The highest Secchi depth recorded, 1.57m was at the end of July (27/7/04).

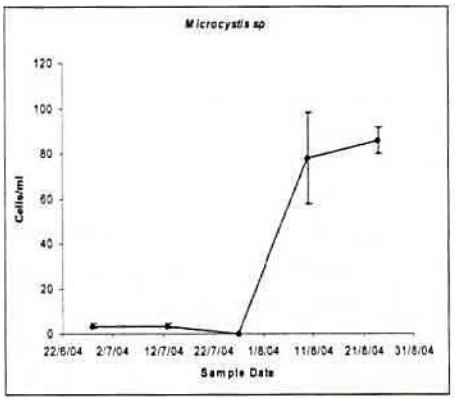
• **Zooplankton Biomass**

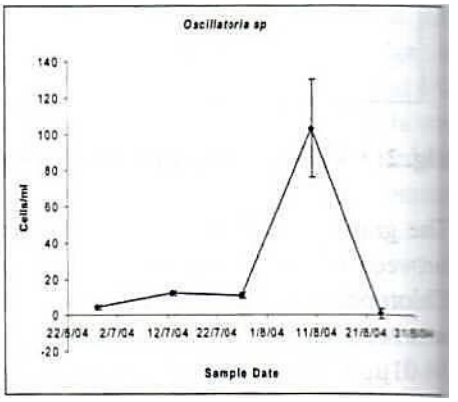
The zooplankton dry weight had two peaks, middle of July and August (0.0967mg/l and 0.1157mg/l respectively). The lowest reading was recorded at the end of July with 0.0542mg/l.



- Blue-Green Composition

Twelve species of Cyanobacteria were identified. These include: Aphanizomenzn flos aquae, Microcystis flos aquae and M. aeruginosa, Oscillatoria (with 60 um Rivularia, Gleocapsa turgida and Anabaena.





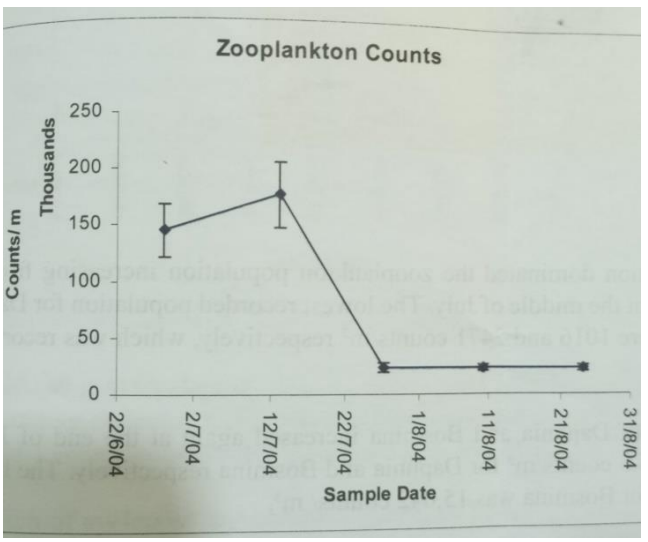
The dominant species of blue green-algae was Microcystis sp because it persisted throughTout the sample dates. Microcystis sp, Oscillatoria and Aphanizome- flos aquae had the highest counts on the second week of August with counts, 44.43, 103.33 and 13.33cells/ml respectively and the lowest at the end of July, counts of Microcystis increased on the last sample date i.e. at the end of Am while the other species declined such as Oscillatoria aghardii.

Zooplankton Composition

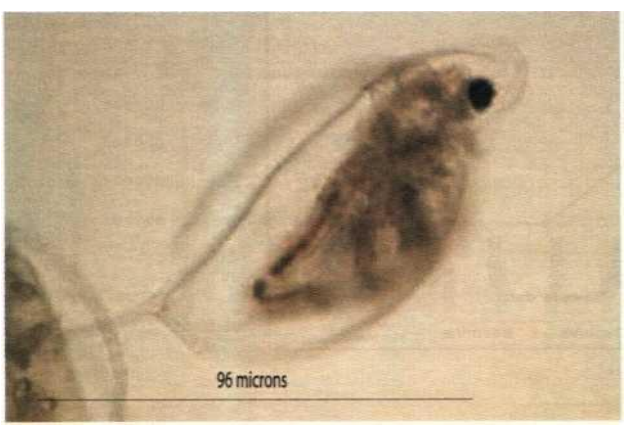
The zooplankton composed of species of Daphnia, Bosmina, Leptodora, Polyphemus, Cyclopoid, Copepods, Branchiomus and Asplanchna.

The total zooplankton population had the highest count in the middle of July with 178,721 counts/m^3 and the lowest count, 146,147 counts/m^3at the end of June. The population continued to decrease till the last sample date with the above 18,000 counts/ m^3.

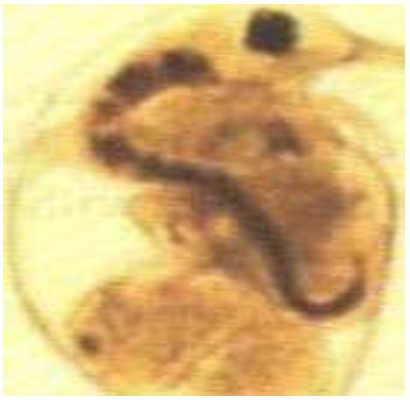
Zooplankton Counts



Daphnia (96pm), Bosmina (48pm), Leptodora, and Polyphemus, Holopedium 386.3counts/m^3 were identified.



Daphnia



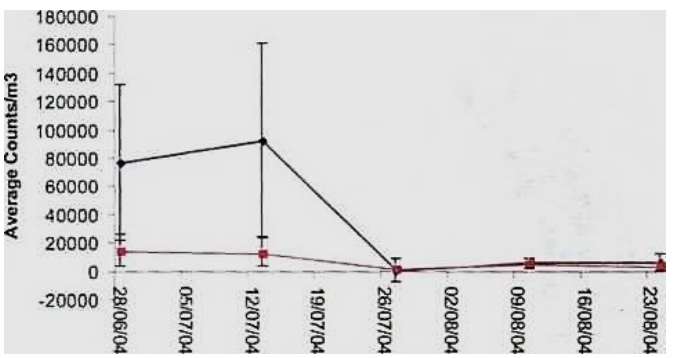
48 microns

Bosmina

Daphnia population dominated the zooplankton population increasing from 77, 099.7 to 92,527 at the middle of July. The lowest recorded population for Daphnia and Bosmina were 1016 and 2471 counts/m^3 respectively, which was recorded at the end of July.

The population of Daphnia and Bosmina increased again at the end of July to 6622.9 and 4016.3 counts/m^3 for Daphnia and Bosmina respectively. The highest count recorded for Bosmina was 15,042 counts/ m^3.

Daphnia and Bosmina



Sample date

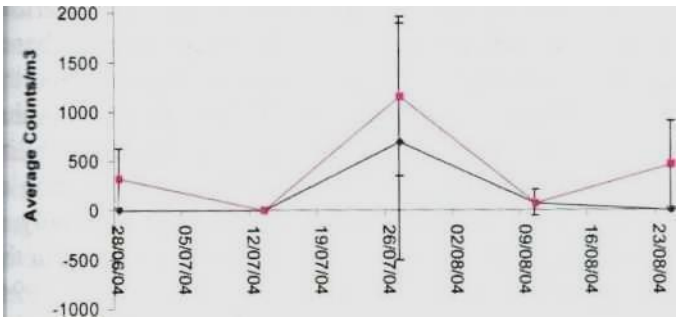
—♦—Daphnia —♦—Bosmina

Daphnia and Bosmina± S.D

Leptodora was identified twice during the sample dates, at the end of July and middle of August, (with 695 counts/m3 which reduced to >77 counts/m^3) and Polyphemus was identified at the end of July with a count of 1158. 4 counts/ m^3.

Leptodora and Polyphemus

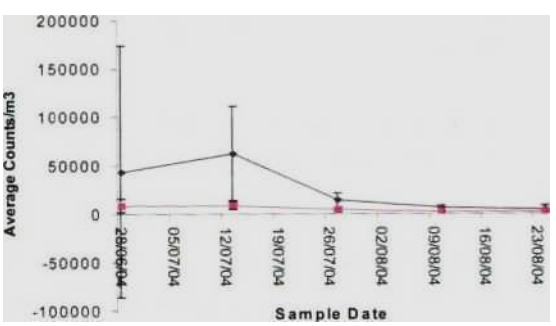
2500 -j



Calanoid (40 pm) Cyclopoid, (48pm), Mysis and Cirripedia were identified in the water samples collected. Cirripedia was identified once and on the first sample date with 193.1 counts/cubic metre. Mysis, twice in July (154.5 and 386.2 counts/m^3).

The graph of cyclopoid and calanoid shows a decrease in the number of counts. Cyclopoid decreased from 43,831 to 5030.9 counts/cubic metre and Calanoid decreased from 8552-2181.9 counts/ m^3. The highest counts were recorded in the middle of July with 62232 counts/ m^3 for cyclopoid and 8940 counts/ m^3 for calanoid.

Cyclopoid and Calanoid



Discussion

Grazing of phytoplankton by zooplankton and the zooplankton dry weight are methods, which are considered as lake water indicators. Grazing by zooplankton has a great influence on the phytoplankton in lakes. This is because; their activities deplete the standing stock of phytoplankton and, may have a significant effect on their dynamics and population ecology (Moss, 1998). They are also globally recognised as pollution indicator organisms in the aquatic environment (Rutherford et al., 1999). The interaction between phytoplankton and zooplankton is based on the composition of the algal community, the availability of nutrients and the composition of the zooplankton (Reynolds, 1984a). Also, Boney (1989) states that this relationship depends on the edibility of the phytoplankton, size, digestibility and the ease of capture by the zooplankton. Hence, the increased population of blue green algae aids the growth and reproduction of zooplankton especially in increased temperature, where moulting and spawning is highest as noticed in the summer months, when this project was carried out. Home and Goldman (1994 made it clear that in eutrophic lakes, zooplankton can filter the entire hypolimnion in a few weeks and soon eat most of the phytoplankton. After the consumption, they die or form resting stages.

The major consumers of phytoplankton, which were found at Hollingworth Lake, include the filter feeders Daphnia, 96pm Bosmina, 48 pm, the small carnivorous leptodora and polyphemus; calanoid and cyclopoid copepods and the rotifers: asplanchna and branchiomus. Cladocerans and rotifers are usually present in the summer months, when food is in much supply.

Rotifers are filter feeders and have a well-developed ciliary corona and crushing mastax, which enable them to ingest particles of up to 10-12pm, the analysis of branchiomus showed that it had a size of 44 pm and is capable of taking up to 18pm particles. Rotifers contribute to the biomass of lakes and are important to the food web by the transfer of energy. They also greatly dominate zooplankton densities in the more eutrophic lakes, but their abundance may have been much greater than it appeared (Moss, 1998).
Asplanchna had a size of 40pm, a grasping mastax and is predatory upon other rotifers, although its diet includes other larger „algae‟ which are ingested whole (Lund, 1965).

Daphnia, because of its competitive ability with different zooplankton (DeMor_ 1989 and Gilbert, 1988), is capable of inhibiting the feeding rates of other daphnias by secreting toxic substances. The presence of blue-green algae filaments, especially of toxic strains, may alter the competitive abilities of Daphnia and other zooplankton taxa (Reynolds, 1984a). The Calanoids are small particle feeders and select actively from those brought near the mouth by the movement of limbs

Paffenhofer et al., 1982 & Peters, 1984). The presence of smaller zooplankton species is attributed to the productive nature of the lake and the enhanced availability of food particles.

Conclusion

The assemblage of blue-green algae in Hollingworth Lake is indicative of the lake‟s richness in nutrient composition. The collection of zooplankton also indicates the presence of feeding abilities in the lake. The interaction between blue-green algae and zooplankton is based on a number of factors including algal composition, competition between zooplankton, the availability of nutrients and the composition of the zooplankton (Reynolds, 1984a). This relationship depended also on the edibility of the phytoplankton, its size, digestibility and the ease of capture by the zooplankton (Boney, 1989). The presence of various zooplankton indicated the various levels at w'hich blue-green algae could be consumed either in small bits or more, which, consequently, have an impact on the standing stock of phytoplankton in the lake.

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