LAKE ROTORUA - MEASUREMENTS OF P-MAX AND BIOASSAY OF NUTRIENT ADDITIONS

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INTRODUCTION

Monitoring the trophic level of Lake Rotorua using the carbon 14 method started in October 1969. The aim has been to obtain comparative P-max values by laboratory incubations, to make some 'in situ' column production measurements, and to carry out bioassay of the effects of adding nutrients to water samples.

This report summarises all the carbon 14 bioassay experiments carried out on Lake Rotorua water samples. The techniques used are those described by Burnet and Wallace (1973)*, where the 1970 and 1971 data are compared with those from other N.Z. lakes.

The 1969/70, and the 1971/72 series of observations comprise both laboratory and 'in situ' experiments. The 1973/76 series are all laboratory measurements. The emphasis throughout these observations has been on comparative results, and laboratory incubations were preferred as variability due to weather is less. No changes, or improvements have been made to the technique as this could have altered the comparative value of the results.

The figures presented are for a small sample of lake water, confined in a bottle, and exposed to the optimum light level for photosynthesis, for a short time (usually 2 hours). This is very different from the real situation in the lake where there is considerable water movement, and often changing light levels.

Two methods have been used for the nutrient addition assay. In both the addition of nutrients was made at the start of incubation. For both Phosphorus and Nitrogen a range of concentrations was used, from 0.0005 to 0.3 gms/M^3. All the additions of other nutrients were at 0.005 gms/M^3. Some of the trials were run with the C14 added at the start of incubation, but in most cases the samples were incubated for 18 hours, the C14 added, and incubation continued for a further 6 hours before filtering. The light level was kept constant at approximately the optimum for photosynthesis. Thus the controls, and the samples plus nutrients were incubated for longer than in natural conditions before the measurements were made.

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The technique, although straightforward, requires considerable attention to detail if large experimental errors are to be avoided. Errors in some of the individual steps have been tested, and trials were run to check the overall variability. A well mixed water sample was incubated in 27 P.V.C. bottles distributed in 10 of the compartments of the incubation box. The mean value for carbon assimilation was 115.1 $mg/M^3.hr$, with a maximum of 130.3 and a minimum of 102.6. The standard deviation was 8.0. During experiments the bottles are incubated in groups of 6 in each compartment. As the within compartment variability is less than the total variability, and each group includes a control, this experimental error is considerably less than the 20% change in carbon assimilation rate which is taken as showing a significant stimulation or inhibition.

RESULTS

All the water samples were collected at Station A in Lake Rotorua, and the 'in situ' incubations were made at that site. The details of all measurements for the 1973/76 series are given in Table 1, and all the P-max values for 2 m samples, i.e., from the zone of active photosynthesis, are shown in Fig. 1F.

The annual cycle has followed a similar pattern each year with the maximum in February or March (late summer-early autumn), followed by a gradual decline, but with quite high values during winter. The minimum in mid-summer is usually followed by a rapid increase to the next maximum.

Measurements do not include bloom conditions, except on 29 January 1975 when a P-max of 285 was recorded from one location. A sample from the most obvious bloom area had a P-max of 46.7 $milligrams/M^3$.

The micronutrient bioassay started in 1971 when responses to both phosphorus and nitrogen were the most obvious effect. Little or no response to the other elements tried was detected at that time. Later the responses to P became less marked, except for 1975 when the highest values were obtained. The responses in 1976, although usually positive, were mainly below the probable error limits.

The responses to nitrogen have remained at about the same level, but were less consistent in 1976. Also tested, but not illustrated, was the response to P + N (combined) and this was usually positive, and often higher than that for either element on its own.

The P and N trials were at a range of levels, from 0.0005 to 0.3 gms/M^3. However it was not practicable to test all levels at all times, thus some positive responses could have been missed. The optimum level for stimulation by P was variable. Frequently P inhibited activity at one level, thus demonstration of a positive response depends on making the addition at the optimum level. However positive responses were obtained at all the levels of addition, but usually at 0.025 or 0.05 gms/M^3. Inhibitions also occurred at all levels of addition.

The nitrogen additions gave more uniform and predictable responses, often with all levels of addition showing a positive response. The combined P & N additions were all at 0.01 g/M^3 of each element.

As the response to P decreased in 1973, more attention was paid to the other elements, and the results of these experiments are summarised in Fig. 1A, B and C.

The striking response to E.D.T.A. (a chelating agent) on its own, and in combination, dominates the 1973/74 results. This response has continued, usually in combination with cobalt, occasionally with copper, and with iron, and with P. (The responses illustrated are those when a combination produced a greater result than either addition on its own.)

Additions of copper at low levels (0.005 gms/M^3) have given both positive responses, and inhibitions (Fig. 1B).

The other elements tested were cobalt, boron, magnesium, zinc, manganese, calcium, molybdenum and B12. Positive responses were obtained with Co, B, Mg, Zn, Mo, and B12. The most marked responses are those shown in Fig. 1C.

The levels of available carbon in Lake Rotorua are low, especially when compared with waters of similar activity (Burnet and Wallace 1973). A number of incubations were made with additions of carbon, but there was no stimulation of activity.

DISCUSSION

Excluding short-lived bloom conditions, the maxima reached in each year are similar. (Comparison with the 1969/72 data is difficult owing to the larger gaps between observations.) Comparing the last 3 years, the 1976 levels are slightly lower, but spread over a longer period. This could be associated with the high wind levels in 1976, and the consequent greater mixing of the lake water. In 1975 high P-max values were obtained for the samples from 8 and 14 m depths, indicating a more stable state, and a build up of nutrients in the deeper water.

With the data available, these analyses so far do not demonstrate a measurable change in the average trophic level between 1970 and 1976.

The results from the nutrient addition experiments indicate a complex situation. The decline in assimilation rate from the February or March maximum follows closely the rate that would be expected if temperature were the main controlling factor. (Laboratory experiments have confirmed that the assimilation rate is approximately half for a 10° C drop in temperature.)

The decline in P-max generally continues on into mid-summer when temperature have risen again; so other factors must also be limiting. There is some indication in the results that the higher responses to nutrient additions occur during the winter, and early summer period, suggesting a greater depletion of nutrients at these times.

The conductivity measurements indicate seasonal change with a maximum in January 1976, and lesser ones in April 1974 and April 1975. However these changes are considerably in excess of those expected from the likely changes in nutrient level, and are probably a reflection of the levels of other salts - possibly related to the balance between inflows, outflows, and evaporation.

The timing and levels of the maxima in algal activity are not clearly related to any single factor. (In Lake Rotoiti for example, the maxima occurs in winter, and follows the overturn.) The patterns observed in Rotorua could be explained if releases of nutrients from the sediments during anoxic conditions provide a significant addition to the system.

If this is the case the effect of measures which will reduce the average level of algal activity, and so the likely occurrence of anoxic conditions, is enhanced by reduction of the sediment releases.

No single element emerges as a consistent limiting factor. I suggest that the situation is fluid, with responses changing as several elements are usually near limiting levels.

It could be significant that copper can be both a stimulant and an inhibitor. Also that E.D.T.A., which is a specific copper chelator has given the highest responses. This could be due to the chelating of copper, or due to E.D.T.A., making other elements more readily available for photosynthesis. Thus E.D.T.A., in combination especially with cobalt and Iron has given marked responses. Data on the natural levels of copper would be needed to pursue this idea further.

Of practical importance is that the levels of copper needed to inhibit activity are often higher than expected. In April 1975, copper added at 0.05 gms/M^3 reduced the assimilation rate to 72%. Additions of copper at this level in a lake of this size is not practicable.

I want to emphasise again that the responses to nutrients described have been obtained under laboratory conditions, and that they are not easily demonstrated. The results may not represent the natural conditions, partly due to the experimental technique, and partly as a much wider range of experiments is needed to avoid misleading results. For example, a number of experiments with mixtures of micronutrients gave no positive results despite the fact that parallel tests of components of the mixture resulted in stimulation

The experiments show that algal activity as measured by carbon 14 is high, and has remained comparable to the data presented in 1973. It appears that a number of factors, and more than one of the nutrients, and micronutrients, are close to limiting at various times.

TABLE 1. The 1973/76 data for water samples from 2M, 8M, and 14M depths.

A. 2 M Samples

DATE	TEMP	C.AVAIL	COND		P-MAX
14.11.73	17.7	2.4	17.9		19.2
21.11.73	17.7	2.3	17.9		33
12.12.73	20.7	2.4	18.1		26.2
8. 1.74	21	2.6	18.2		38.1
7. 2.74	23.1	2.3	18.2		40.6
6. 3.74	20.5	2.3	18.5		132.7
8. 4.74	18	2.4	18.8		81.7
16. 5.74	13	2.6	18.5		85.9
6. 6.74	12.1	2.8	17.6		43.1
11. 7.74	9.7	2.1	18.4		57.4
8. 8.74	10.1	2.9	18.3		81
12. 9.74	11.8	2.2	18.6		19.6
11.10.74	14.1	2.7	18.3		66.3
14.11.74	16.4	2.3	18.1		42.7
12.12.74	19.8	2.4	17.7		35.9
				AV	60.4
16. 1.75	23.9	2.3	18		33
29. 1.75	24	2.2	0		46.7
13. 2.75	22.1	2.2	18.4		143.2
18. 3.75	20.5	2.4	18		134.9
17. 4.75	18.1	3	19		78.6
14. 5.75	14.5	2.6	18		87
24. 6.75	10.7	2.8	17		60.7
22. 7.75	8.5	2.7	17.6		37.5
12. 8.75	8.6	2.7	17.8		36.8
24. 9.75	12.1	3	17.3		12.2
21.10.75	14	3	17.5		52.3
18.11.75	17.2	3.8	17.6		73.3
16.12.75	19.2	2.6	18.9		69.3
				AV	68.2
20. 1.76	20.6	2.8	20.5		61
17. 2.76	18.9	3.5	17.8		115.3
17. 3.76	19.5	2.8	19.4		102.2
14. 4.76	17.4	3.2	19		117
12. 5.76	13.9	2.8	18.1		70.4
16. 6.76	10.2	2.9	18.8		62
13. 7.76	8.5	3.1	17.7		61.2
11.8.76	8.8	3.2	18.3		56
21. 9.76	11.2	3.4	18		41.7
12.10.76	13.4	3.1	18.2		42.4
16.11.76	14.6	2.7	18.3		38.3
14.12.76	18.4	2.9	18.5		78.9
				AV	70.5
12. 1.77	18.4	3.4	18.4		113.8
1. 2.77	19.5	2.9	18.1		70.4

Temp. ^{o}C.
Carbon available. Gms/M^{3}.
Conductivity. Millisiemens per metre at $25^{o}C$.
P-max. Mg/M^{3}.

B. 8 M. Samples

DATE	TEMP	C.AVAIL	COND	P-MAX
8. 1.74	21	2.6	18.2	31.8
7. 2.74	22.9	2.4	18.3	46.7
6. 3.74	20.3	2.5	18.7	145
8. 4.74	18	2.8	18.9	67.8
16. 5.74	13	2.7	18	93.2
5. 6.74	12.1	2.3	17.9	33.3
11. 7.74	9.7	2.9	18.4	89.5
8. 8.74	10.1	2.6	18.6	78.9
12. 9.74	11.8	3.4	18.1	46
11.10.74	14.1	2.8	18	62.4
4.11.74	16.4	3	18	53.4
12.12.74	19.3	2.7	18.1	48.7
16. 1.75	23.7	3.2	17.6	27.7
29. 1.75	24	2.7	17.9	32.4
13. 2.75	21	2.7	18.2	223.2
18. 3.75	20.5	2.6	18.2	110.8
17. 4.75	17.9	2.8	18	82.2
14. 5.75	14.5	2	17.8	62.3
24. 6.75	10.7	4.6	17.5	120.2
22. 7.75	8.5	3.4	18	66.6
13. 8.75	8.5	3	17.2	20.8
24. 9.76	12	4.5	16.9	29.2
21.10.75	13.9	3.4	17.7	73.1
18.11.75	17.1	5.5	17.7	73.8
16.12.75	19.2	2.6	19.1	77.7
20. 1.76	19.9	3.1	20.5	66.6
17. 2.76	18.8	3.7	18.5	119.6
17. 3.76	19.2	3.1	18.4	116.9
14. 4.76	17.4	2.9	19.1	98.5
12. 5.76	13.8	3.7	17.3	105
16. 6.76	10.1	3.6	18.8	84.7
13. 7.76	8.5	3.4	17.8	69.2
11. 8.76	8.8	3.4	18.3	64
21. 9.76	11	2.5	18.4	37.3
12.10.76	13.2	3.4	18.3	53.8
16.11.76	14.6	2.5	18.2	40.2
14.12.76	17.9	3.6	18.4	111.7
12. 1.77	18.4	3.4	18.4	139.2
1. 2.77	19.5	3.4	18.5	91.2

C. 14 M. Samples

DATE	TEMP	C.AVAIL	COND	P-MAX
12.12.73	19.7	2.4	18.4	27.5
7. 2.74	20.8	3.7	18.4	24.4
6. 3.74	20.3	2.7	18.8	137.3
8. 4.74	18	2.9	18.9	75.2
16. 5.74	13	3.4	18.4	93.6
5. 6.74	12.1	2.6	18.1	34
11. 7.74	9.7	2.5	17.8	65.6
8. 8.74	10.1	2.5	18.4	73.4
12. 9.74	11.8	3	18.3	70.5
11.10.74	14.1	2.6	17.1	46.4
14.11.74	16.4	2.6	18.3	41.8
12.12.74	19.3	2.7	18	43.4
16. 1.75	21.4	4.5	18.6	26
29. 1.75	24	2.4	17.9	23.1
13. 2.75	20.7	3	17.8	202.3
18. 3.75	20.5	2.7	18.2	126.7
17. 4.75	17.8	2.9	17.1	72.9
14. 5.75	14.5	2.9	17.8	119.7
24. 6.75	10.7	3.1	18	82
22. 7.75	8.5	3.1	17.1	57.7
12. 8.75	8.5	4.4	17.3	63.7
24. 9.75	11.9	3.5	17	24.2
21.10.75	13.8	3.5	17.8	69
18.11.75	17	4.4	17.7	76.5
16.12.75	18.8	2.7	19.1	84
20. 1.76	19.3	3.7	20.6	52
17. 2.76	18.8	3.2	18.4	99.7
17. 3.76	18.9	3.8	18.5	125.4
14. 4.76	17.4	3.9	19.2	121.7
12. 5.76	13.7	3.2	18	94.1
16. 6.76	10.1	2	17.8	46.2
13. 7.76	8.5	3.5	17.7	72.3
11. 8.76	8.8	4	18.4	74.4
21. 9.76	11	2.9	18.4	32.6
12.10.76	12.9	3.5	18.3	63
16.11.76	14.6	2.9	18.4	45.6
14.12.76	17.1	3.6	18.3	72.5
12. 1.77	18.3	3.3	18.6	116.1
1. 2.77	19.5	3.5	18.3	90.3

Fig 1. Lake Rotorua - Station A.

A. The responses to E.D.T.A., and the response to E.D.T.A., with an element.

B. Stimulations and inhibitions produced by copper added at 0.005 gms/M^3.

C. The greatest stimulation to additions other than P and N.

D. All the recorded responses to the addition of P.

E. All the recorded responses to the addition of N.

F. The P-max values measured for water samples from 2M depth.