RESULTS OF MONITORING NEW ZEALAND LAKES, 1992 - 1996

Volume 1 - General Findings

NIWA Client Report: MFE80216
June 1998

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prepared for

Ministry for the Environment

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CONTENTS

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Executive Summary

The Lake Managers Handbook, edited by Vant (1987), recommended six variables as being indicative of the trophic state of a lake, namely; concentrations of Chlorophyll *a*, total phosphorus and total nitrogen, Secchi depth, dissolved oxygen depletion rate, and phytoplankton species and biomass. Large changes in the trophic state of a lake produce observable changes in all of these variables. Smaller changes of trophic state also produce change in these variables, but not all are observable because the changes can be too small to detect. The New Zealand Lake Monitoring Programme (LMP) set out to find how to observe, in a cost-effective way, as many of the small changes in these six variables as possible to enable development of a cheap but effective monitoring methodology for lakes.

This study developed and tested a systematic process for analysing lake monitoring data to detect whether monitored lakes were changing their trophic states or remaining stable. Firstly, the data on important variables was deseasonalised and then assessed for existence of a statistically significant trend with time, or in other words, to look for a signal of change with time in each variable. Secondly, methods were developed which enabled the trends observed separately in the different variables in a lake to be combined into two relative indicators of change. The first indicator is the average Percentage Annual Change (PAC) in the trophic state variables plus its standard error. The second indicator is the Change of Trophic State (CTS) value, with its standard error, which is a measure of the probability that a lake has changed trophic state. While these two systems of measuring change are different, they give similar results and indicate which lakes have clearly changed trophic status, which have probably changed, and which lakes have probably not changed.

Another indicator has been developed which is an absolute indicator of lake trophic level. It calculates a specific numerical value for the trophic level of a lake from the annual average chlorophyll *a*, Secchi depth, total phosphorus and total nitrogen values for the lake. This trophic level index (TLI) changes in accord with changes in the annual average values of the variables and generally reflects the changes detected by the CTS and PAC relative trophic level indicators. The TLI enables easy comparison of the trophic level of different lakes, or changes in the tropic level of a lake over time.

The results of monthly monitoring seventeen lakes from 1992 to 1996 indicate that they have changed as follows:

- 3 lakes have become less eutrophic and have improved their status. They are Omapere, Whangape, Hamilton (Rotoroa).
- 3 lakes have probably improved. They are Rotorua, Rotoiti NI and Hayes.

- 8 lakes did not really change their trophic status. They are Maratoto, Forsyth, Taharoa, Pupuke, Okataina, Tarawera, Rotokakahi, and Tutira.
- 2 lakes may be degrading and need continued monitoring. They are Alexandrina and Brunner.
- Lake Okareka is deteriorating and remedial measures need to be considered.
- Maratoto and Pupuke show some evidence of increased eutrophication and should also be monitored in the future.

Fifteen of the seventeen lakes gave significant measures of temperature increase. From 1992 to 1994 these lakes indicated a temperature rise of $0.35^{o} \pm 0.13^{o}$C per year in average lake temperature across both the North and South Islands. These lakes are not likely to continue to warm at this rate indefinitely but the nature of the warming cycle cannot be determined by this data alone.

The new method of combining trends in five different variables, as developed in this study, enables trophic state changes to be identified with greater confidence than by examining the trends in the variables separately. The assessment of the individual variables showed that total phosphorus, with 88% correct signals of change, gave the most reliable indication of trophic state change in the monitored lakes. Chlorophyll *a*, total nitrogen, Secchi depth and dissolved oxygen depletion rate gave correct signals in approximately 58% of the responses. No single variable gave a completely reliable signal. The confident assessment of trophic state change was possible if three variables gave similar, consistent indications of change, even if the changes were not large. Phytoplankton species and biomass data did not give any significant indications of change or stability in the lakes investigated, and this topic area needs further development.

The monitoring and data analysis methods used in this study were sensitive and able to detect small degrees of change; much smaller than those noticeable by the general public. For example, small improvements of about 3% per year were observed in Lake Rotoiti NI over a 4 year period. Achievement of this type of sensitivity was one of the objectives of this programme. Also, the TLI gave estimates of the rate of change in trophic level in the lakes which were found to be changing.

Draft, cost-effective lake monitoring protocols for unstratified and stratified lakes, which are based on the results of the LMP, are proposed in this report. Thus for lakes selected for monitoring, this report provides specific guidance on the location of sampling stations, sampling depths, variables, methods for analysing the samples and data, and recommendations on how to interpret the results toward specific assessments of change or stability of trophic state. The TLI enables the trophic level of lakes to be stated numerically and changes in individual lakes or groups of lakes to be reported on in a quantitative way.

Technical Summary

A lake monitoring programme (LMP) was set up whereby 26 New Zealand lakes were monitored during 1992-1996. Seventeen lakes were monitored for periods from three to four years. Two sampling stations were set up on each lake at their deeper sites with samples taken monthly from both epilimnia and hypolimnia when stratified or from two depths when isothermal. Secchi depth was measured and depth/temperature/dissolved oxygen profiles were taken for on-site identification of the thickness of the thermal layers. Samples were then taken for measurement of concentrations of Chlorophyll *a*, total phosphorus, total nitrogen, phytoplankton biomass and species. Values of dissolved nutrients, turbidity, pH and conductivity were obtained from all samples. Suspended solids concentrations in shallow lakes were also measured.

The variability in the data collected had 4 sources, namely: seasonal change, weather effects, short and long term trends. Trends which continued for 3 years or more were considered to be long term trends. The assumption was made that, over 3 years or more, weather perturbations and short term trend effects would cancel themselves out.

The first requirement for analysis of the data was to find a method to determine whether there was long term change in data containing a lot of seasonal variability. The second requirement was to express changes observed in different variables, in the same units, so as to be able to combine the results from the different variables into a single index of change. A technique to deseasonalise the data was developed from observed temperature data and then applied to the trophic state variables of Chlorophyll *a*, (Chla) Secchi depth, (SD) total phosphorus (TP) and total nitrogen (TN). A simple regression line was fitted to the deseasonalised residual data. From the slope of the regression line, it was possible to calculate change in the variables in terms of common units, namely; their *Percent Annual Change (PAC)*and their *Change of Trophic State* . The p-value of the regression line had to be less than 0.05 for the result to be used in subsequent calculations. The standard error of the slope was also determined.

The p-values of the regression slopes were used to determine Change of Trophic State (CTS) values. A positive CTS value indicates change to a more eutrophic state.

A CTS value of +3 or -3 was assigned to p-values <0.01

A CTS value of +2 or -2 was assigned to p-values between 0.01 and 0.02

A CTS value of +1 or -1 was assigned to p-values between 0.02 and 0.05

A CTS value of 0 was assigned to p-values > 0.05

CTS values were also assigned to dissolved oxygen depletion rates from the stratified lakes on a similar basis. It was possible to calculate the *average CTS value, its standard error, and p-value* for each lake from the 4 unstratified lake trophic state variables or the 5 stratified lake trophic state variables. The *average PAC value, its standard error and p-value* was also calculated for each lake from the same variables. The CTS and PAC values are sensitive relative indicators of trophic level, i.e. they can signal that small changes in trophic level have occurred.

A method to determine an absolute trophic level index value (TLI) was developed to enable calculation of a numerical value for the trophic level of a lake from its annual averages of Chla, SD, TP, and TN. This absolute TLI enables the trophic levels of fairly different types of lakes to be compared and was found to change in accord with the CTS and PAC values, the relative indicators of change.

A change of trophic state in a lake was indicated by the mean of the CTS and PAC p-values for that lake, according to the evaluation scheme shown below;

Mean p-value range	**Interpretation**
< 0.1	Definite Change
0.1 - 0.2	Probable Change
0.2 - 0.3	Possible Change
> 0.3	No Change

The p-values of each of the CTS and PAC averages for a lake had to be in the same range for a confident assessment of the type of trophic level change which had occurred.

Little information was extracted from the phytoplankton data because funding did not permit analysis of all samples collected, nor research into which New Zealand species are most indicative of eutrophic or oligotrophic conditions. More investigation into the nature of this variable is needed before it can be used as a sensitive indicator of trophic change.

Detailed results obtained from the LMP are shown in Fig. 2.1 to Fig. 27.7, and Table 2.1 to Table 27.3 in Volume 3 of this report and are discussed in Chapters 2 to 26 in Volume 2. Assessment of these results has enabled the authors of this report to propose cost-effective monitoring protocols for unstratified and stratified lakes.

GENERAL FINDINGS OF THE LAKES MONITORING PROGRAMME

PART 1 CONCEPTS OF PROGRAMME DESIGN

P1.1 Introduction

The New Zealand Lakes Water Quality Monitoring Programme (LMP) was first proposed by Smith et al. in 1989 in the report "A National Water Quality Network for New Zealand". This report was comprehensive, proposing a monitoring network for both rivers and lakes including which lakes should be sampled, how they should be sampled and how the samples should be analysed. The report initiated discussion on the possibility of carrying out a lakes monitoring programme which was started in February 1992. The sampling of the lakes ceased in June 1996 after a large database on New Zealand lakes had been generated. Inspection of the data collected and changed financial circumstances caused the LMP to be altered slightly during the data collection period.

This report on the state of some important New Zealand lakes is the first report on the LMP database. Further investigation and interpretation of the data could be carried out at a later date.

P1.2 Objectives

The objectives of the New Zealand Lakes Water Quality Monitoring Programme (LMP) were to:

- Provide a good database on the water quality in the 1990's of some of New Zealand's more important lakes.

- Use this database to develop a sensitive, cost-effective Lakes Monitoring Protocol which will enable detection of small changes in the trophic state of lakes.

P1.3 Lakes selected

A broad spectrum of lake types were sampled to enable a widely applicable monitoring methodology to be developed. However, none of the large, deep lakes were included in the programme because the funding for the LMP did not permit the expense of monitoring this type of lake. (Data from Lake Taupo has been made available by Environment Waikato to assist in the formulation of the Lakes Trophic Index.) Funding diminished as the project proceeded and the monitoring of some lakes was discontinued. The lakes which were monitored are listed in Table 1 along with the periods of their monitoring. They have been separated into two groups, (a) the unstratified or intermittently stratified lakes, and (b) the stratified lakes, because of the different limnology of the two different lake types. The lakes are listed in a north to south order within each group in Table 1. The location of each lake within New Zealand is shown in Figs. 1A,B.

P1.4 Design concepts

The Lake Managers Handbook (Vant 1987) suggests that the most informative indicators of changing trophic state are Chlorophyll *a* (Chla), Secchi depth (SD), total phosphorus (TP), total nitrogen (TN), oxygen depletion rate (HVOD), and phytoplankton species and biomass. However, these variables can vary independently from each other. For example, if in a lake phytoplankton growth is limited by phosphorus availability, total nitrogen can increase without the phytoplankton increasing their concentration. Phytoplankton species may change from those with a relatively low chloroplyll *a* content to others containing a lot of chlorophyll *a* per unit biomass, thus increasing the chlorophyll *a* content of the lake when little else has changed. Floods can bring in a lot of organic and/or inorganic matter from the catchment into a lake; the organic matter can affect the oxygen depletion rate and the inorganic matter will alter the Secchi depth, but little else in the lake.

Nevertheless, when a lake undergoes a large change in trophic state, differences are usually observed in all the variables noted above. However, a small but definite change in trophic state, will cause changes to occur in all six of the variables but may not all be observed because of short-term variability or difficulty in detecting a small degree of change. In order to develop a sensitive method of detecting change of trophic state, all six variables have been monitored and methods sought for combining this information into relative indexes of change in trophic state.

Efforts were also made to find a method to categorise the trophic state of a lake in a systematic numerical manner with each integer value of the classification scheme designating a different class of lake. The values of the trophic variables observed in the lake would be used to calculate the trophic level index value (TLI) of the monitored lakes. Further, if changes occurred in the trophic variables in a lake, the calculated TLI for that lake should change in a manner which reflected the observed changes.

Other variables were also measured as part of the programme to determine their importance in a monitoring programme; they were soluble nutrients, turbidity, conductivity and pH.

P1.5 Structure of this report

Volume 1 presents a summary of the findings of the LMP investigation. Details of the statistical methods used for the evaluation of the data are given in Volume 2, Chapter 1. There are also chapters of detailed commentary on the results of the analysis of the data on each lake and draft recommendations for monitoring strategies in Volume 2. Volume 3 contains the data, and results of analysis of the data collected on each lake. Thus this report on the "Results of Monitoring New Zealand Lakes, 1992-1996" consists of:

Volume 1: General Findings

Volume 2: Comment on Results

Volume 3: Data and Results

PART 2 SUMMARY OF FINDINGS

The results of the LMP provided a number of clear signals about change in the trophic state of the lakes monitored. These results have shown the lakes monitoring proposal of Smith et al. (1989) to be sound and have endorsed their judgement of the optimal mode to proceed with an experimental monitoring monitoring programme. It has produced data enabling development of a simple, effective monitoring methodology.

P2.1 Validation of trend detection technique

Large changes occur in lakes as a result of the seasons. These changes are more or less regular and particular attention has been paid to devising a data analysis system which removes the seasonal variability, permitting the residual, non-seasonal values in the trophic state variables to be observed. After deseasonalising, the residuals still vary as a result of factors such as weather at the time of observation. Long term trends in these residuals were determined using linear regression with a measure of their statistical significance. Since the interpretation of time trends is most important, only the results from the seventeen lakes with three or more years of data are mentioned here.

Table 2 is a summary of the temperature results. They are consistent with all the lakes reporting the same type of change; as might be expected with a climatic change operating over the whole country. The average temperature change observed was $0.35^{o} \pm 0.13^{O}C$ per year, indicating that the analytical technique used to calculate temperature trends gives consistent results. Fig. 2 shows the temperature results from Lake Rotoroa (Hamilton Lake) which indicate that the temperature increased from 1992 to 1996. There is some evidence of this pattern reversing in 1997 suggesting the start of a cooling trend. The determination of the time trend in temperature in the lakes is relatively unimportant from the point of view of changes in the trophic state of the lakes. However, it is important in that it indicates that the deseasonalising techniques used are sensitive in observing a relatively small degree of change in data which has a large annual variation. The same deseasonalising and trend analysis techniques used with the temperature data were used on Chla, SD, TP and TN data. The results from these analyses were used in three different ways to quantify change in trophic state.

P2.2 Methods for assessing Trophic State Change

P2.2.1 Percent Annual Change (PAC) value

The changes per year in each of the 4 shallow lake variables (Chla, SD, TP, TN) and the 5 stratified lake variables (the shallow lake variables plus HVOD), was determined and the percent annual change (PAC) was obtained by dividing the change per year by the long term average value for each variable. The average PAC value, standard error, plus the p-value of the average for each lake was then obtained from the individual variable values. The results are shown in Table 3. The p-value of the PAC average gives the probability that such a calculated average value could be obtained by chance, if its value was in fact zero.

P2.2.2 Change of Trophic State (CTS) value

The statistical significance of the trend of each trophic state variable with time, expressed also as a p-value (see Fig. 2), allowed a change of trophic state (CTS) value to be allocated according to the following scheme:

p-value	**CTS**
$p<0.05$	0
$0.05 \geq p > 0.02$	± 1
$0.02 \geq p > 0.01$	± 2
$p \leq 0.01$	± 3

The p-value of a trend with time quantifies the probability of observing a trend at least as large as the value calculated when there is no trend in the data.

+ denotes change to a more eutrophic state

\- denotes change to a less eutrophic state

The CTS values obtained for each variable for each lake, and their averages, standard error, and p-values of the averages are shown in Table 4. The p-value of each CTS average gives the probability that such an average could be obtained by chance, if its value were in fact zero.

The PAC values assess the magnitude of the changes in the variables (Table 3) whereas the CTS values (Table 4) assess the statistical significance of these changes.

P2.3 Trophic Level Assessment

The third method of measuring change was by using the Trophic Level Index (TLI) results from the data from the 24 lakes monitored from 1992 to 1996. The details of this development are given in Section 1.9, Volume 2, but the values defining the scheme are shown in Table 5. The system permits calculation of a trophic level equivalent for each of Chla, SD, TP and TN and their average provides the TLI for each lake for each year when annual averages of Chla, SD, TP and TN are available, as shown for the monitored lakes in Table 6. In addition, the annual average TLI values, their trends with time, standard errors and p-values are shown for the 16 lakes with annual averages for 3 or more years. (Lake Tarawera was 3 months short of a full 3 years sampling and no TLI trend was calculated for it.)

P2.4 Determination of change of Trophic Level

The determination of whether a lake has changed with time is essentially done from the results obtained for the relative indicators of change, the PAC and CTS averages. The TLI trend with time can be very informative if the trophic state variables show small but similar trends with time as is the case with Lake Okareka, but can be misleading if only one variable shows a large degree of change such as Chla in Lake Maratoto (Table 6). As a result of this instability, the CTS and PAC values are used to confirm or reject the observed TLI time trends.

The decision on whether a lake has changed over time is made by examining the mean of the CTS and PAC p-values (see Table 7). If the mean p-value is derived from 2 p-values which are essentially both in the same range of one of the ranges shown in the table below,

Mean p-value range	Interpretation
< 0.1	Definite Change
0.1 - 0.2	Probable Change
0.2 - 0.3	Possible Change
> 0.3	No Change

then a confident assessment can be made as to the likelihood of change having occurred. The TLI trend value (Table 7) gives an indication of the magnitude of change which may be occurring in lake. This calculated rate of change is confirmed or rejected by whether it is in agreement or not with the degree of change indicated by the PAC and CTS averages and their p-values. There has to be good consistency between all these values if a firm assessment of change or stability in the trophic level of a lake with time is to be made.

P2.5 Results of Trophic State Assessment

The results of monthly monitoring seventeen lakes from 1992 to 1996 (Table 7) is that they were assessed to have changed as follows:

- 3 lakes have definitely become less eutrophic and have improved. They are Omapere, Whangape, and Hamilton (Rotoroa).
- 3 lakes have probably improved. They are Rotorua, Rotoiti NI and Hayes.
- 8 lakes did not really change their trophic level. They are Maratoto, Forsyth, Taharoa, Pupuke, Okataina, Tarawera, Rotokakahi, and Tutira.
- 2 lakes may be degrading and need continued monitoring. They are Alexandrina and Brunner.
- Lake Okareka is deteriorating and needs consideration of remedial measures.
- Maratoto and Pupuke showed some evidence of increased eutrophication and should also be monitored in the future.

P2.6 Assessment of Individual Trophic State Variables

In an attempt to determine which variable was the best trophic state indicator, the CTS value of a variable was compared with the assessed change in a lake. If the indicator signalled a change in the lake which was in agreement with the assessed change in the lake, or the lack of change, then the variable was considered to have given a correct signal and was marked with an asterisk as shown in Table 8. For each variable, the number and percentage of correct signals was obtained and are shown in the bottom row of Table 8. TP is seen to give the best prediction of when a lake is changing or not changing, with a response of 88% correct signals. Chla, SD, TN were really equivalent, all giving about a 60% correct detectable response but the DO depletion rate was relatively weak giving a 50% correct response for 8 lakes but no value for Lakes Taharoa and Pupuke.

This particular analysis shows that no variable on its own can be relied on to give information which determines that a lake has changed its trophic state. When all the lake variables are considered together however, a fairly accurate assessment of whether a lake has changed its trophic state or not, can be obtained. It was found that three or more variables were required to give consistent signals to indicate a clear result about change of trophic state as determined by the average PAC and CTS values. This substantiates the hypothesis put forward in the design of the LMP.

DO depletion rates are difficult to calculate accurately from monthly monitoring data, for the reasons discussed by Burns (1995). The calculations are complex and require excellent data. Further investigation is required to determine the optimum methods for calculating HVOD rates.

P2.7 Investigative or strictly monitoring routines? What variables should be measured?

The question of whether to take samples for dissolved nutrients in the epilimnion or whether to take any hypolimnion samples, needs to be raised. Since only epilimnetic Chla, SD, TP, TN and hypolimnetic dissolved oxygen profile values are used in calculating CTS, PAC and TLI values it could be argued that these are the only parameters that should be sampled and analysed. This is a valid proposition if the nature of a lake is well understood from previous sampling of epilimnetic soluble nutrients and hypolimnetic sampling of total and soluble nutrients. Until a lake is well understood, there should be an element of investigative as well as monitoring sampling, in a monitoring program. Unless there is some understanding of the limnology of a lake, changes observed from a strictly limited monitoring program could be difficult to interpret. Dissolved nutrient concentrations, besides having value in themselves, enable calculations of TON and Pdiff values which are more directly related to the organic particles in a lake than are TN and TP values and can aid in interpreting the TN and TP data. A careful cost/benefit analysis should be done for each lake to determine optimal sampling programs when setting up monitoring investigations.

The valuable information obtained from the macrophyte surveys of Champion et al. (1995, 1996) clearly indicates that macrophyte surveys should be part of shallow lake monitoring programmes.

Other cost/benefit issues to consider are whether to analyse for suspended sediment, turbidity, pH and conductivity. Turbidity data from hypolimnion samples occasionally gave an indication of when bottom stirring occurred, but generally did not give a great deal more information than that available from the SD data. Suspended sediment analyses provided useful background information in unstratified lakes, but again much of the information obtained from suspended sediment data could be obtained from a careful analysis of SD data. Also, little use has been made of the pH and EC data which has been collected, in spite of there being some quite clear trends with time in some of this data.

Phytoplankton species and biomass data is customarily used in determining change of trophic state. This data was collected in the LMP, but the initial analyses of it, displayed in Volume 3, revealed no definitive information on change of trophic state, even for Lake Omapere which showed the greatest degree of change of all the lakes monitored. This was the reason why phytoplankton species and biomass was not used as a trophic state indicator as envisaged in the design of the LMP. Phytoplankton species and biovolume could be sensitive indicators of change but more research needs to be done on relating specific species to eutrophic or oligotrophic conditions. Appropriate statistical procedures would also have to be devised to discern trends in the data. Unfortunately, funding did not permit this research to be done within the LMP.

P2.8 Detailed Results

Volume 1 has provided a summary of the findings of the LMP. However, this was a large study and there is much more valuable information in the detailed results in Volumes 2 and 3. Any person interested in any of the lakes studied in the LMP would gain a deeper understanding of those lakes and New Zealand lakes in general, by inspecting the information presented in these Volumes 2 and 3.

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Fig. 1A: Lakes monitored in the North Island as part of the Lakes Monitoring Program (Lake Taupo was not monitored).

Fig. 1B: Lakes monitored in the South Island as part of the Lakes Monitoring Program (Lake Coleridge was not monitored).

Fig. 2: Lake Rotoroa temperature data showing the drop in the residual temperatures in 1997.

Table 1: Lakes sampled as part of the New Zealand Lakes Water Quality Monitoring Programme.

(A) Unstratified or Intermittently Stratified Lakes

	Lake	**Period Sampled**
1	Omapere	Feb '92 to June '96
2	Whangape	Apr '92 to June '96
3	Rotoroa (Hamilton)	Mar '92 to June '96
4	Maratoto	Apr '92 to June '96
5	Rotorua	Mar '89 to June '96
6	Dudding	Feb '92 to May '94
7	Pearson	Mar '92 to June '94
8	Forsyth	Mar '92 to June '95
9	Alexandria	Apr '92 to June '95
10	Frankton Arm (Wakatipu)	Nov '92 to June '95

(B) Stratified Lakes

11	Taharoa	Feb '92 to June '96
12	Waikere	Aug '94 to June '96
13	Pupuke	Feb '92 to Apr '96
14	Rotoiti NI	Feb '92 to June '96
15	Okataina	Feb '92 to June '96
16	Okareka	Feb '92 to June '96
17	Tarawera	Oct '92 to June '95
18	Rotokakahi	Dec '92 to June '96
19	Rotoma	Nov '92 to July '93
20	Okaro	Feb '92 to Nov '92
21	Tutira	Feb '92 to June '96
22	Rotoiti SI	Feb '92 to June '94
23	Brunner	Mar '92 to June '95
24	Lady	Mar '92 to May'94
25	Tekapo	Mar '92 to Sep '92
26	Hayes	Mar '92 to June '96

Table 2: Observed trends of change with time in New Zealand lake epilimnion temperatures, Feb 1992 to June 1996.

Lake	Change in Temperature °C per year
Shallow or Intermittently Stratified Lakes	
Non-significant changes are in brackets	
Omapere	0.42
Whangape	(+0.09)
Hamilton	0.31
Maratoto	0.15
Rotorua	0.3
Pearson	0.59
Forsyth	0.64
Alexandrina	(+0.13)
Stratified Lakes	
Taharoa	0.24
Pupuke	0.33
Rotoiti NI	0.22
Okareka	0.35
Okataina	0.26
Tarawera	0.46
Rotokakahi	0.35
Tutira	0.39
Brunner	(-0.06)
Hayes	0.22
Average	**0.35**
Std. dev.	0.14

Table 3: Percent Annual Change (PAC values) in variables of lakes monitoried from 1992 to 1996.

Lake	PAC - % Annual Change					Average PAC (%/yr)	Standard Error	P-Value of PAC Average
	Chlorophyll	Secchi Depth x -1.0	Total Phosphorus	Total Nitrogen	Dissolved Oxygen Depletion			
			Shallow or Intermittently Stratified Lakes					
			(*Non-significant changes are in brackets.)					
Omapere	-55	-22.5	-37	-20.1		**-34**	8	0.02
Whangape	-21.6	-25.8	-26.3	-10.1		**-21**	3.7	0.01
Hamilton	-10.6	-4.8	-10.8	-16.8		**-11**	2.5	0.02
Maratoto	45	7.6	(+0.3)	-11		**10**	12.1	0.45
Rotorua	-10.1	insuffici-ent data	(+0)	-1.4		**-4**	3.1	0.18
Forsyth	(-4.4)	(+1.0)	(-1.6)	-18.8		**-5**	4.8	0.39
Alexandrina	(+1.4)	12.1	6.3	(-2.2)		**5**	2.9	0.21
			Stratified Lakes					
Taharoa	(-3.2)	(+1.3)	(-3.7)	(-2.0)		**0**	0	1
Pupuke	10.5	8.9	(-4.0)	-8.1		**2.8**	4.3	0.56
Rotoiti NI	(-4.5)	-3.2	-7.1	(-1.1)	-3.5	**-2.8**	1.3	0.1
Okareka	9.6	5.7	7.1	(-0.3)	(-3.8)	**4.5**	1.93	0.08
Okataina	4.7	-2.8	(+0.5)	-5.3	0	**-0.63**	1.67	0.7
Tarawera	(+1.5)	(-3.6)	(+5.5)	-19.4	(-2.7)	**3.9**	3.9	0.37
Rotokakahi	15	(-1.4)	(+0.7)	(-1.5)	-3.4	**2.3**	3.2	0.51
Tutira	(+2.2)	(-3.3)	(+0.4)	(+0)	(-4.2)	**0**	0	1
Brunner	32.2	3	(+3.5)	(+1.9)	(-3.7)	**7**	6.3	0.33
Hayes	-23.9	(-0.7)	-6.9	-3.6	(+1.6)	**-6.9**	4.4	0.19

The P-value of each PAC average gives the probability that the calculated average value could be obtained by chance, if its value were in fact zero.

Table 4: Change to Trophic State (CTS) values for variables from lakes monitored from1992 to 1996.

Lake	CTS values based on p-values (+3 to -3)					Average CTS Values	Standard Error	P-Value of CTS Average
	Chlorophyll	Secchi Depth x -1.0	Total Phosphorus	Total Nitrogen	Dissolved Oxygen Depletion			
			Shallow or Intermittently Stratified Lakes					
Omapere	-3	-3	-3	-3		**-3**	0	<0.01
Whangape	-3	-3	-3	-3		**-3**	0	<0.01
Hamilton	-2	-3	-3	-3		**-2.75**	0.25	0.02
Maratoto	3	3	0	-3		**0.75**	1.44	0.63
Rotorua	-3	insuffici-ent data	0	-3		**-2**	1	0.18
Forsyth	0	0	0	-3		**-0.75**	0.75	0.39
Alexandrina	0	3	1	0		**1**	0.71	0.25
			Stratified Lakes					
Taharoa	0	0	0	0		**0**	0	1
Pupuke	3	3	0	-3		**0.75**	1.43	0.63
Rotoiti NI	0	-3	-1	0	-3	**-1.4**	0.67	0.11
Okareka	3	3	1	0	0	**1.4**	0.68	0.11
Okataina	1	-3	0	-3	0	**-1**	0.84	0.3
Tarawera	0	0	0	-3	0	**-0.6**	0.6	0.38
Rotokakahi	3	*	0	0	-1	**0.4**	2.3	0.59
Tutira	0	*	0	0	0	**0**	0	1
Brunner	3	3	0	0	0	**1.2**	0.73	0.18
Hayes	-3	0	-3	-3	0	**-1.8**	0.73	0.07

The P-value of each CTS average gives the probability that such a calculated average value could be obtained by chance, if its value were in fact zero.

Table 5: Values of variables which define the boundaries of different Trophic Levels.

Lake Type	Trophic Level	Chla (mg/m3)	Secchi Depth (m)	TP (mg P/m3)	TN (mg N/m3)
Ultra-microtrophic	0.0 - 0.9	0.13 - 0.33	33 - 25	0.84 - 1.8	10.0 - 22
Microtrophic	1.0 to 1.9	0.33 - 0.82	25 -15	1.8 - 4.1	22 - 46
Oligotrophic	2.0 to 2.9	0.82 - 2.0	15 - 7.0	4.1 - 9.0	46 - 99
Mesotrophic	3.0 to 3.9	2.0 - 5.0	7.0 - 2.8	9.0 - 20	99 - 213
Eutrophic	4.0 to 4.9	5.0 - 12	2.8 - 1.1	20 - 43	213 - 458
Supertrophic	5.0 to 5.9	12 - 31.0	1.1 - 0.4	43 - 96	458 - 984
Hypertrophic	6.0 to 6.9	>31	<0.4	>96	>984

Table 6: Annual averages, Trophic Level Index values, and TLI trends with time for 24 New Zealand lakes.

LAKE	LAKE	Chla (mg/m3)	SD (m)	TP (mgP/m3)	TN (mg/m3)	TLc	TLs	TLp	TLn	TLI Average	Std. Err. TL av	TLI trend units/yr	Std. Err. TLI trend
Omapere	Feb'92-Jan'93	33.52	0.25	104.9	863	6.09	6.45	6.10	5.23	**5.97**	**0.26**		
Omapere	Feb'93-Jan'94	14.66	0.62	66.0	651	5.18	5.56	5.51	4.86	**5.28**	**0.16**		
Omapere	Feb'94-Jan'95	3.47	1.11	25.5	360	3.59	4.97	4.31	4.08	**4.24**	**0.29**		
Omapere	Feb'95-Jan'96	8.32	0.99	33.4	507	4.56	5.09	4.65	4.53	**4.71**	**0.13**		
Omapere	***Averages***	***14.99***	***0.74***	***57.4***	***595***	***4.86***	***5.52***	***5.14***	***4.68***	***5.05***	***0.19***	***-0.48***	***0.22***
Taharoa	Feb'92-Jan'93	1.33	9.84	4.0	160	2.53	2.57	1.98	3.02	**2.53**	**0.21**		
Taharoa	Feb'93-Jan'94	1.05	9.36	4.4	183	2.27	2.63	2.08	3.20	**2.55**	**0.25**		
Taharoa	Feb'94-Jan'95	0.95	8.36	5.2	142	2.16	2.78	2.30	2.86	**2.53**	**0.17**		
Taharoa	Feb'95-Jan'96	1.02	8.66	4.0	187	2.24	2.73	1.98	3.23	**2.54**	**0.28**		
Taharoa	***Averages***	***1.09***	***9.06***	***4.4***	***168***	***2.30***	***2.68***	***2.08***	***3.08***	***2.54***	***0.10***	***0.001***	***0.005***
Waikere	Aug'94-Jun'95	1.22	10.43	4.5	154	2.44	2.49	2.13	2.98	**2.51**	**0.18**		
Waikere	Aug'95-Jun'96	2.22	7.62	10.0	198	3.10	2.89	3.13	3.30	**3.11**	**0.08**		
Waikere	***Averages***	***1.72***	***9.03***	***7.3***	***176***	***2.77***	***2.69***	***2.63***	***3.14***	**2.81**	**0.11**		
Pupuke	Apr'92-Mar'93	6.81	6.23	11.3	276	4.34	3.13	3.28	3.74	**3.62**	**0.27**		
Pupuke	apr'93-Mar'94	4.74	5.81	11.5	251	3.94	3.21	3.30	3.61	**3.52**	**0.16**		
Pupuke	Apr'94-Mar'95	5.67	5.55	10.7	209	4.13	3.26	3.21	3.37	**3.50**	**0.22**		
Pupuke	Apr'95-Mar'96	7.48	5.01	10.7	225	4.44	3.38	3.21	3.47	**3.63**	**0.28**		
Pupuke	***Averages***	***6.18***	***5.65***	***11.0***	***241***	***4.21***	***3.25***	***3.25***	***3.55***	***3.56***	***0.11***	***0.001***	***0.037***
Whangape	Apr'92-Mar'93	37.01	0.39	92.0	979	6.20	6.01	5.93	5.39	**5.88**	**0.17**		
Whangape	Apr'93-Mar'94	29.17	0.35	106.5	986	5.94	6.13	6.12	5.40	**5.90**	**0.17**		
Whangape	Apr'94-Mar'95	18.65	0.51	47.6	718	5.45	5.76	5.10	4.99	**5.32**	**0.17**		
Whangape	Apr'95-Mar'96	10.94	0.75	43.6	773	4.86	5.37	4.99	5.08	**5.07**	**0.11**		
Whangape	***Averages***	***23.94***	***0.50***	***72.4***	***864***	***5.61***	***5.81***	***5.54***	***5.22***	***5.54***	***0.12***	***-0.301***	***0.08***

TLc is the trophic level value calculated from the Chla annual average

TLs is the trophic level value calculated from the Secchi depth annual average.

TLp is the trophic level value calculated from the Total Phosphorus annual average.

TLn is the trophic level value calcuated from the Total Nitrogen annual average.

LAKE	LAKE	Chla (mg/m3)	SD (m)	TP (mgP/m3)	TN (mg/m3)	TLc	TLs	TLp	TLn	TLI Average	Std. Err. TL av	TLI trend units/yr	Std. Err. TLI trend
Rotoroa	Apr'92-Mar'93	23.39	0.89	33.2	1216	5.70	5.20	4.64	5.68	**5.30**	**0.25**		
Rotoroa	Apr'93-Mar'94	14.26	1.14	25.4	1107	5.15	4.94	4.31	5.55	**4.99**	**0.26**		
Rotoroa	Apr'94-Mar'95	15.98	1.09	28.8	763	5.28	4.98	4.46	5.07	**4.95**	**0.17**		
Rotoroa	Apr'95-Mar'96	12.35	1.09	21.1	722	4.99	4.98	4.07	4.99	**4.76**	**0.23**		
Rotoroa	***Averages***	***16.50***	***1.05***	***27.1***	***952***	***5.28***	***5.03***	***4.37***	***5.32***	***5.00***	***0.11***	***-0.17***	***0.035***
Maratoto	Apr'92-Mar'93	13.90	0.77	28.3	1517	5.12	5.34	4.44	5.96	**5.22**	**0.31**		
Maratoto	Apr'93-Mar'94	9.45	0.64	31.7	2194	4.70	5.52	4.59	6.45	**5.31**	**0.43**		
Maratoto	Apr'94-Mar'95	43.96	0.71	32.1	1241	6.39	5.42	4.60	5.70	**5.53**	**0.37**		
Maratoto	Apr'95-Mar'96	61.20	0.56	29.0	1211	6.76	5.66	4.47	5.67	**5.64**	**0.47**		
Maratoto	***Averages***	***32.13***	***0.67***	***30.3***	***1541***	***5.74***	***5.49***	***4.53***	***5.95***	***5.43***	***0.18***	***0.15***	***0.017***
Rotorua	Sep'94-Jul'95	8.82	3.15	41.6	290	4.62	3.89	4.93	3.80	**4.31**	**0.28**		
Rotorua	Aug'95-Jun'96	11.10	2.76	33.7	304	4.87	4.03	4.66	3.86	**4.36**	**0.24**		
Rotorua	***Averages***	***9.96***	***2.96***	***37.6***	***297***	***4.75***	***3.96***	***4.80***	***3.83***	***4.33***	***0.48***		
Okataina	Jun'92-Jun'93	1.28	10.55	6.9	93	2.49	2.48	2.66	2.32	**2.49**	**0.07**		
Okataina	Jul'93-Jul'94	1.69	10.88	6.4	83	2.80	2.43	2.55	2.17	**2.49**	**0.13**		
Okataina	Jul'94-Jun'95	1.60	11.58	8.3	85	2.74	2.35	2.89	2.20	**2.55**	**0.16**		
Okataina	Jul'95-Jun'96	1.97	10.23	7.1	88	2.97	2.52	2.69	2.24	**2.60**	**0.15**		
Okataina	***Averages***	***1.64***	***10.81***	***7.1***	***87***	***2.75***	***2.44***	***2.70***	***2.23***	***2.53***	***0.24***	***0.039***	***0.01***
Rotoiti NI	Mar'92-Feb'93	5.67	6.14	20.4	197	4.13	3.15	4.03	3.30	**3.65**	**0.25**		
Rotoiti NI	Mar'93-Feb'94	5.17	5.48	22.7	196	4.03	3.28	4.16	3.29	**3.69**	**0.24**		
Rotoiti NI	Mar'94-Feb'95	4.52	6.47	22.2	160	3.88	3.09	4.14	3.03	**3.53**	**0.28**		
Rotoiti NI	Mar'95-Feb'96	4.32	6.68	20.3	194	3.83	3.05	4.02	3.27	**3.55**	**0.23**		
Rotoiti NI	***Averages***	***4.92***	***6.19***	***21.4***	***187***	***3.97***	***3.14***	***4.09***	***3.22***	***3.61***	***0.11***	***-0.046***	***0.027***
Rotokakahi	Dec'92-Nov'93	2.09	6.76	11.5	171	3.03	3.03	3.30	3.11	**3.12**	**0.06**		
Rotokakahi	Jan'94-Dec'94	2.23	7.70	14.9	143	3.10	2.88	3.63	2.88	**3.12**	**0.18**		
Rotokakahi	Jan'95-Dec'95	2.51	7.42	13.8	157	3.24	2.92	3.54	3.00	**3.17**	**0.14**		
Rotokakahi	***Averages***	***2.28***	***7.29***	***13.4***	***157***	***3.12***	***2.94***	***3.49***	***3.00***	***3.14***	***0.07***	***0.025***	***0.14***

LAKE	LAKE	Chla (mg/m3)	SD (m)	TP (mgP/m3)	TN (mg/m3)	TLc	TLs	TLp	TLn	TLI Average	Std. Err. TL av	TLI trend units/yr	Std. Err. TLI trend
Tarawera	Jan'93-Dec'93	1.18	9.03	9.0	77	2.40	2.68	3.00	2.07	**2.54**	**0.20**		
Tarawera	Jan'94-Dec'94	1.13	10.11	12.3	77	2.35	2.53	3.39	2.07	**2.59**	**0.28**		
Tarawera	***Averages***	***1.16***	***9.57***	***10.7***	***77***	***2.38***	***2.61***	***3.20***	***2.07***	***2.56***	***0.16***		
Okareka	Jul'92-Jun'92	1.84	9.88	6.1	175	2.89	2.56	2.50	3.14	**2.77**	**0.15**		
Okareka	Jul'93-Jul'94	1.90	9.36	6.3	175	2.93	2.63	2.55	3.14	**2.81**	**0.14**		
Okareka	Jul'94-Jun'95	2.67	8.22	8.9	170	3.30	2.80	2.98	3.11	**3.05**	**0.11**		
Okareka	Jul'95-Jun'96	2.58	7.70	7.4	184	3.27	2.88	2.75	3.21	**3.02**	**0.13**		
Okareka	***Averages***	***2.25***	***8.79***	***7.2***	***176***	***3.10***	***2.72***	***2.69***	***3.15***	***2.91***	***0.27***	***0.1***	***0.035***
Taupo	Oct'94-Sep'95C	0.66	14.60	4.0	83	1.76	2.01	1.97	2.16	**1.98**	**0.08**		
Taupo	Oct'95-Sep'96	0.53	14.60	4.8	79	1.52	2.01	2.20	2.10	**1.96**	**0.15**		
Taupo	Oct'96-Sep'97	0.70	14.60	5.3	84	1.83	2.01	2.32	2.18	**2.08**	**0.11**		
Taupo	***Averages***	***0.62***	***14.60***	***5.0***	***82***	***1.70***	***2.01***	***2.16***	***2.15***	***2.01***	***0.06***	***0.05***	***0.04***
Tutira	Mar'92-Feb'93	4.39	3.49	17.5	316	3.85	3.78	3.83	3.92	**3.84**	**0.03**		
Tutira	Mar'93-Feb'94	5.49	3.46	17.5	316	4.10	3.79	3.83	3.92	**3.91**	**0.07**		
Tutira	Mar'94-Feb'95	5.02	3.40	15.6	281	4.00	3.81	3.69	3.76	**3.81**	**0.07**		
Tutira	Mar'95-Feb'96	3.69	4.00	16.2	314	3.66	3.63	3.73	3.91	**3.73**	**0.06**		
Tutira	***Averages***	***4.65***	***3.59***	***16.7***	***307***	***3.90***	***3.75***	***3.77***	***3.87***	***3.82***	***0.03***	***0.043***	***0.027***
Dudding	Mar'92-Feb'93	3.89	2.22	43.4	1000	3.72	4.26	4.98	5.42	**4.60**	**0.38**		
Dudding	Feb'93-Mar'94	5.94	1.99	39.4	817	4.19	4.37	4.86	5.16	**4.64**	**0.22**		
Dudding	***Averages***	***4.91***	***2.10***	***41.4***	***908***	***3.95***	***4.32***	***4.92***	***5.29***	***4.62***	***0.20***		
Rotoiti SI	Apr'92-Mar'94	1.25	7.61	3.9	55	2.47	2.89	1.94	1.63	**2.23**	**0.28**		
Rotoiti SI	May'93-Apr'94	0.92	9.83	4.4	61	2.13	2.57	2.08	1.76	**2.13**	**0.17**		
Rotoiti SI	***Averages***	***1.09***	***8.72***	***4.1***	***58***	***2.30***	***2.73***	***2.01***	***1.70***	***2.18***	***0.15***		
Brunner	May'92-Jun'93	0.84	6.71	5.3	131	2.03	3.04	2.33	2.76	**2.54**	**0.23**		
Brunner	Aug'94-Jun'95	1.39	5.59	5.5	135	2.58	3.25	2.37	2.80	**2.75**	**0.19**		
Brunner	Aug'93-Jun'94	0.95	6.18	6.3	133	2.16	3.14	2.54	2.78	**2.65**	**0.21**		
Brunner	***Averages***	***1.06***	***6.16***	***5.7***	***133***	***2.26***	***3.15***	***2.41***	***2.78***	***2.65***	***0.11***	***0.055***	***0.09***

LAKE	LAKE	Chla (mg/m3)	SD (m)	TP (mgP/m3)	TN (mg/m3)	TLc	TLs	TLp	TLn	TLI Average	Std. Err. TL av	TLI trend units/yr	Std. Err. TLI trend
Lady	Aug'92-Jun'93	1.11	3.10	8.9	184	2.34	3.91	2.98	3.21	**3.11**	**0.32**		
Lady	Aug'93-Jun'94	1.04	3.09	10.7	208	2.26	3.91	3.21	3.36	**3.19**	**0.34**		
Lady	***Averages***	***1.08***	***3.10***	***9.8***	***196***	***2.30***	***3.91***	***3.09***	***3.29***	***3.15***	***0.22***		
Alexandrina	Apr'92-Mar'93	3.17	6.23	12.4	208	3.49	3.13	3.40	3.37	**3.35**	**0.08**		
Alexandrina	Apr'93-Mar'94	1.75	8.86	9.7	210	2.84	2.70	3.10	3.38	**3.00**	**0.15**		
Alexandrina	Apr'94-Mar'95	2.71	5.80	10.7	192	3.32	3.21	3.22	3.26	**3.25**	**0.02**		
Alexandrina	***Averages***	***2.54***	***6.96***	***11.0***	***203***	***3.22***	***3.02***	***3.24***	***3.34***	***3.20***	***0.07***	***-0.05***	***0.17***
Pearson	Mar'92-Feb'93	0.74	6.02	6.2	132	1.88	3.17	2.52	2.77	**2.59**	**0.27**		
Pearson	Mar'93-Feb'94	0.95	5.67	7.9	117	2.16	3.24	2.83	2.62	**2.71**	**0.22**		
Pearson	***Averages***	***0.84***	***5.84***	***7.0***	***125***	***2.02***	***3.20***	***2.67***	***2.70***	***2.65***	***0.16***		
Forsyth	Apr'92-Mar'93	17.90	0.81	89.9	806	5.40	5.28	5.90	5.14	**5.43**	**0.17**		
Forsyth	Apr'93-Mar'94	23.80	0.66	90.1	909	5.72	5.49	5.91	5.30	**5.60**	**0.13**		
Forsyth	Apr'94-Mar'95	14.10	1.36	105.3	502	5.14	4.76	6.10	4.52	**5.13**	**0.35**		
Forsyth	***Averages***	***18.60***	***0.94***	***95.1***	***739***	***5.42***	***5.18***	***5.97***	***4.98***	***5.39***	***0.14***	***-0.15***	***0.18***
Hayes	Aug'92-Jun'93	10.91	3.23	33.8	430	4.86	3.86	4.67	4.32	**4.43**	**0.22**		
Hayes	Aug'93-Jun'94	5.51	3.82	33.7	422	4.10	3.68	4.66	4.29	**4.18**	**0.20**		
Hayes	Aug'94-Jun'95	5.59	3.46	30.0	384	4.12	3.79	4.51	4.17	**4.15**	**0.15**		
Hayes	Aug'95-Jun'96	6.39	3.34	29.0	376	4.27	3.83	4.47	4.14	**4.18**	**0.14**		
Hayes	***Averages***	***7.10***	***3.46***	***31.6***	***403***	***4.34***	***3.79***	***4.58***	***4.23***	***4.23***	***0.34***	***-0.08***	***0.045***
Wakatipu	May'93-Apr'94	0.44	10.98	4.2	69	1.32	2.42	2.02	1.93	**1.92**	**0.23**		
Wakatipu	May'94-Apr'95	0.40	8.51	7.2	70	1.20	2.75	2.71	1.95	**2.15**	**0.37**		
Frankton Arm	***Averages***	***0.42***	***9.74***	***5.7***	***70***	***1.26***	***2.59***	***2.37***	***1.94***	***2.04***	***0.20***		
Averages						3.66	3.67	3.66	3.66				

Table 7: Assessment of Lake Trophic Level and change of Trophic Level with time.

Lake	Average CTS Values	P-Value of CTS Average	Average PAC (%/yr)	P-Value of PAC Average	Mean P-Value	Assessment From mean P-values	Trophic Level Index Value	TLI Trend (levels/yr)	TLI Trend *TRUE or NOT*	LAKE TYPE
						Unstratified Lakes				
Omapere	**-3**	<0.01	**-34**	0.02	**0.01**	**Improved**	4.7 ± 0.1	-0.48 ± 0.22	**TRUE**	Eutrophic
Whangape	**-3**	<0.01	**-21**	0.01	**0.01**	**Improved**	5.1 ± 0.1	-0.30 ± 0.08	**TRUE**	Supertrophic
Hamilton	**-2.75**	0.02	**-11**	0.02	**0.02**	**Improved**	4.8 ± 0.2	-0.17 ± 0.04	**TRUE**	Eutrophic
Maratoto	**0.75**	0.63	**10**	0.45	**0.54**	**No Change**	5.4 ± 0.2	-0.15 ± 0.02	**Not True**	Supertrophic
Rotorua	**-2**	0.18	**-4**	0.18	**0.18**	**Probable Improvement**	4.3 ± 0.5			Eutrophic
Forsyth	**-0.75**	0.39	**-5**	0.39	**0.39**	**No Change**	5.4 ± 0.1	-0.15 ± 0.18	**No Trend**	Supertrophic
Alexandrina	**1**	0.25	**5**	0.21	**0.23**	**Possible Deterioration**	3.2 ± 0.1	-0.05 ± 0.17	**No Trend**	Mesotrophic
						Stratified Lakes				
Taharoa	**0**	1	**0**	1	**1**	**No Change**	2.54 ± 0.1	0.00 ± 0.00	**No Trend**	Oligotrophic
Pupuke	**0.75**	0.63	**2.8**	0.56	**0.59**	**No Change**	3.6 ± 0.1	-0.01 ± 0.04	**No Trend**	Mesotrophic
Rotoiti NI	**-1.4**	0.11	**-2.8**	0.1	**0.1**	**Probable Improvement**	3.6 ± .1	-0.05 ± 0.03	**TRUE**	Mesotrophic
Okareka	**1.4**	0.11	**4.5**	0.08	**0.09**	**Deterioration**	3.0 ± 0.1	0.1 ± 0.04	**TRUE**	Meso/Oligotrophic
Okataina	**-1**	0.3	**-0.63**	0.7	**0.5**	**No change**	2.5 ± 0.2	-0.04 ± 0.01	**Not True**	Oligotrophic
Tarawera	**-0.6**	0.38	**3.9**	0.37	**0.4**	**No Change**	2.6 ± 0.2			Oligotrophic
Rotokakahi	**0.4**	0.59	**2.3**	0.51	**0.54**	**No Change**	3.1 ± 0.1	-0.03 ± 0.14	**No Trend**	Mesotrophic
Tutira	**0**	1	**0**	1	**1**	**No Change**	3.8 ± 0.03	0.04 ± 0.03	**Not True**	Mesotrophic
Brunner	**1.2**	0.18	**7**	0.33	**0.26**	**Possible Deterioration**	2.7 ± 0.1	-0.06 ± 0.09	**No trend yet**	Oligotrophic
Hayes	**-1.8**	0.07	**-6.9**	0.19	**0.13**	**Probable Improvement**	4.2 ± 0.1	-0.08 ± 0.05	**TRUE**	Eutrophic

The guide used in the mean P-value evaluation is;

P-value range	***Interpretation***
< 0.1	***Definite change***
0.1 - 0.2	***Probable change***
0.2 - 0.3	***Possible change***
> 0.3	***No change***

The P-value of each CTS and PAC average gives the probability that such calculated average values could be obtained by chance, if their values were in fact zero.

Table 8: Comparison of Change of Trophic State results from assessment of all variables with signals from individual variables. (*Variables giving correct signals are asterisked)

Lake	CTS values based on p-values (+3 to -3)					Average CTS Values	Standard Error	P-Value of CTS Average	Assessment of Change
	Chlorophyll	Secchi Depth x -1.0	Total Phosphorus	Total Nitrogen	Dissolved Oxygen Depletion				
			Shallow or Intermittently Stratified Lakes						
			*Variables giving correct signals are asterisked						
Omapere	*-3	*-3	*-3	*-3		**-3**	0	<0.01	**Improved**
Whangape	*-3	*-3	*-3	*-3		**-3**	0	<0.01	**Improved**
Hamilton	*-2	*-3	*-3	*-3		**-2.75**	0.25	0.02	**Improved**
Maratoto	3	3	*0	-3		**0.75**	1.44	0.63	**No Change**
Rotorua	*-3	insufficient data	0	*-3		**-2**	1	0.18	**Probable Improvement**
Forsyth	*0	*0	*0	-3		**-0.75**	0.75	0.39	**No Change**
Alexandrina	*0	3	1	*0		**1**	0.71	0.25	**Possible Deterioration**
			Stratified Lakes						
Taharoa	*0	*0	*0	*0		**0**	0	1	**No Change**
Pupuke	3	3	*0	-3		**0.75**	1.43	0.63	**No Change**
Rotoiti NI	0	*-3	*-1	0	*-3	**-1.4**	0.67	0.11	**Probable Improvement**
Okareka	*3	*3	*1	0	0	**1.4**	0.68	0.11	**Probable Deterioration**
Okataina	1	-3	*0	-3	*0	**-1**	0.84	0.3	**Probably, no change**
Tarawera	*0	*0	*0	-3	*0	**-0.6**	0.6	0.38	**No Change**
Rotokakahi	3	*0	*0	*0	-1	**0.4**	2.3	0.59	**No Change**
Tutira	*0	*0	*0	*0	*0	**0**	0	1	**No Change**
Brunner	3	3	*0	*0	*0	**1.2**	0.73	0.18	**Possible change**
Hayes	*-3	0	*-3	*-3	0	**-1.8**	0.73	0.07	**Probable Improvement**
Number of correct signals from variable*	**11**	**10**	**15**	**10**	**4**				
Percentage correct signals from variable	65%	59%	88%	59%	50%				

The P-value of each CTS avarage gives the probability that such a calculated average value could be obtained by chance, if its value were in fact zero.