VARIABILITY OF PHYSICAL AND BIOLOGICAL PARAMETERS IN LAKE TAUPO: BIO-FISH SURVEY 2004-5

CBER Contract Report 75

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Introduction

This project was initiated by the Lakes and Waterways Action Group (LWAG) in response to declining water quality of Lake Taupo (Gibbs, 2004). Information was sought on variability of physical and biological parameters across different parts of the lake particularly in relation to use of only one profiling site (Station A) or three profiling sites (Stations A, B and C) used in previous studies (e.g. Gibbs, 2004). Furthermore, the Taupo District Council (TDC) has a concern that some taste and odour problems (e.g. geosmin) experienced in its water supply may be due to cyanobacteria that accumulate in the near-shore region where water supply intakes are located. The TDC also sought information about variability of phytoplankton biomass across Lake Taupo.

The objective of this study was to carry out a series of BIO-FISH transects of Lake Taupo, to observe the variability of temperature, chlorophyll *a*, dissolved oxygen and conductivity.

Methods

'BIO-FISH' runs were conducted on 5 occasions between 16 December 2004 and 8 June 2005. A map of the path of the runs on Lake Taupo is shown in Figure 1. The BIO-FISH is an underwater measuring system with PC software that a user directs to control the depth of immersion of a multi-sensor probe towed by boat (Figure 2). The system consists of the multi-sensor probe, a steering motor, winch, power supply interface and computer. The depth of the equipment is positioned with 'wings' on the probe and by altering the speed of the boat. The multi-sensor probe is equipped with 7 sensors which measure water depth, temperature, conductivity, dissolved oxygen, chlorophyll fluorescence, light transmittance and incoming (planar) photosynthetically active radiation (PAR) at 4 Hz. Data are registered on a computer together with Global Positioning System longitudinal and latitudinal positions and depth from an echo sounding.

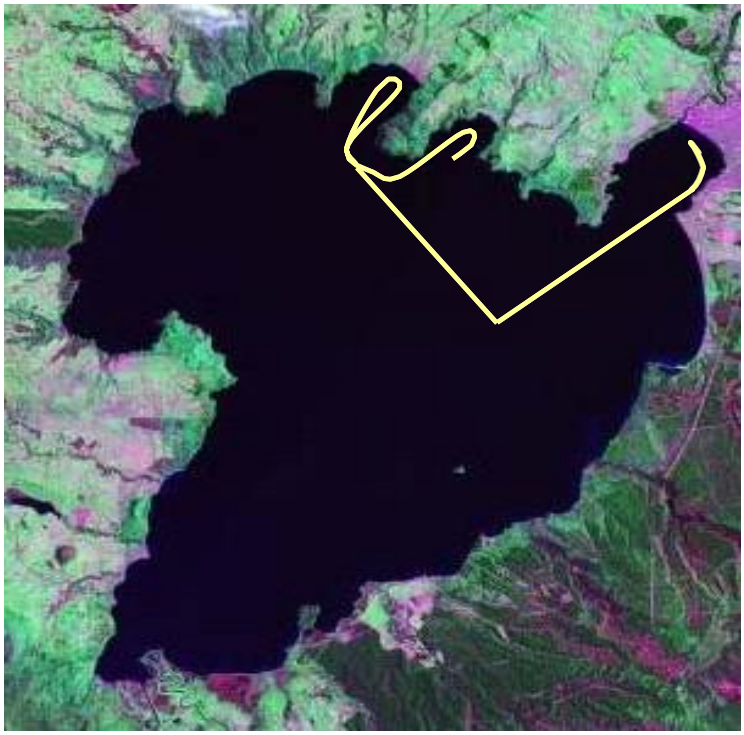

Figure 1. Map of Lake Taupo showing path of BIO-FISH run (light line), starting near Taupo township. Right-angle change of path in middle of lake is at Station A. Total path length is approximately 43 km.

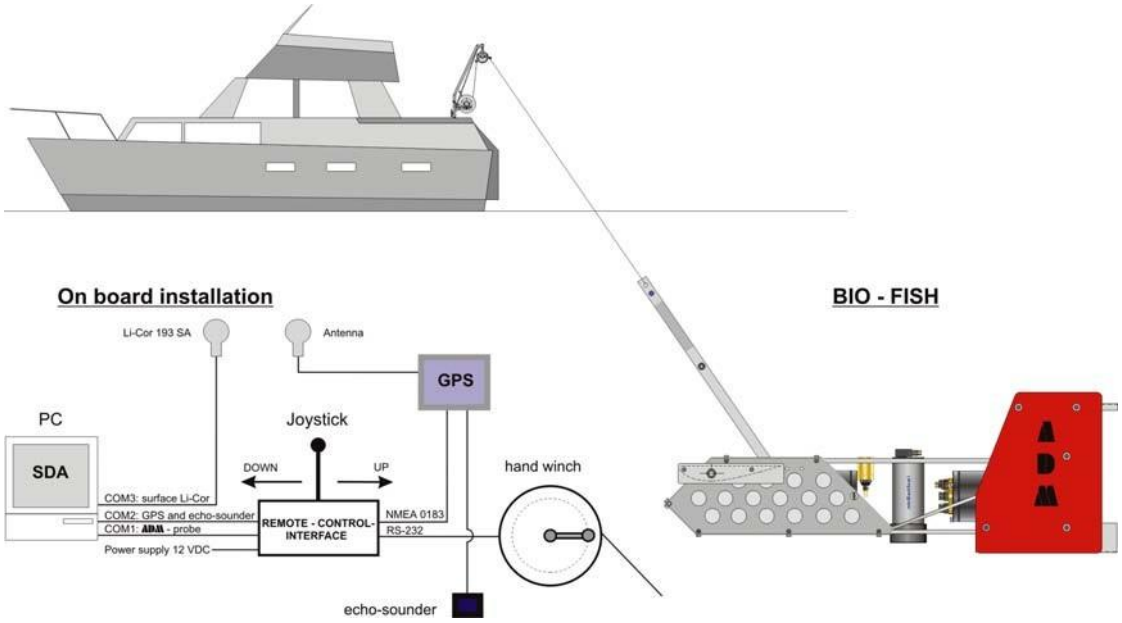

Figure 2. Boat and on-board and underwater set up of BIO-FISH. Note: not to scale (underwater instrument approximately 80 cm in length).

Table 1. BIO-FISH sensor details.

Probe	Manufacturer	Resolution	Accuracy	Response time
Pressure	Keller	0.01 dBar	± 0.1 % FS	20 ms
Temperature	ADM-Elektronik	0.001 °C	± 0.01 °C	20 ms
Conductivity	ADM-Elektronik	0.001 mS/cm	± 0.01 mS cm^{-1}	50 ms
Dissolved oxygen	AMT Analysenmeßtechnik GmbH	0.1 % saturation	1.5 % of saturation	c. 200 ms
Transmissiometer	ADM-Elektronik	0.01 %	1 %	50 ms
Fluorometer	Dr. Haardt Optik Mikroelektronik miniBackScat	0.05 µg L^{-1}	Not quantified	150 ms
Photosynthetically active radiation	Li-Cor 192 SA	Not quantified	± 5 % reading	Not quantified

BIO-FISH data collected on PC were processed using Ocean Data View software in order to generate colour 'curtains' of the data from the temperature, dissolved oxygen, conductivity, transmissiometer and fluorometer probes. The curtain scale dimensions are presented as a distance from commencement of recording (horizontal axis starting adjacent to the Harbour Master's Office) and depth (vertical axis).

Readings from the BIO-FISH were validated in a number of ways. Conductivity-temperature-depth profiles that also included beam transmittance, fluorescence and PAR, were taken with a Sea-Bird 'CTD' (referred to hereafter as CTD profiles) at up to three sites during the BIO-FISH runs. These data were used to 'calibrate' the temperature, dissolved oxygen, fluorometer and conductivity probes by making small adjustments to all the BIO-FISH readings obtained during the sampling day. The use of the the CTD in this mode was considered to provide a good cross-check on the validity of the BIO-FISH readings.

In addition, we made comparisons of University of Waikato (UoW) CTD data with CTD data collected as part of Environment Waikato's "Lake Taupo long-term monitoring programme" undertaken by NIWA. The NIWA CTD is a Richard Brancker Research XR420f equipped with a Yellow Springs Instrument 7390 DO sensor and a Seapoint Chlorophyll Fluorometer. Comparisons made at Station A (Figure 1) included data separated by not more than a few days. No adjustments were made to temperature or dissolved oxygen readings as a result of these comparisons. Conductivity readings from the UoW CTD were consistently slightly lower than the NIWA readings and it was decided for consistency, to adjust the UoW CTD and Bio-Fish readings to match those of the NIWA CTD. Comparisons of fluorescence between the two CTDs reflected differences in the type of probe and their respective settings. Previous comparisons of solvent-extracted chlorophyll *a* from grab samples at discrete depths against UoW CTD fluorescence (Ryan et al., 2005) give a 1:1 relationship between chlorophyll *a* in units of $\mu g\ L^{-1}$ and fluorescence output in mV, with a correlation coefficient c. 0.8. However, the UoW BIO-FISH runs and CTD profiles of fluorescence were equated to chlorophyll *a* concentration based on NIWA CTD fluorescence profiles adjusted to chlorophyll *a* concentration (Appendix 1).

Results

Figure 3 shows the BIO-FISH depth profile for the entire BIO-FISH transect, where 0 km denotes the start of the run from near the Taupo township (refer to Fig. 1). The depth of most 'dives' was 40 to 50 m. Due to a malfunction of the BIO-FISH, runs were incomplete on 16-12-04 and 24-03-05. In addition, there are reliable data for dissolved oxygen only for the run on 8-06-05. There are, however, CTD profile data for all dates (not all presented here) and comparisons are available of profile data taken by the NIWA and UoW CTDs on days separated by relatively brief intervals, i.e., not more than 4 days. There was excellent reproducibility of results between temperature, dissolved oxygen and conductivity for the two independent sets of CTD profiles (Appendix 1). The chlorophyll fluorescence data were more variable, most likely due to calibration of fluorescence to chlorophyll *a*, variations in irradiance that affected comparisons in the surface 20 m (i.e. due to 'quenching' of fluorescence), and the inherent temporal variability of chlorophyll *a* profiles that contributed to variations in intervals separating each comparison of the profiles. The calibration of fluorescence to chlorophyll *a* was based on NIWA data when several grab samples were analysed for solvent-extractable chlorophyll *a* at the same time as a CTD profile was taken (Appendix 2). UoW BIO-FISH and CTD fluorescence profiles were then adjusted to match those of the calibrated NIWA data.

Temperature in Lake Taupo from the BIO-FISH runs differs widely between the 5 days sampled by UoW, reflecting the inherent seasonality (Figure 4). There is strong variability in thermocline depth across the lake on the first two sample days, 16-12-04 and 21-01-05, which most likely reflects the propagation of internal waves along the thermocline and interactions of these waves with the bed in shallower regions of the lake. This displacement of the thermocline was around 20 m on 16-12-04, slightly greater than on 21-01-05. Water temperature in the surface waters was highest on 10-02-05 and the thermocline was relatively shallow on this day and the preceding sampling day, 16-01-05. By 8-06-05 there had been a large decrease in surface water temperature compared with the preceding BIO-FISH run on 24-03-05. On this day the thermocline had also deepened considerably, to about 60m, as a forerunner to winter overturn (mixing).

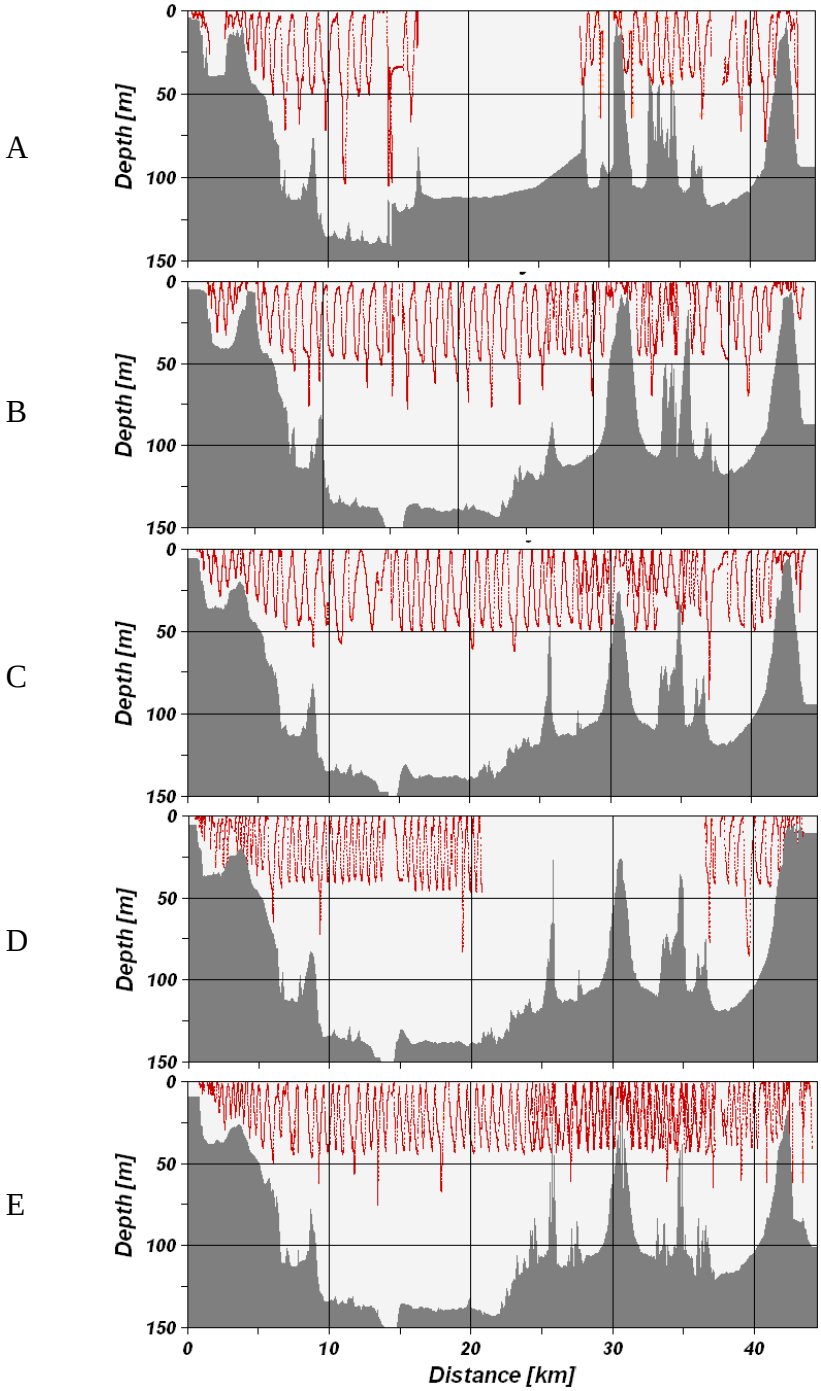

Figure 3. BIO-FISH profiling patterns on the five dates. A) 16-12-04, B) 21-01-05, C) 10-02-05, D) 24-03-05 and E) 8-06-05.

Chlorophyll fluorescence shows some intriguing features that inevitably cannot be explained fully here. The gradual depression of fluorescence in surface waters (upper 20 m) over the length of each of the first three runs, particularly on 10-02-05, is most likely due to progressively greater fluorescence inhibition (quenching) of phytoplankton caused by increasing irradiance over the duration of each run. Observations based on surface grab samples at this time indicated that *Botryococcus* sp. was the dominant phytoplankter, with relatively low densities of cyanobacteria consisting mostly of colonies of the genus *Anabaena* (Appendix 3). While attempts were made to start BIO-FISH runs in the dark or at first light, completion of each run was not until around midday, when quenching was likely to be well developed under on sunny days. Undertaking BIO-FISH runs at night was not carried out because of potential navigation difficulties. In contrast to the first three BIO-FISH runs, conditions were comparatively cloudy on the last two BIO-FISH runs, which may have resulted in reduced fluorescence inhibition.

Another very prominent feature of the first four BIO-FISH runs is the existence of a deep chlorophyll maximum (DCM). This layer is closely associated with the thermocline, generally lying slightly below it, notably on 16-12-04. There was little variation in the DCM position and concentration over the length of each of the BIO-FISH runs on most days though on 16-12-04 (Figure 5A) the DCM position appeared to be influenced by the variations in position of the thermocline, most likely in association with propagation of internal waves (cf. Figure 4A).

By 8-06-05, the DCM had disappeared in association with progressive deepening of the thermocline prior to winter overturn. Vincent et al. (1983) observed peak phytoplankton production in winter in Lake Taupo and, based on the relatively high fluorescence readings over the entire depth of the surface mixed layer, it appears that there would be a greater areal biomass on 8-06-05 than encountered during any of the other BIO-FISH runs that took place during the period of more intense summer stratification. It seems likely that with deepening of the thermocline, there was likely to be entrainment of nutrients from deeper in the water column, stimulating an increase in phytoplankton production and biomass in the surface layer despite lower mean light intensities in association with both a deeper mixed layer and

the transition towards winter.

Specific conductivity on the first two days of BIO-FISH runs did not appear to be influenced strongly by the prevailing stratification and was more variable horizontally, for given depths in the lake. By the last three BIO-FISH runs there was generally greater specific conductivity below the thermocline and it was at this time that different water masses were more readily distinguished (Figure 6). For example, there appeared to be an intrusion of water of slightly higher conductivity near the start of the BIO-FISH run (i.e. near the Taupo township) on 8-06-05. While conductivity is potentially valuable in tracking different water masses, the complexity of the BIO-FISH conductivity signature in the lake suggests that additional information on lake currents and temperature time series (e.g. thermistor chains) would be required to more fully resolve the origin and transport of water in Lake Taupo.

A BIO-FISH dissolved oxygen run for only one day (8-06-05) is presented in Figure 7 as there were ongoing problems with the probe for the other sampling days. The distribution of dissolved oxygen on this day was strongly influenced by the prevailing stratification; concentrations were relatively homogenous and slightly above saturation levels in the surface mixed layer, while below the level of the thermocline (c. 50 to 60 m water depth) concentrations were slightly depleted from saturation levels.

The timing of the BIO-FISH profiles can be put in the context of the long-term data collected by NIWA at Station A, as part of Environment Waikato's Lake Taupo long-term monitoring programme. Figure 12 shows dissolved oxygen and conductivity, and Figure 13 shows temperature and chlorophyll fluorescence, all for the period 1 June 2004 to 30 June 2005. From these figures it is evident that the BIO-FISH measurements coincide with the 'set-up' of the summer surface mixed layer in December, rapid heating of this layer in January, followed by rapid deepening and cooling of the surface mixed layer in May. The depth distribution of chlorophyll fluorescence was relatively constant at Station A through summer months (December-April), but was marked by a rapid increase in May, corresponding to relatively high BIO-FISH chlorophyll fluorescence readings in the surface mixed layer in this month (Fig. 5E).

A

B

C

D

E

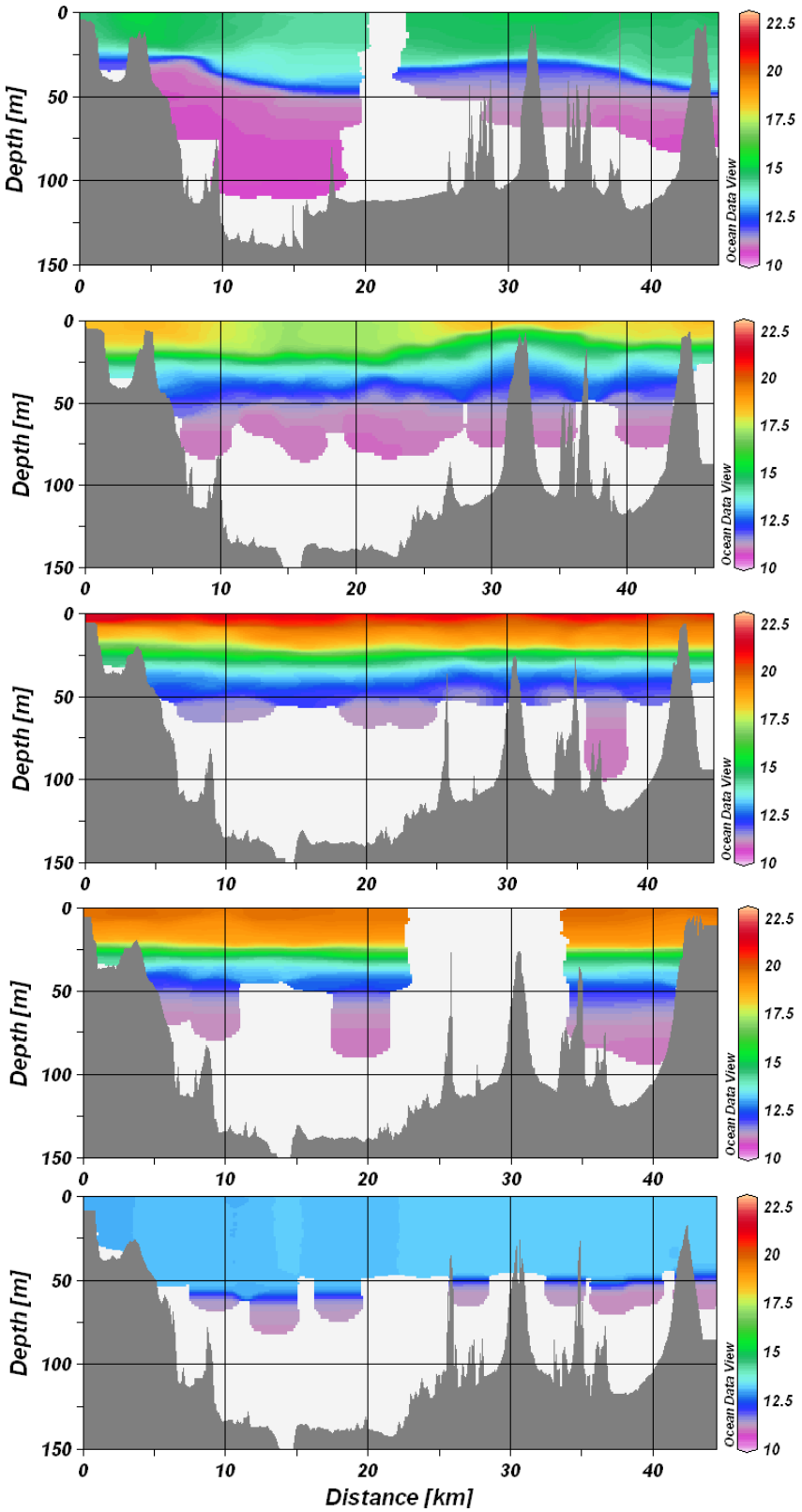

Figure 4. Temperature (^{o}C) in Lake Taupo from BIO-FISH runs on the five dates. A) 16-12-04, B) 21-1-05, C) 10-02-05, D) 24-03-05 and E) 8-06-05.

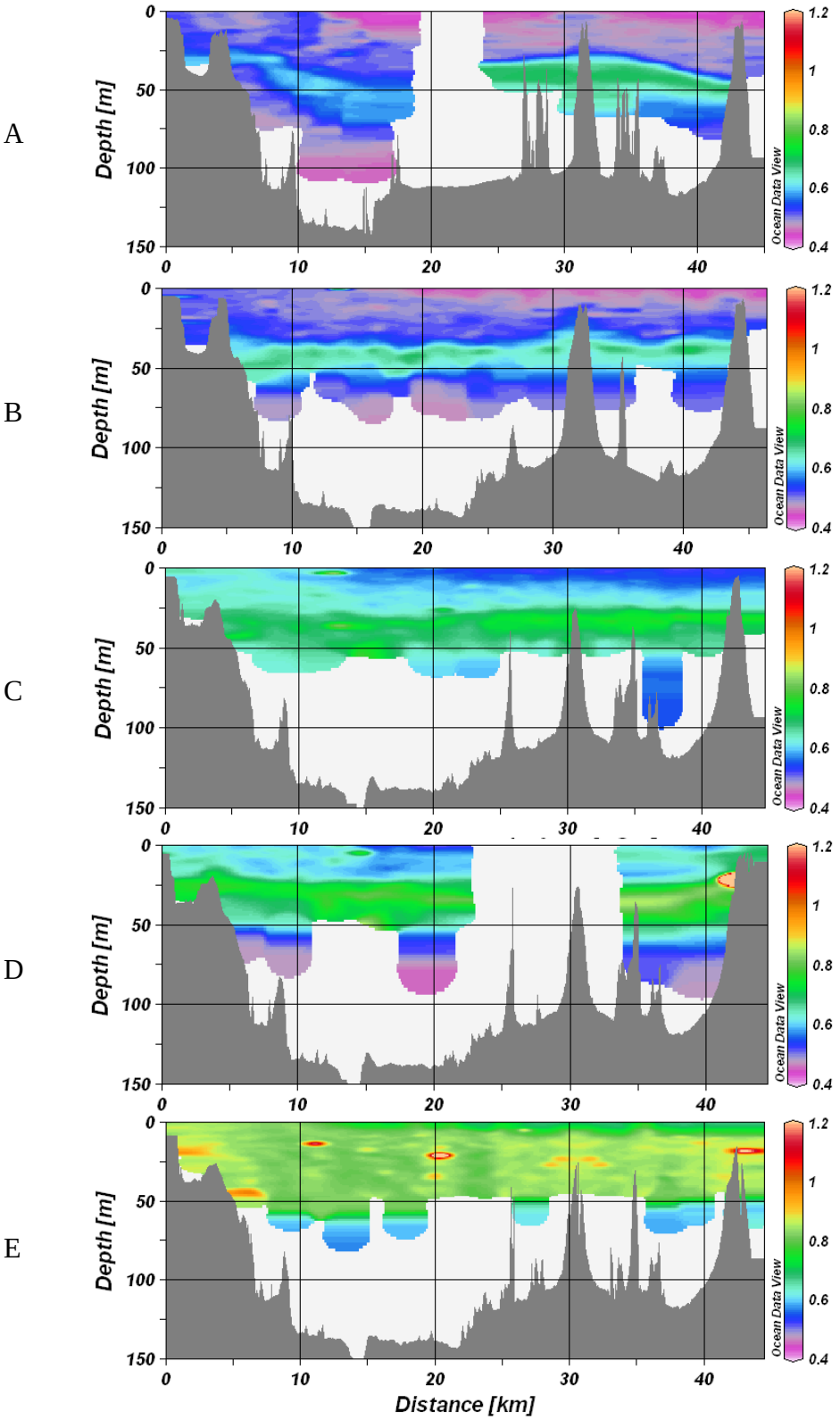

Figure 5. Chlorophyll fluorescence (≡ μg L^{-1}) in Lake Taupo from BIO-FISH runs on the five dates. A) 16-12-04, B) 21-1-05, C) 10-02-05, D) 24-03-05 and E) 8-06-05.

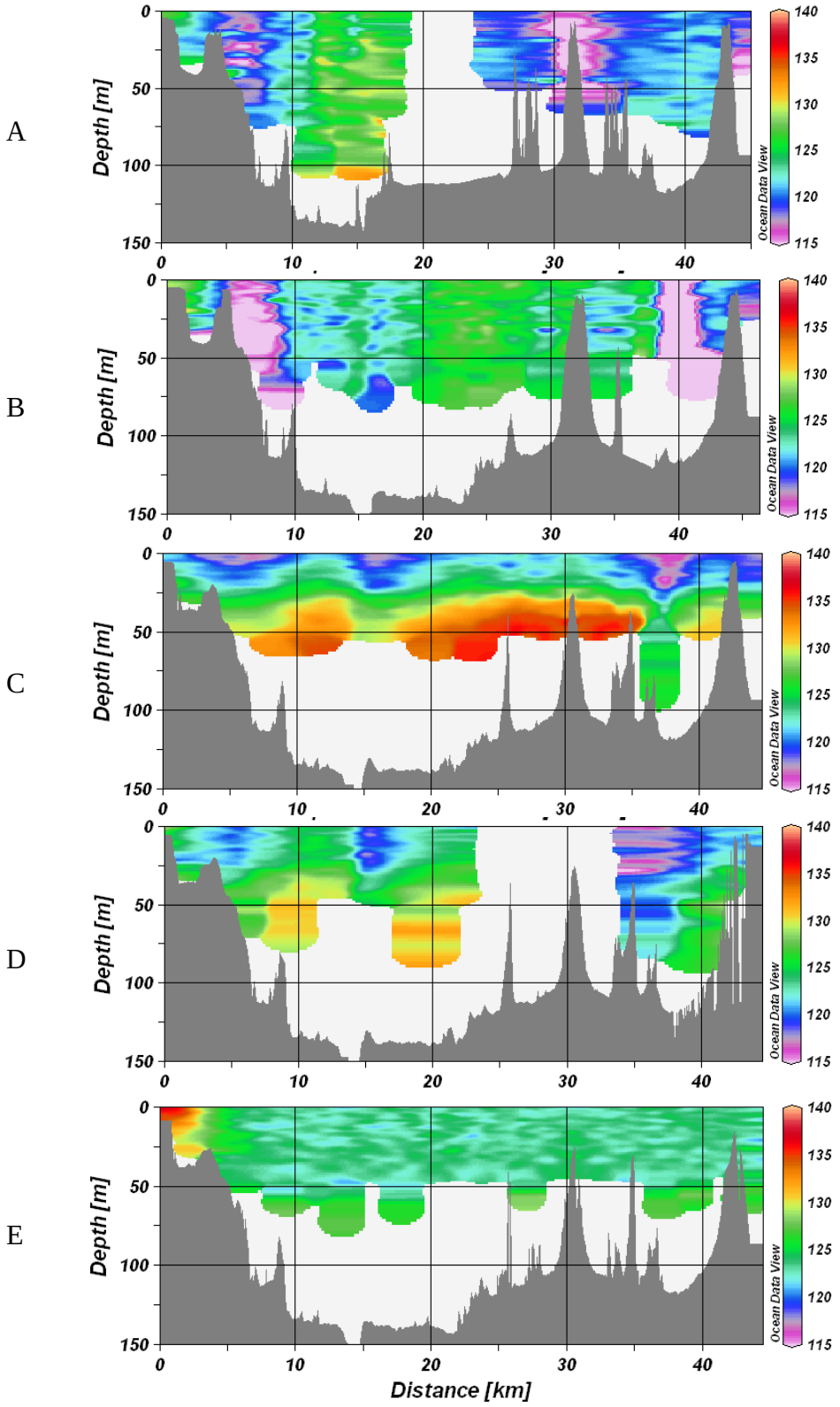

Figure 6. Specific conductivity ($\mu S\ cm^{-1}$) in Lake Taupo from BIO-FISH runs on the five dates. A) 16-12-04, B) 21-1-05, C) 10-02-05, D) 24-03-05 and E) 8-06-05.

A

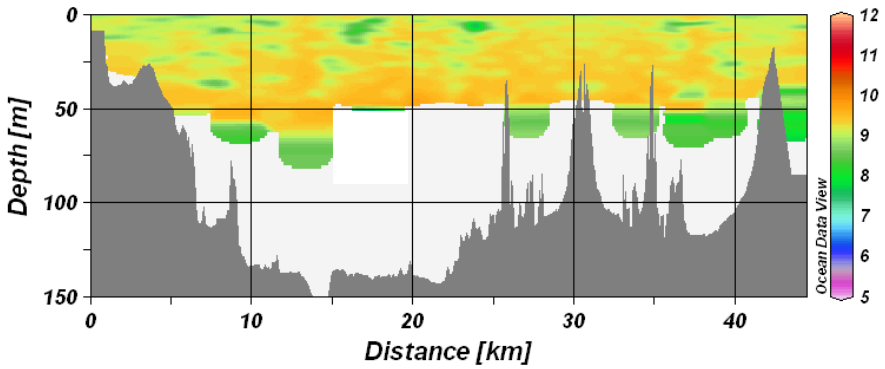

Figure 7. Dissolved oxygen (mg L^{-1}) in Lake Taupo from a BIO-FISH run on 8-06-05.

The deep chlorophyll maximum was evident in fluorescence profiles at Station A (Figure 13) but appeared less prominent in these profiles than in the BIO-FISH transects (Figure 5) due to different scales; the scale in Figure 13 was to accommodate the relatively high fluorescence readings that occurred throughout the water column in later winter.

Conductivity readings derived from the BIO-FISH runs do not present a coherent picture across the lake or through time. By contrast, the long-term conductivity readings, show a clear increase in conductivity in the hypolimnion, most likely corresponding to geothermal origins.

Discussion and possible projects arising

The present BIO-FISH study can be regarded as a preliminary investigation that has led to a number of interesting observations that can serve as the basis for more targeted and specific studies on the dynamics of Lake Taupo.

It is evident that inhibition of fluorescence by bright light is likely to be a problem for any study that attempts to carry out widespread observations of chlorophyll fluorescence in the surface mixed layer of Lake Taupo during daylight. In the absence of navigating a boat at night or in partial darkness, large numbers of solvent-extracted chlorophyll *a* measurements will be required to comprehensively document phytoplankton distributions in the surface mixed layer. Arising from this, however, is an interesting observation that may provide the basis for a detailed study:

1) What is the time course of photoinhibition or quenching of fluorescence, how are the associated photosynthetic parameters affected by variations in mixing dynamics in the surface mixed layer and, is it possible to model the daily time course of photoinbition or quenching? Achieving the latter could potentially allow extrapolation of daytime fluorescence measurements to equivalent concentrations of chlorophyll *a* in the surface mixed layer.

The DCM has been clearly delineated in the BIO-FISH runs in Lake Taupo. The presence of the DCM may well form a barrier (in addition to the density gradient) that hinders the transport of nutrients to the surface layer, i.e., a self-propagating situation. The biomass of the DCM varies spatially with the generation of internal waves, but the question arises: what controls the evolution of the DCM over the time course of seasonal stratification? This could form the basis for a detailed study of the dynamics of the DCM in Lake Taupo:

2) What is the balance between increments (i.e. growth), losses (i.e. respiration, grazing and other mortality) and sedimentation (or buoyancy) of phytoplankton in the DCM? This study would require measurements to decipher phytoplankton composition and succession in the DCM, growth rates in response to different light and nutrient conditions, and rates of loss attributable to zooplankton grazing

and sedimentation (or buoyancy). We hypothesise that the existence of the DCM is indicative of high water clarity and relatively 'healthy' lake conditions (see long-term data given in Appendix 4). It may be possible, however, to develop indicators such as vertical position or physiological state of phytoplankton in the DCM as a more sensitive integrated indicator of lake health than measurements of water clarity or nutrient concentrations, which often show high variability. It may also be possible to develop a set of criteria under which the DCM could disappear, e.g., from increased light attenuation as a result of high phytoplankton biomass in the surface mixed layer.

The BIO-FISH data has produced some interesting observations of distributions of temperature, dissolved oxygen, specific conductivity and chlorophyll fluorescence in Lake Taupo, but the frequency of data collection does not necessarily allow dominant processes to be quantified. A comprehensive *in situ* monitoring system is being set up in the Rotorua lakes to provide measurements of water column temperature, surface and bottom dissolved oxygen and surface chlorophyll fluorescence at high frequency using telemetry to provide immediate connectivity of the lake data to a user. Consideration could be given to setting up a similar system in Lake Taupo, so that a series of studies may be possible to complement, for example, routine CTD or BIO-FISH profiles across the lake, potentially allowing:

3) A) The extent of inhibition of chlorophyll fluorescence based on diurnally varying light, mixing regime (from the thermistor chain) and phytoplankton composition and distributions. This might allow daytime fluorescence profiles to be extrapolated to chlorophyll *a* concentrations, with results validated by solvent extracted chlorophyll *a*. Once again it is important to emphasise the importance of making allowance for fluorescence quenching so that progress can be made in getting widespread measurements of chlorophyll *a* concentrations in the surface mixed layer.

   B) The use of *in situ* instrumentation would allow determination of the extent of variation of parameters on a diurnal basis (e.g. stratification, chlorophyll fluorescence and dissolved oxygen concentration). A number of related studies

could be initiated, e.g., is *diurnal* stratification a prerequisite for buoyant cyanobacterial blooms?

The present study has not dealt with the light field in Lake Taupo or the factors that affect it, although irradiance profiles are collected as a component of the BIO-FISH runs. One of the peculiarities of Lake Taupo is that light penetration often peaks in summer (Appendix 3) when cyanobacterial biomass is highest. Many of the cyanobacteria are highly condensed into colonies, however, leading to far lower relative light attenuation than if these colonies had been dispersed into individual cells. A study could be initiated to look at:

4) Colony sizes of cyanobacteria in Lake Taupo, how this affects their buoyancy and relative light attenuation, and how colony size might be affected by turbulence and prevailing environmental conditions and physiological status (e.g. nutrient levels) of the cells. This information could be used to better understand potential for formation of cyanobacterial blooms in Lake Taupo.

This study has not undertaken any analysis of nutrient concentrations in Lake Taupo. Phytoplankton biomass in the lake has consistently been found to be most strongly limited by nitrogen rather than phosphorus, and management strategies for control of water quality and clarity are predicated upon control of nitrogen sources, particularly nitrate, to the lake. If, however, nitrogen fixation is important in either 1) promoting growth of specific N-fixing benthic algae or cyanobacteria over non N-fixing algae, or 2) contributing significantly to the total nitrogen budget to the lake, then there may be major management implications for Lake Taupo's nutrient management. A study of nitrogen fixation could be initiated to:

5) Quantify nitrogen fixation by both benthic and planktonic algae and elucidate its role in the succession and dominance of N-fixing algae in Lake Taupo, and in the overall nitrogen budget of the lake.

Acknowledgments

We acknowledge the support of the Lakes and Waterways Action Group (LWAG) in initiating this project and obtaining funding for the BIO-FISH surveys. We are particularly grateful to Paul White, Jane Penton and Dr Nick Bradford for arrangements made in relation to the project. We also acknowledge the support of the Taupo Harbour Master, Les Porter and Brent; the use of the boat and their experience were essential ingredients in the completion of the surveys. Environment Waikato's "Lake Taupo long-term monitoring programme" data was collected by NIWA. Bill Vant provided useful comments on a draft of this report. This study would not have been possible without funding to support the Environment Bay of Plenty Chair in Lakes Management and Restoration at Waikato University. Alex Ring (Department of Biological Sciences, University of Waikato) assisted with the three of the BIO-FISH runs and David Burger with one of the runs.

References

Gibbs, M. M. (2004). Lake Taupo long term monitoring programme 2002-2003: including two additional sites. NIWA client report TR 2004/05. NIWA, Hamilton.

Vincent, W. F. (1983). Phytoplankton production and winter mixing: contrasting effects in two oligotrophic lakes. *Journal of Ecology 71*: 1-20.

Appendix 1. Comparisons of UoW and NIWA CTD profile data at Station A

Comparisons are available of profile data taken by the NIWA and UoW CTDs on days separated by relatively brief intervals, i.e., not more than 4 days (Figures 8-10). There was excellent reproducibility of results between temperature, dissolved oxygen and conductivity for the two sets of CTD profiles. The calibration of fluorescence to chlorophyll *a* was based on NIWA data when several grab samples were analysed for solvent-extractable chlorophyll *a* at the same time as a CTD profile was taken (Appendix 2). UoW BIO-FISH and CTD fluorescence profiles were then adjusted to match those of the calibrated NIWA data.

Only one day separated the NIWA CTD profile (15-12-04) and the UoW CTD profile (16-12-04) taken in December. The difference in the temperature profile between these days was most likely the result of the stage of propagation of an internal wave at the thermocline (region of rapid temperature change at around 40 m depth) but could also have been partly due to heating and strengthening of stratification by the time of the UoW profile. The elevated thermocline was also reflected in a shallower peak of chlorophyll fluorescence in the UoW profile, which would also have been enhanced by strengthening stratification. Fluorescence in the upper 20 m is also more strongly suppressed in the NIWA profile taken later in the day, most likely due to greater quenching under stronger irradiance, either due to time of day or greater incoming irradiance on 16-12-04, though variations due to the different fluorescence probes can also not be ruled out. Differences in the dissolved oxygen profiles were likely mostly due to time of measurement, as the UoW profile was very early in the morning and differences became less marked with increasing water depth, indicating that phytoplankton photosynthesis may have contributed to higher levels of dissolved oxygen later in the day.

The second comparison of CTD profiles was 21-01-05 (UoW) versus 25-01-05 (NIWA). It is apparent that the 4-day duration between the two profiles had brought about significant water column changes. A strongly mixed zone in the upper 20m on 21-01-05, denoted by the vertical isotherm in the UoW profile, is absent in the NIWA profile four days later. By

comparison, the NIWA profile shows considerable warming and a relatively linear decline in temperature from the surface to a depth of nearly 80 m. The effect of the difference in temperature on the profiles of dissolved oxygen and conductivity is negligible, but the fluorescence profiles differ considerably. There is a sharp fluorescence peak just below 40 m depth in the UoW profile while the NIWA profile shows a maximum of fluorescence smeared over depths between about 50 and 80 m. This result suggests that chlorophyll fluorescence associated with the deep chlorophyll maximum (DCM) may vary considerably over short periods of time, and that the DCM position is likely to be strongly influenced by the prevailing stratification regime. Once again, the NIWA fluorescence profile showed stronger inhibition in surface (upper 20 m) waters.

The closest comparison between the two sets of CTD profiles was on 21-03-05 (NIWA) and 24-03-05 (UoW). Temperature and fluorescence profiles almost overlap, although there are subtle shifts in dissolved oxygen and conductivity profiles. The only difference between the fluorescence profiles is slightly greater inhibition observed in surface (upper 20 m) waters of the NIWA profile.

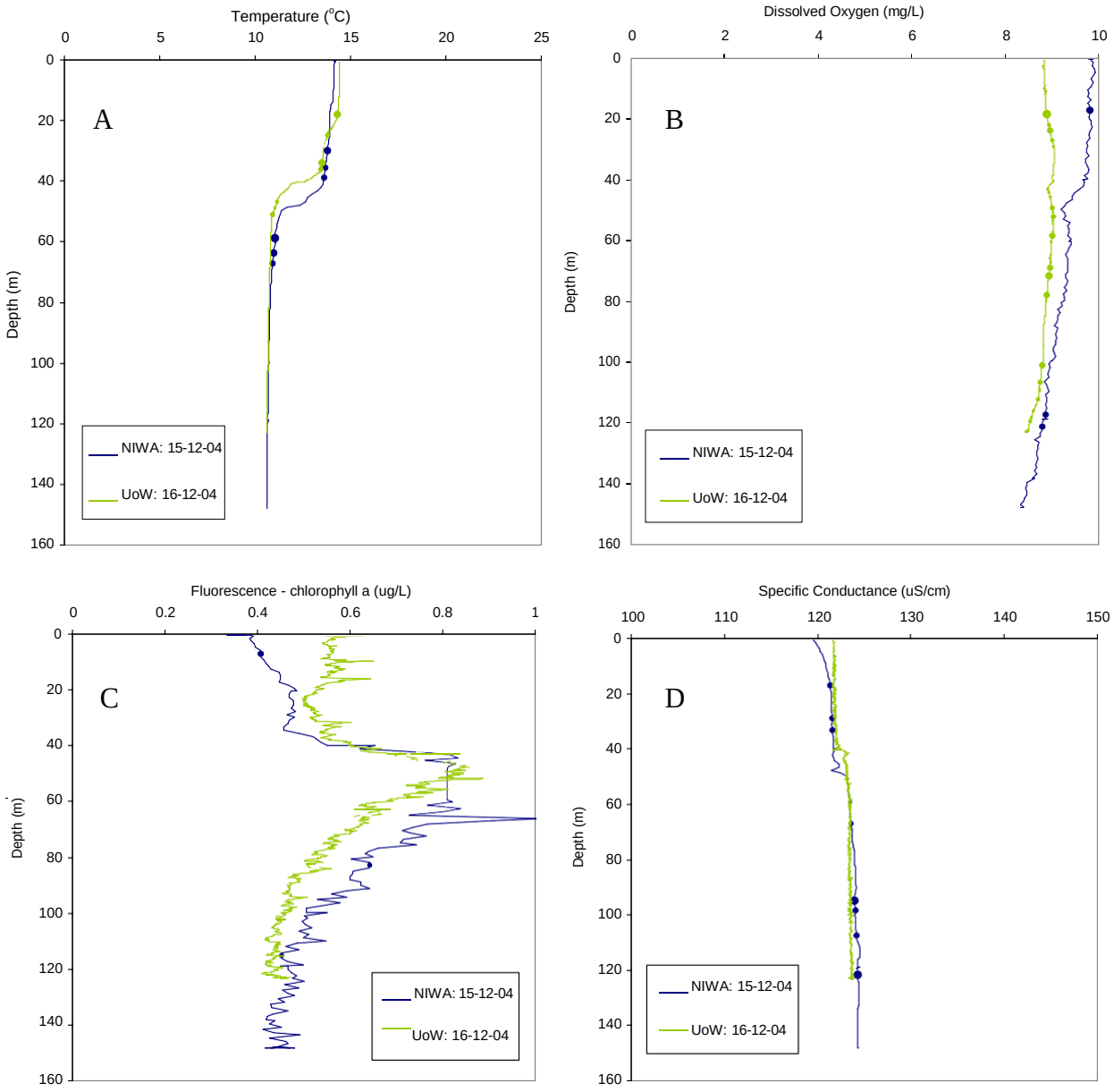

Figure 8. Comparison of NIWA and UoW CTD profiles in December 2004. A) temperature, B) dissolved oxygen concentration, C) specific conductance and D) calibrated fluorescence profiles.

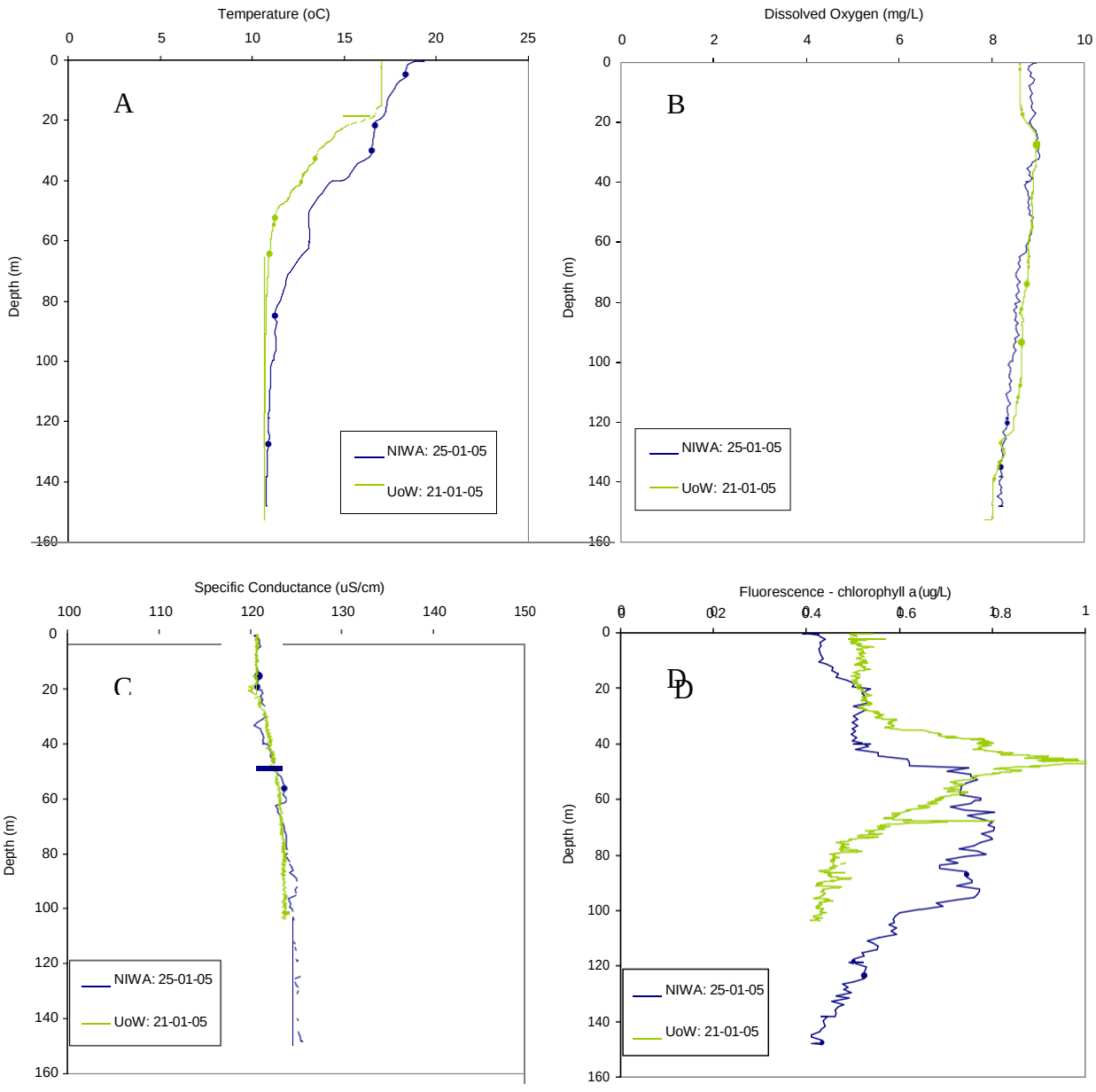

Figure 9. Comparison of NIWA and UoW CTD profiles at site A in January 2005. A) temperature, B) dissolved oxygen concentration, C) specific conductance and D) calibrated fluorescence profiles.

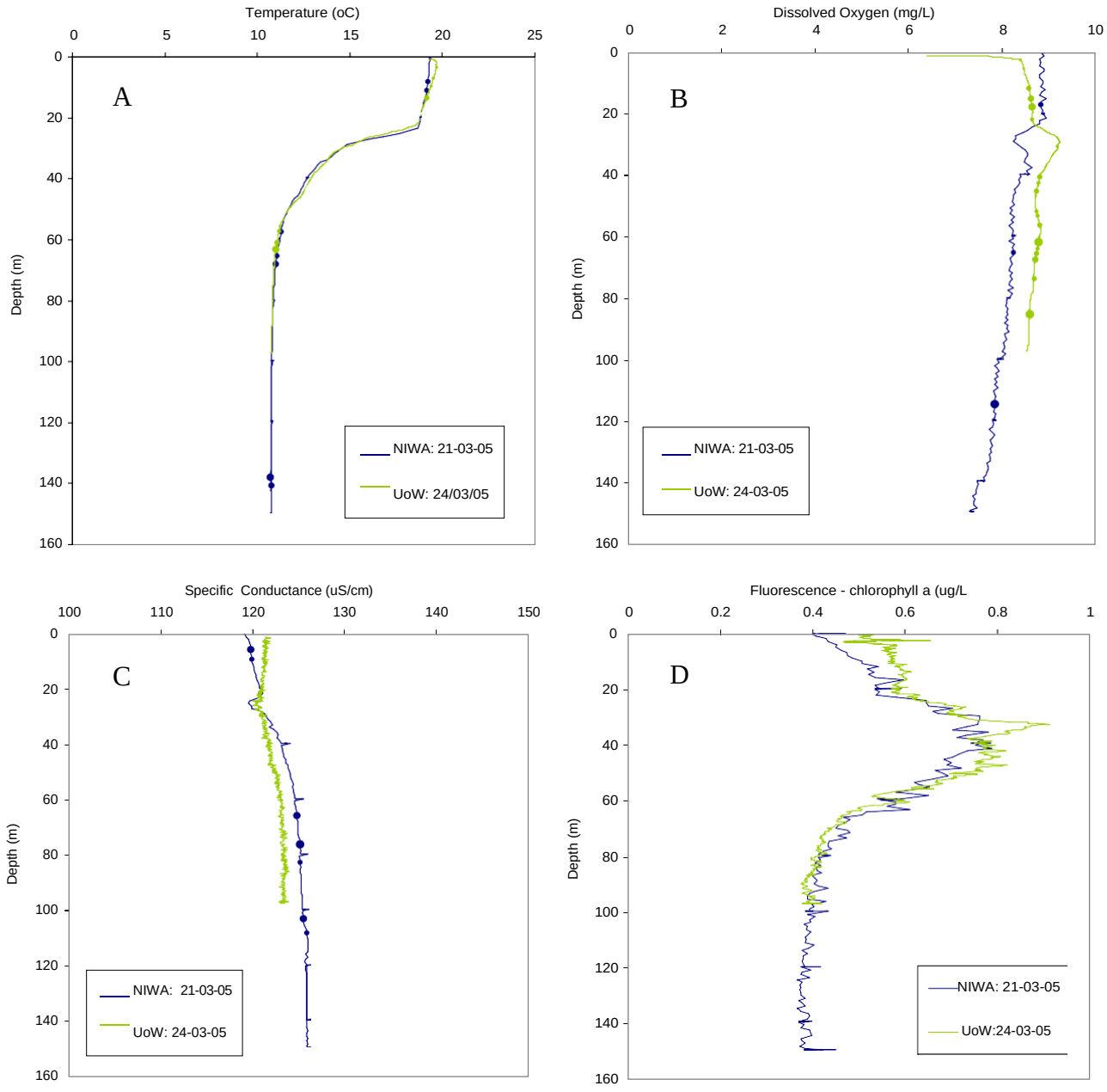

Figure 10. Comparison of NIWA and UoW CTD profiles at site A in March 2005. A) temperature, B) dissolved oxygen concentration, C) specific conductance and D) calibrated fluorescence profiles.

Appendix 2. Calibration of NIWA fluorescence and solvent-extracted chlorophyll a

Figure 11 shows a continuous blue line representing a fluorescence profile, taken on 21-10-04, and corresponding solvent-extracted chlorophyll *a* concentrations taken from discrete depth grab samples on the same day. The green line shows the raw fluorescence data multiplied by 0.8 and with 0.3 added. This line bears a very close relationship to the solvent-extracted chlorophyll a in μg L^{-1} except in the surface 20 m where it is likely that quenching influenced the strength of fluorescence signal.

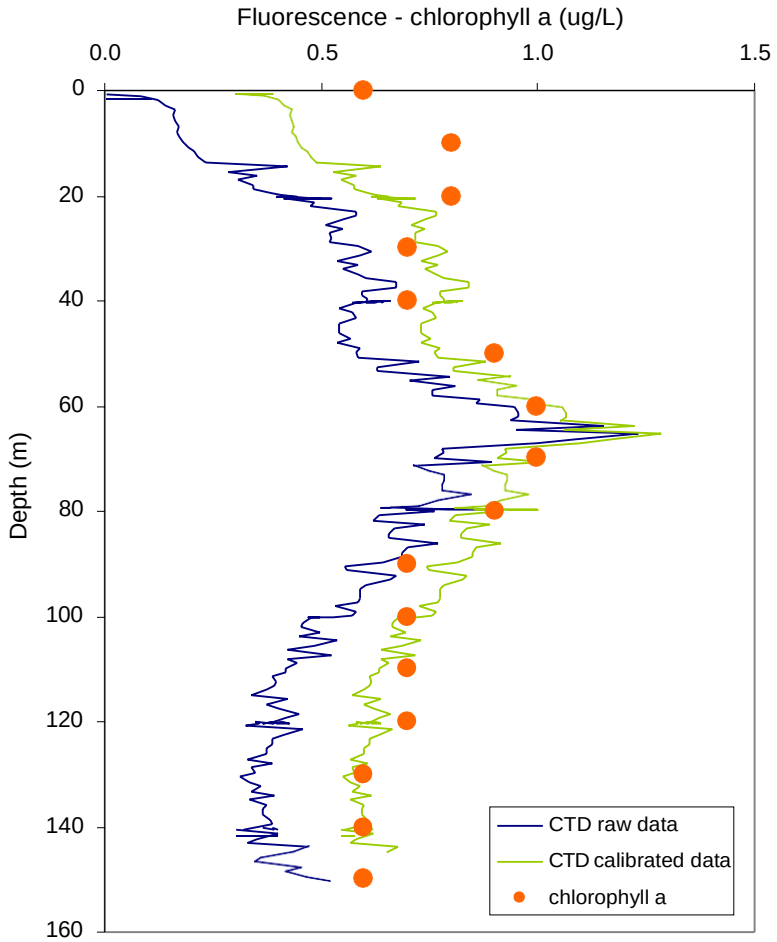

*Figure 11. Raw fluorescence profile (blue line), solvent-extracted chlorophyll a from discrete grab samples (orange dots) and adjusted fluorescence profile (green line) obtained from 0.8*raw fluorescence + 0.3. NIWA data is from Environment Waikato's Lake Taupo long-term monitoring programme.*

Appendix 3. Observations by Dr Nick Bradford of phytoplankton on 17-03-05

Water samples taken by Nick Bradford on March 17th 2005:

Weather calm, overcast, drizzling (not good for visual spotting), samples taken between 10.15 am and 12.45 pm.

site No	name	southern latitude in °, min	NZ Map Grid	eastern longitude in °, min	NZ Map Grid	Description	visual growth	Botryococcus cells / litre*	Cyanobacteria cells / litre*
1	Centre North	38 43.874	2761689.168	175 53.647	6270876.176	1.7 NM south of Whakaroa Pt	3	5100	70
2	Waihaha	38 43.465	2749456.17	175 45.184	6272022.485	400 m of beach, water depth (wd): 30 m	3	4560	145
3	Kawakawa	38 40.197	2756398.462	175 49.844	6277852.135	200 m S of buoy, wd: 30 m	3 - 4	5130	112
4	Kinloch	38 39.971	2763897.185	175 55.008	6278027.664	400 m of marina, wd: 40 m	3 - 4	8600	160
5	Whakaipo	38 41.258	2767489.53	175 57.541	6275526.831	300 m from lakefront, wd: 43 m	4	5500	286
6	Mine Pt.	38 43.525	2768828.65	175 58.562	6271286.198	200 m off point, wd: 78 m	3 - 4	5900	128
7	Te Kahaiakahu	38 47.943	2774346.563	176 02.565	6262922.003	400 m off point, wd: 44 m	3	6840	42
8	Tapuahararu bay	38 42.571	2776569.606	176 03.865	6272788.968	1 NM S of pumping station, wd: 42 m	4	4700	145

Dear Paul, David, Max, Bill, I had the opportunity to take water samples from the Northern parts of Lake Taupo, using the Harbourmasters Boat, courtesy of LWAG, last Thurs. 17.3.05

Cyanobacter colonies were visible by naked eye inspection from the White Cliffs in the east, through the centre of the lake and to Waihaha in the west, the growth was light/moderate and was distributed fairly homogeneously to inspection througout the lake but was slightly lighter in the centre and in Taupo bay, and slightly heavier in Whakaipo Bay. At each site I did and estimated visual inspection and compared it with the worst I had seen in Lake Taupo (not very scientific but I was unsure of the accuracy of the plankton net samples as yet), I also took a vertical 20 metre pankton net sample at each site.

Visual score 1-10 with 10 being the heaviest growth I have seen. The plankton net provides a 65ml sample, I took a 5ml sample from each and counted the colonies of Botryococcus and Cyanobacter and tried to count/estimate the cells per colony. Each Botyrococcus colony seemed to have about 3000 cells/colony (hard to estimate) and each Cyanobacter colony about 1500 cells. However I felt that the Cyanobacter colonies were broken up by the sampling method compared to the size in the Lake and took one sample of a

floating Cyanobacter colony that was a little above average size (say 7 on a scale of 1-10). On checking this colony when home, this had broken into 5 pieces, the estimated size of the original colony was 30-40,000 cells, emphasizing the colonies are large and well separated in the lake, which impacts on the correct collection method to give a true picture in the lake. Interestingly it was only Cyanobacter that was visible to the naked eye, colonies were separated by 1-2 feet. Hope you find this of some help though am still concerned the sampling method is not picking up as much Cyanobacter as there appeared to be in the upper visible layers of the lake.

Kind regards, Nick Bradford.

* Densities have not been calibrated and may be better used for comparative considerations of *Botryococcus* and cyanobacterial densities [D. Hamilton]

Appendix 4. Data from Environment Waikato's long-term monitoring programme conducted by NIWA

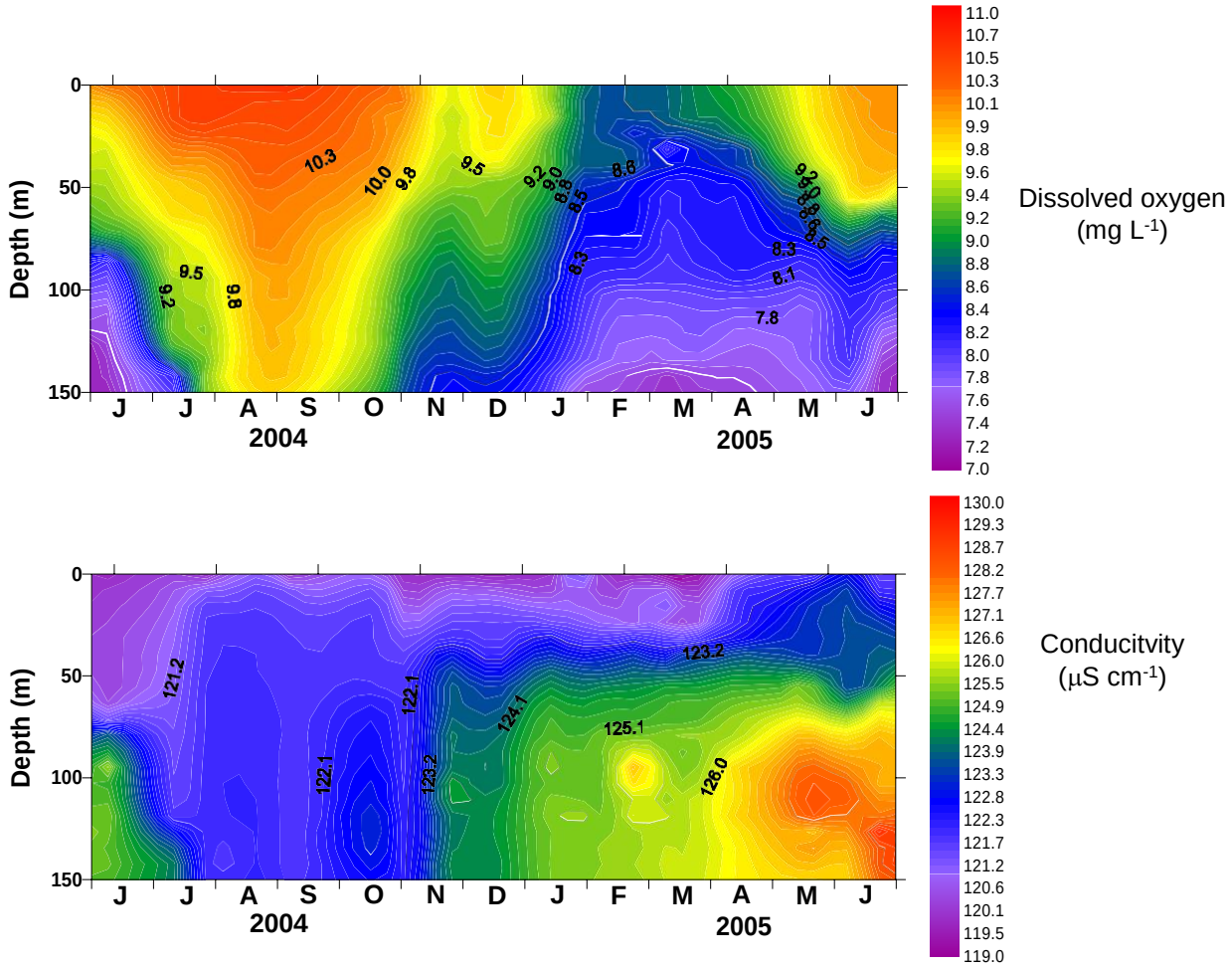

Figure 12. Dissolved oxygen and conductivity data from depth profiles at Station A from June 2004 to June 2005.

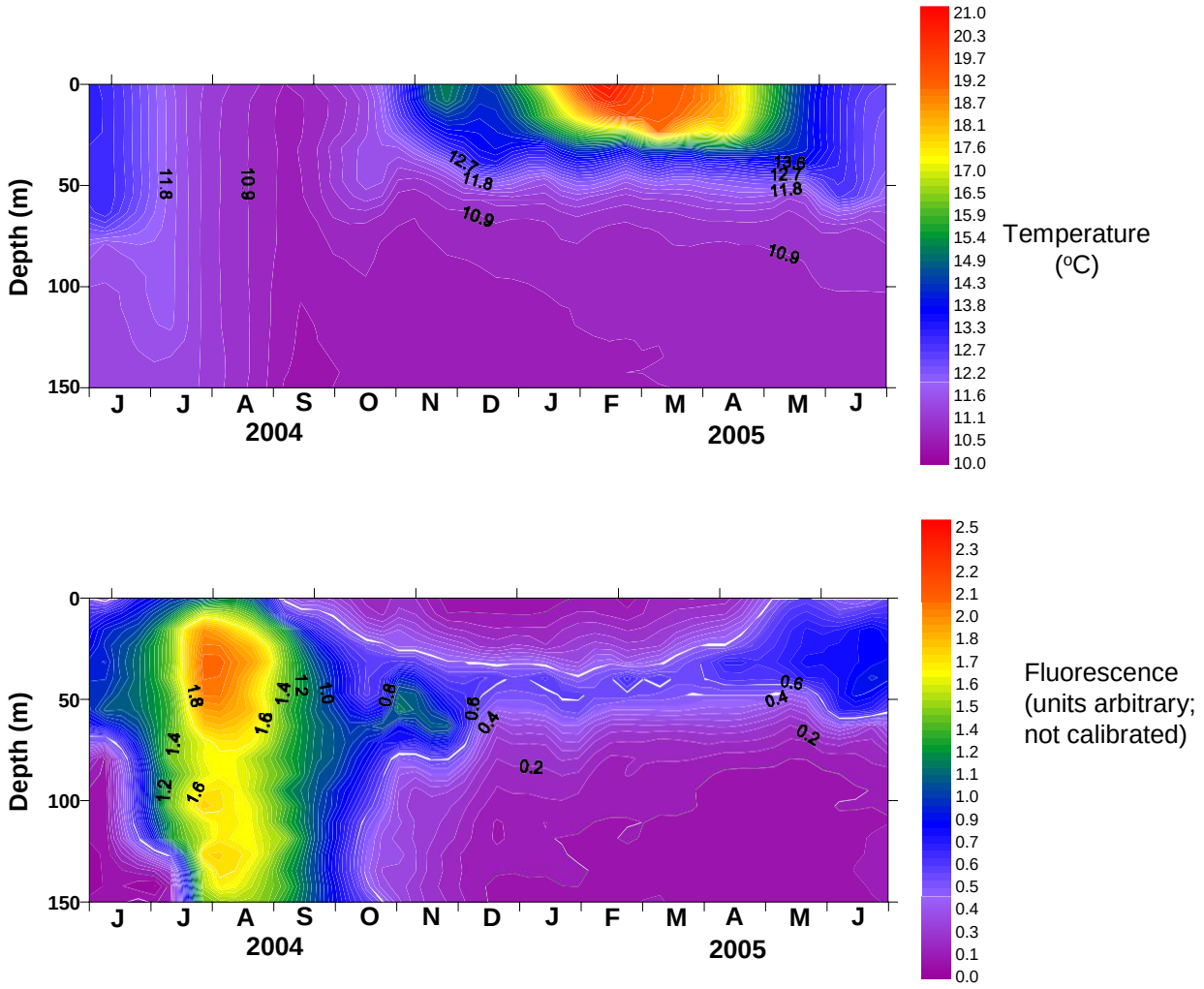

Figure 13. Temperature and chlorophyll a data from depth profiles at Station A from June 2004 to June 2005.

Appendix 5. Observations of Secchi disk depth in Lake Taupo, 2004-5

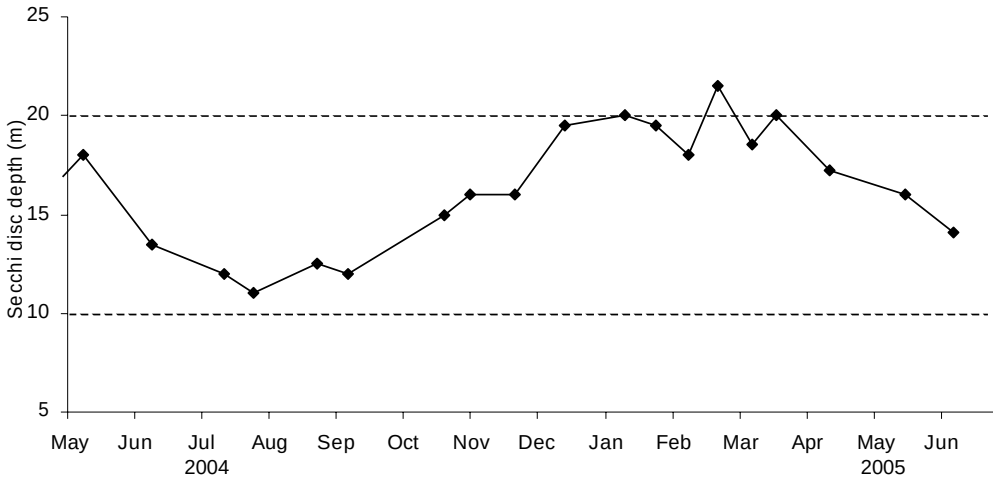

Figure 14. Secchi depth data at Station A. Observations are by NIWA as part of Environment Waikato's Lake Taupo long-term monitoring programme.