

Lake Brunner water quality update: December 2011

Lake Brunner is a large (41 km²), deep lake (max. depth 109 m) inland from Greymouth on the West Coast. It has high water quality proving a popular recreational destination for people within and beyond the region. Intensive agriculture in the catchment has led to nutrient increases and a decline in water quality. This has been observed following the commencement of monitoring early in the 1990's. This monitoring currently consists of bi-monthly sampling at three lake sites and seven river sites around the catchment. The central lake site has been monitored monthly as of 2010. More detail on sampling protocols can be found in the 2011 WCRC SoE report ¹.

Central lake monitoring supports the longest and most comprehensive data record, and this has been used to determine the water quality trends presented in this report. This report is intended to update a broader analysis contained in the 2011 WCRC SoE report ¹. More information on the processes occurring in Lake Brunner can be found in the 2008 ² and 2011 ¹ West Coast Surface Water Quality reports.

Lake processes

Lake Brunner is oligotrophic (low nutrient) and algal productivity is very strongly limited by the availability of phosphorus, throughout the year, as indicated by nutrient (molar) ratios of nitrogen and phosphorus. The average total nitrogen to total phosphorus ratio is 69:1, with the ratio of nitrate to dissolved reactive phosphorus much higher (200:1). The Redfield ratio of 16:1 is considered the approximate ratio required by lake phytoplankton and plants, so growth is clearly limited by the amount of phosphorus. Dissolved reactive phosphorus is almost absent as it is consumed immediately when it becomes available. There has been no apparent change in the level of phosphorus limitation since 1992. The lake retains 50 to 55% of phosphorus transported from the catchment by burial in the sediment, and 30% of nitrogen is retained by burial or removed by denitrification.

The lake has a long residence time (1.14 years) which enhances the retention of nutrients by the lake. Because of an enhanced capacity for nutrient storage by burial in the sediment, lakes with long residence times are less sensitive to phosphorus loading and are more resilient than lakes that are flushed faster. But, this is on the condition that primary productivity does not exceed a level that could result in anoxia (no oxygen) at the sediment/water interface, on the bottom of the lake. This happens when enough dead organic matter sinks to the bottom and rots, which uses up the oxygen. Different chemical and biological processes then occur, and phosphorus stored in the sediment can be released. This then adds to the phosphorus already coming from tributaries. More phosphorus increases algal growth, rotting organic matter, less oxygen etc. Thus begins a vicious cycle and the problem is very hard to fix.

Council monitor's vertical oxygen and temperature profiles throughout the year. Currently, oxygen at the bottom of the lake stays high enough to avoid this undesirable cycle, and when phosphorus inputs are contrasted against anticipated outputs, no obvious phosphorus recycling is apparent. This is also supported through an absence of surface phosphorus increases in winter, when deep water that has been trapped at the bottom of the lake over summer by a warm surface layer is able to be mixed once the surface cools. This mixing was apparent from June to July 2011 (Figure 1). However, there has been a significant increase in hypolimnetic oxygen consumption since the early 1990s. The increase in hypolimnetic oxygen consumption is a clear sign that there is a trend of increased eutrophication in the lake between 1992 and 2011, which has

already been indicated by decreased clarity, and increasing chlorophyll and total phosphorus and total nitrogen concentrations. The lowest recorded hypolimnetic oxygen levels occurred in June 2011 when it decreased to 5 mg/L (45% saturation), shortly before mixing in July (Figure 1).

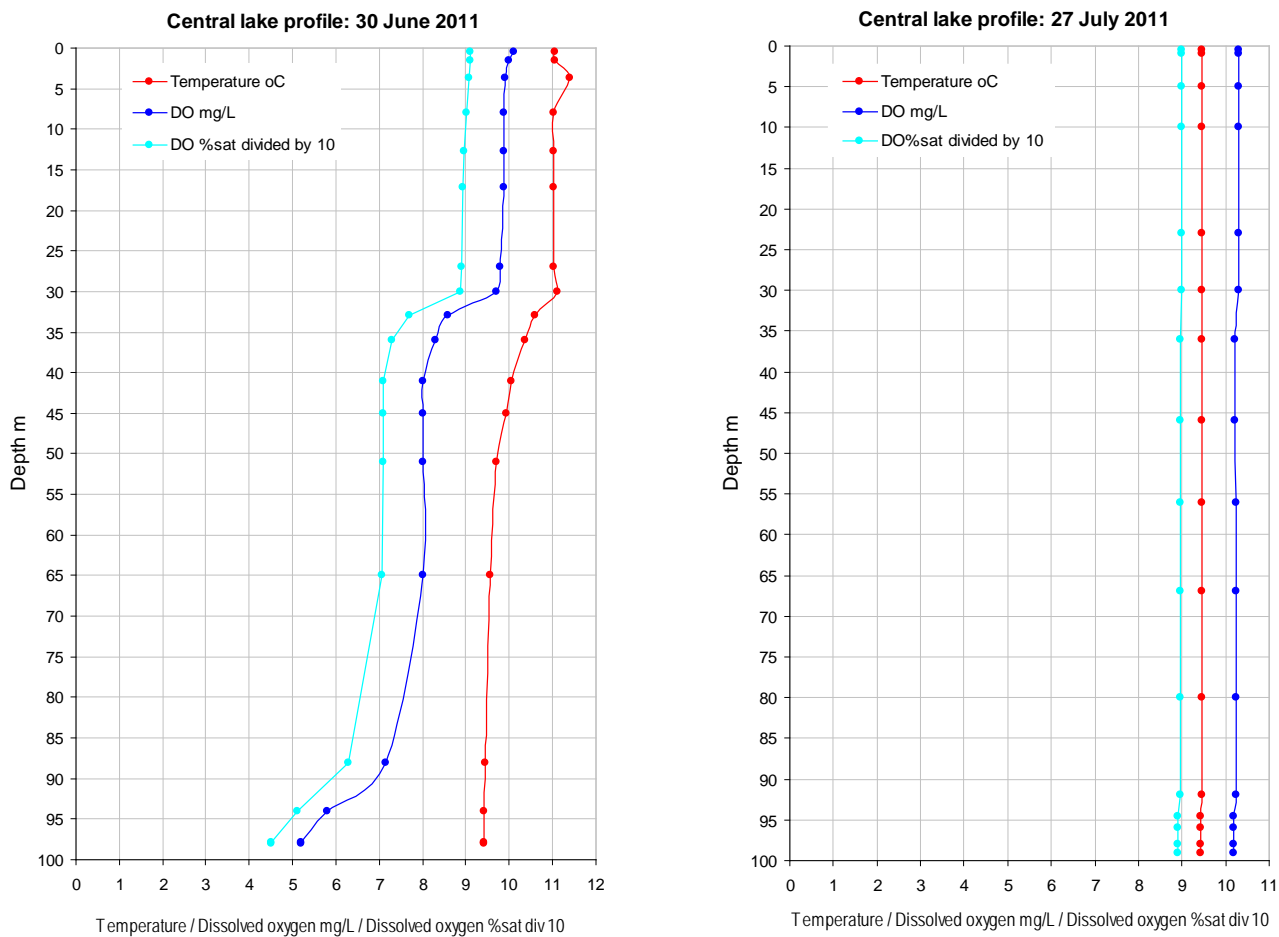


Figure 1 Vertical profiles of temperature, dissolved oxygen (mg/L), and dissolved oxygen saturation (DO%sat). DO%sat is the percentage of oxygen the water has relative to its maximum holding capacity at a given temperature. It has been divided by 10 so it can be compared to the other measurements, so 4.5 on the graph is 45% saturation. This is just less than half the amount of oxygen expected to be present.

Water quality trends

As data is continually collected, water quality trends can be re-assessed with new data. At some point the oldest data can be excluded from trend evaluation should there be more than one trend in the dataset. For this reason, trends have been evaluated in the Lake Brunner data for both the full dataset from 1992-2011, and the shorter dataset of 2001-2011. Trends have been evaluated using the Seasonal Kendall test in Time Trends v3.0 (refer to the WCRC 2011 Surface Water Quality report ¹ for more information).

From the early 1990's until now, chlorophyll (a measure of algal biomass) and nutrient concentrations have increased, and Secchi depth (a measure of water clarity) has decreased, suggesting that agricultural intensification may have led to a deterioration in lake water quality over this period (Table 1). These trends are considered statistically significant meaning there is a high chance they are real.

In the shorter time period from 2001 until now, many of these trends were still apparent, but for some their statistical significance was reduced, hence they may not be as strong. From 2001-2011, the trend in TN and TP remained significant. The Trophic Level Index (TLI) showed a significant decline from 1992-2011 but was not as strong from 2001-2011. The TLI is calculated using total phosphorus (TP), total nitrogen (TN), secchi clarity, and chlorophyll measurements with the purpose of determining the eutrophication status of a lake over time.

Coloured dissolved organic matter (CDOM) has been monitored since 2003, thus has only been evaluated from 2003 to 2011. CDOM is the substance that gives many West Coast lakes and rivers their distinctive brown colour, and has the appearance of tea staining. It is important to note that CDOM constitutes dissolved matter, and not solid material suspended in the water. The latter is measured by weighing material filtered from a lake water sample and is described as total suspended solids (TSS). Levels of CDOM appear to have increased significantly over the time they have been measured. It is not clear what might cause an increase in CDOM. This has not been measured in the tributaries, so contributions from around the catchment are uncertain. Further research is underway to learn more about CDOM dynamics in Lake Brunner and its catchment.

Chlorophyll increased significantly from 1992 -2011, which suggests an increase in algal productivity. Increasing algal productivity and CDOM will reduce lake clarity, but a statistically significant reduction in clarity and chlorophyll a was only observed from 1992-2011 and not 2001-2011. Agricultural intensification has been attributed as the cause of increased algal productivity, particularly phosphorus (the key limiting nutrient). Total phosphorus has increased significantly since 2001.

Seasonality has a major role in creating variation over time for many of the parameters measured in the lake (Figure 2 and 3). The linear trend lines shown on the graphs are a guide to the overall trend in the data. In some cases the trend maybe complex and head both up and down within the timeframe displayed, but this will not be apparent from linear trend evaluation (linear regression analysis).

Table 1 Results from Seasonal Kendall trend analysis. Confidence levels are given as a percentage. Highlighted cells indicate trends that are significant at a $p < 0.05$ level, i.e. >95% confidence.

	Record	Trend	Confidence		Record	Trend	Confidence
Algae (chlorophyll)	1992-2011	Up	99.9 ($p=0.001$)		2001-2011	Up	92
Clarity	1992-2011	Down	99.9		2001-2011	Down	77
Dissolved phosphorus	1992-2011	Up	99.9		2001-2011	Up	52
Nitrate	1992-2011	Up	99.9		2001-2011	Up	54
Total nitrogen	1992-2011	Up	99.9		2001-2011	Up	97
Total phosphorus	1992-2011	Up	99		2001-2011	Up	98
Suspended solids	n/a	n/a	n/a		2001-2011	Up	61
CDOM (g340)	n/a	n/a	n/a		2001-2011	Up	99.9
CDOM (g440)	n/a	n/a	n/a		2001-2011	Up	99.9
TLI	1992-2011	Up	99.9		2001-2011	Up	87

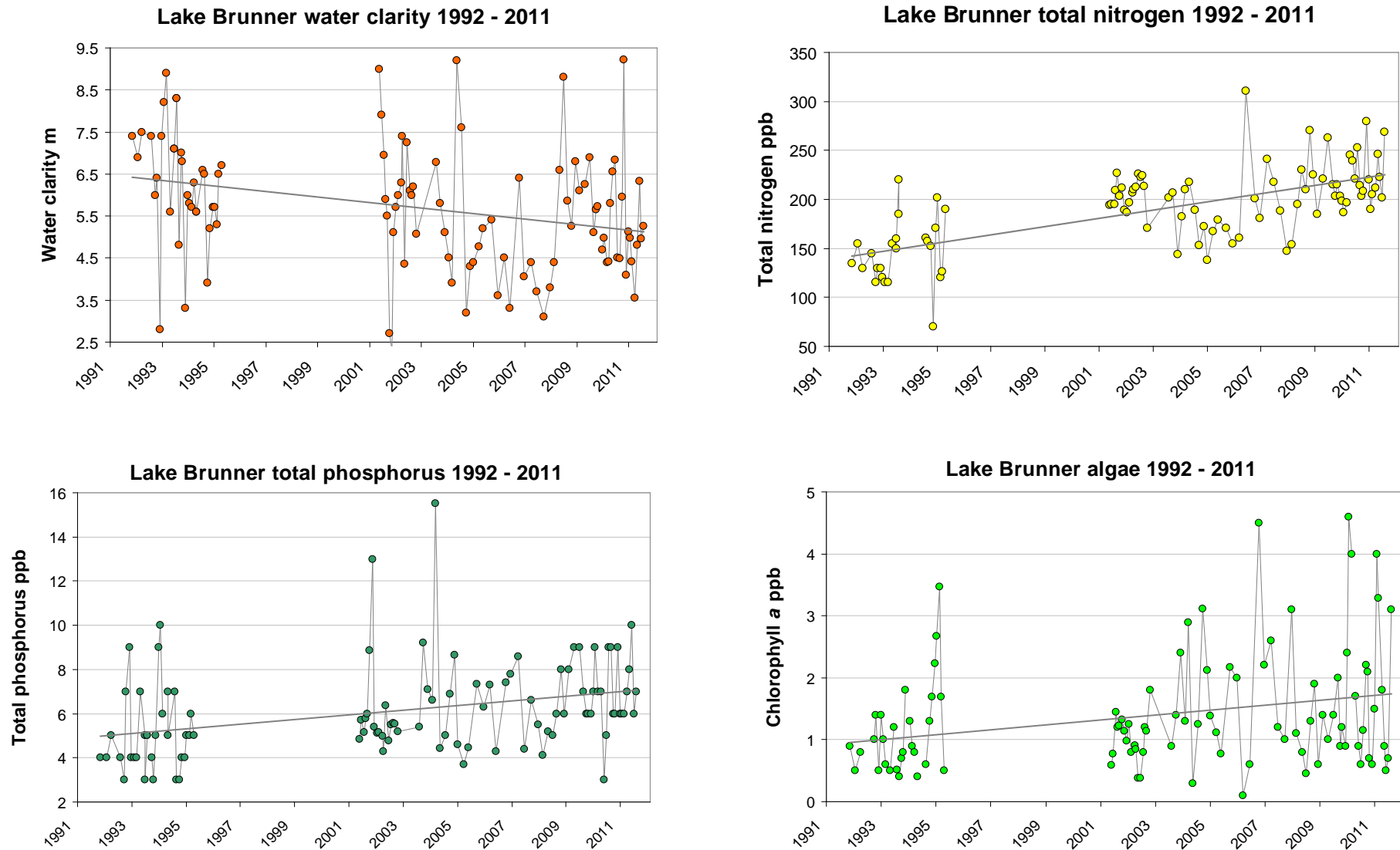


Figure 2 Full data record for water clarity, total nitrogen, total phosphorus, and phytoplanktonic algal abundance (as indicated by levels of chlorophyll a). Polynomial regression lines are overlaid in grey.

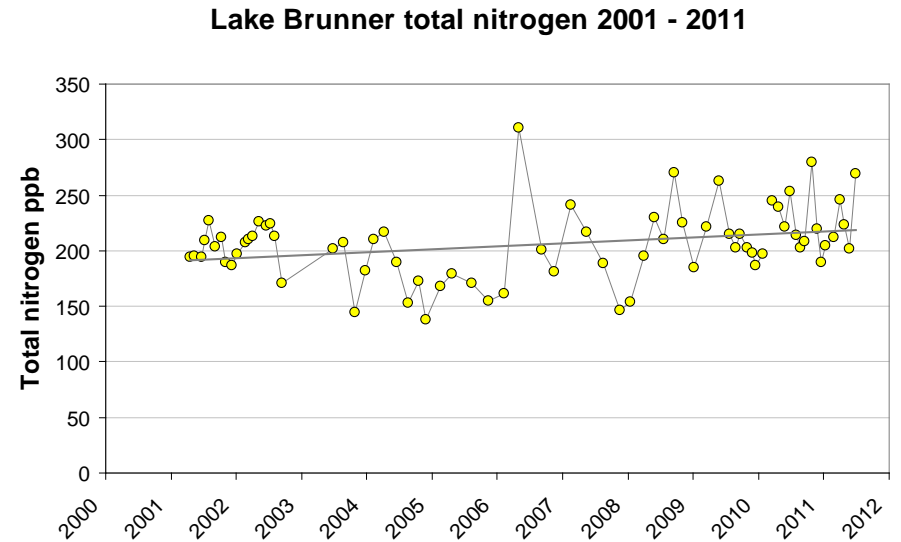
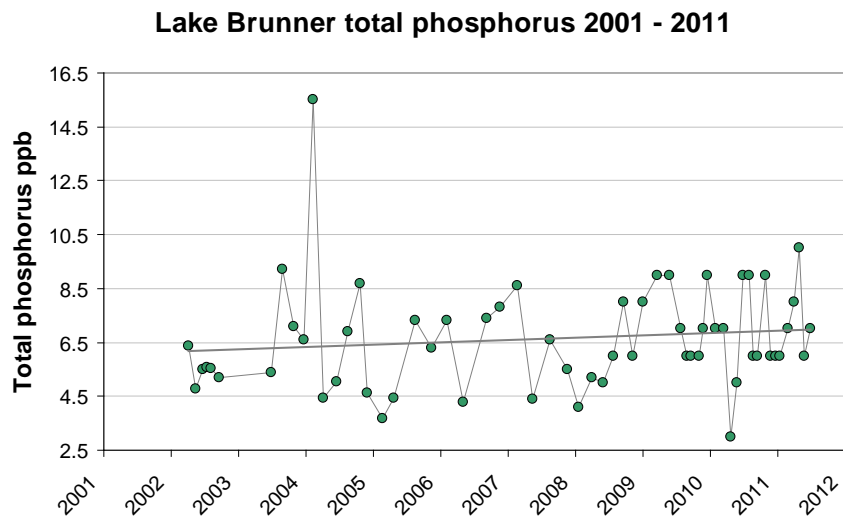
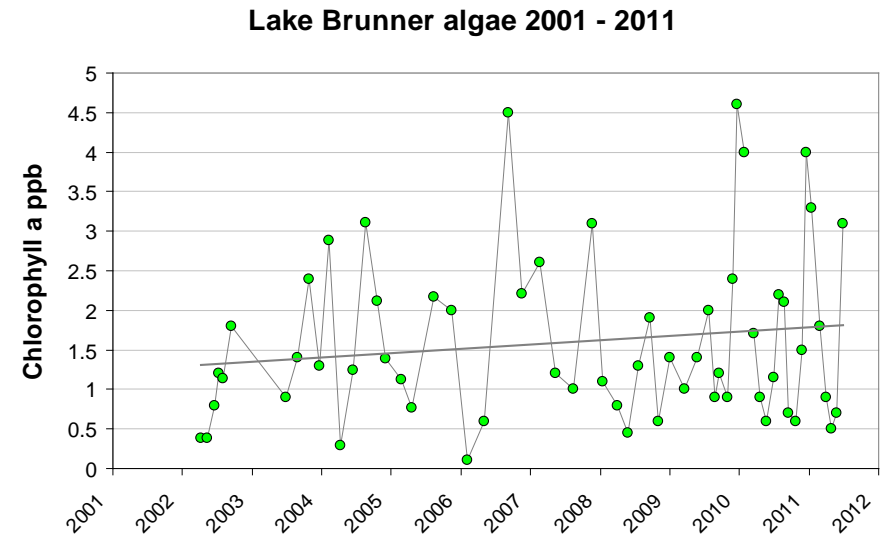
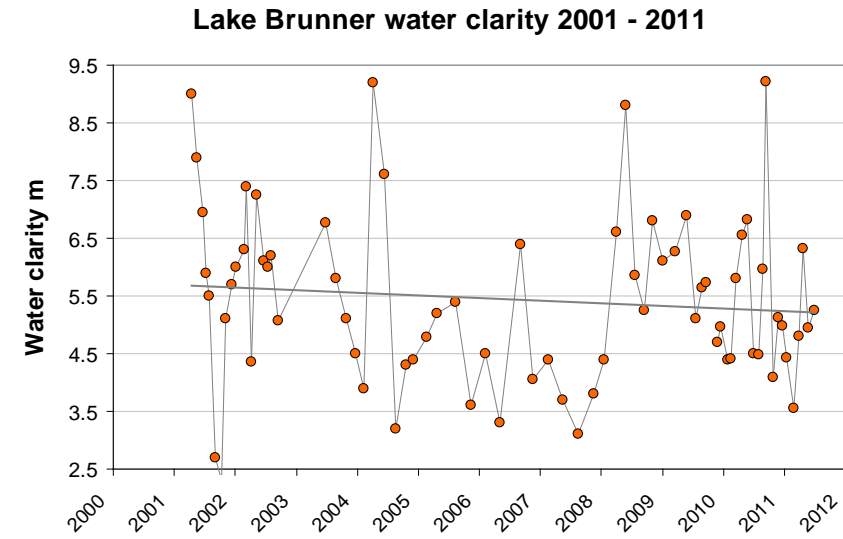


Figure 3a Recent data record for water clarity, total nitrogen, total phosphorus, and phytoplanktonic algal abundance (as indicated by levels of chlorophyll a). Polynomial regression lines are overlaid in grey.

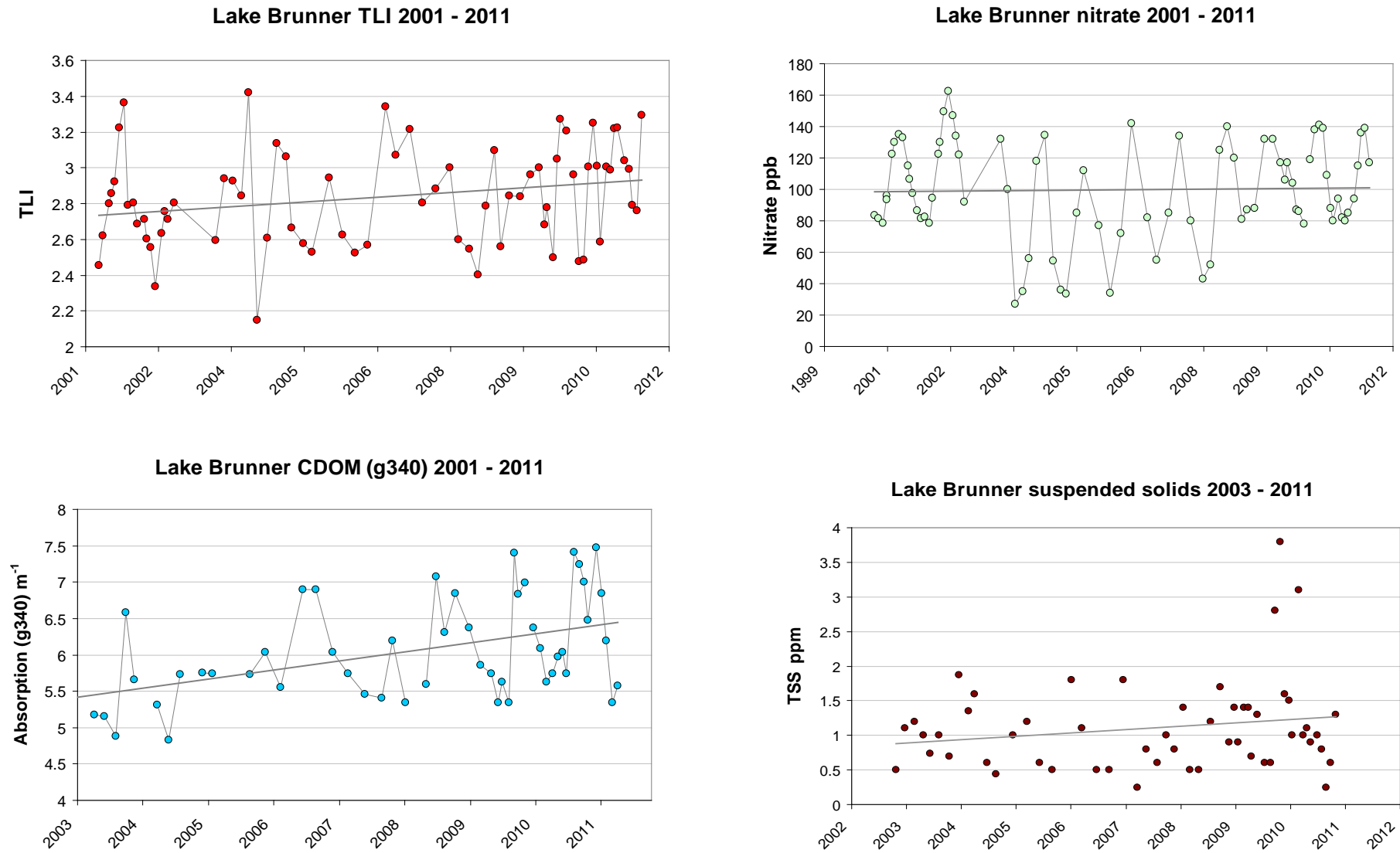
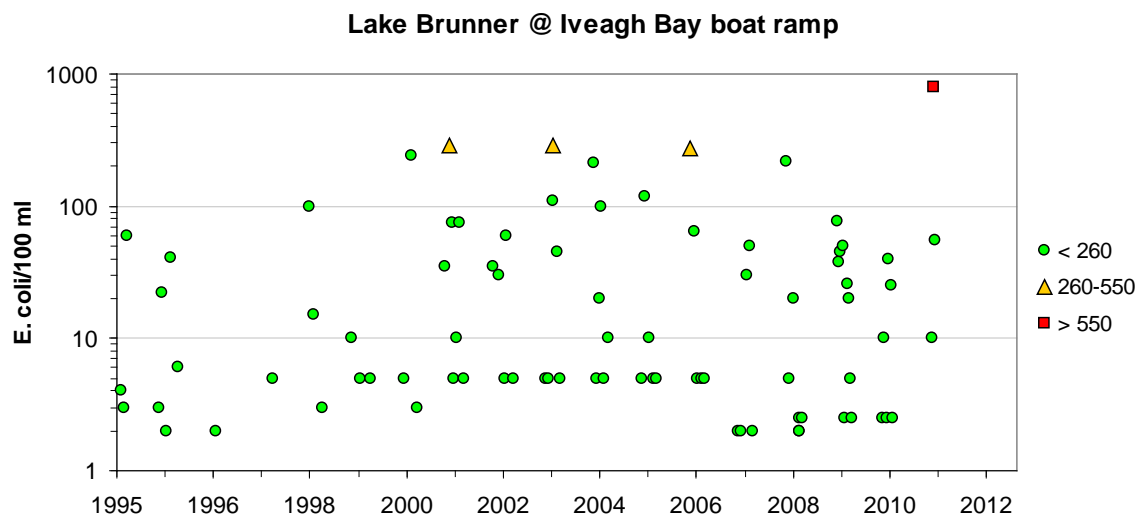
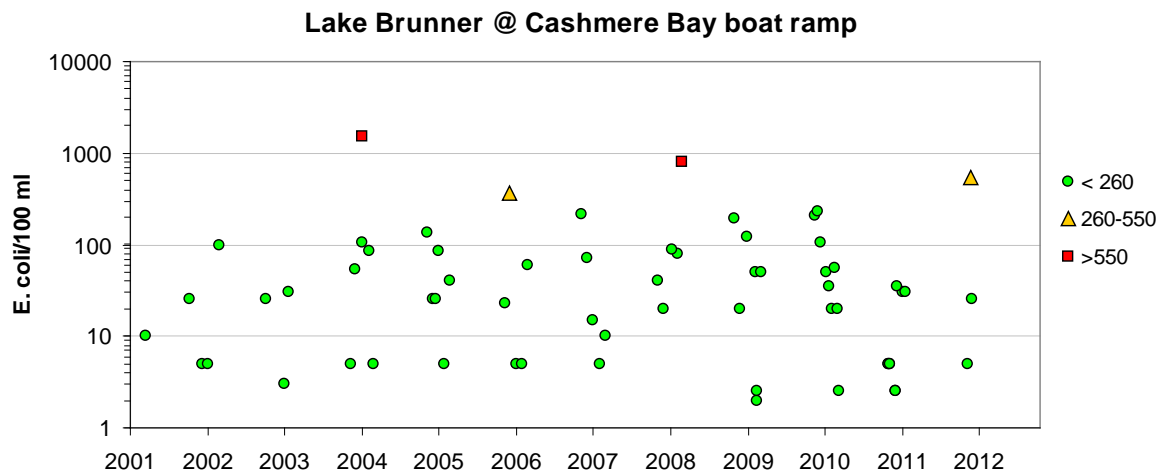


Figure 3b Recent data record for water clarity, total nitrogen, total phosphorus, and phytoplanktonic algal abundance (as indicated by levels of chlorophyll *a*). Polynomial regression lines are overlaid in grey.

Suitability for swimming in the lake

Monitoring of faecal pathogen indicators (*E. coli*) between November and March is conducted each year at Iveagh Bay, Cashmere Bay, and Moana boat ramp. Occasional spikes in these indicators have occurred over time. This is most likely a result of nearby water fowl when samples are collected (based on records of water fowl numbers concurrent with each *E. coli* sample), or significant rainfall events that will cause substantial run-off from surrounding land. The 2011-2012 sampling round was partially completed at the time of writing, and the exceedances during this round occurred as a result of substantial rainfall prior to sampling (Figure 4). Overall, suitability for swimming has been good at these sites, but water fowl and heavy rain can increase disease risk for bathers.



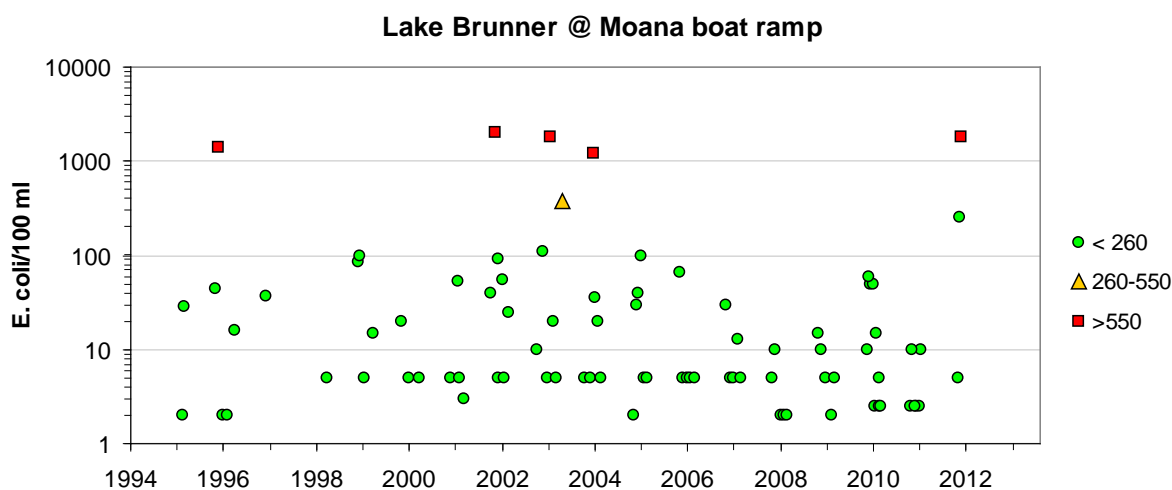


Figure 4 Individual sample results for Lake Brunner contact recreation monitoring sites. Single sample criteria are used; circles indicate acceptable pathogen levels for swimming, triangles indicate low risk, and squares indicate a moderate to high risk for bathing.

Conclusions

Lake Brunner currently remains in an oligotrophic (low nutrient) state, safe for swimming and other recreational activities. Unfortunately water quality has declined since the early 1990's, as indicated by a decrease in clarity, and an increase in nutrients and algal productivity. Fortunately these trends have been less pronounced from 2001 to 2011. It maybe that this degradation has slowed or ceased, or that seasonal variability is masking trends in some of these parameters. For example, clarity – a key water quality benchmark – showed no statistically significant trend from 2001 to 2011. Clarity is driven primarily by algal productivity and CDOM. Both demonstrate increases over the shorter 2001-2010 period, but only the increase in CDOM was significant. Submerged plant surveys between 1982 and 2009 indicated that changes in water quality over this period were not sufficient to alter plant communities in any significant, observable way (refer 2011 WCRC Surface Water Quality Report ¹). While increased nutrient loss from agriculture has been attributed as the reason for increased algal growth, additional research is required to understand more about sources of CDOM.

Comparison of phosphorus inputs from tributaries, to those expected to be retained in the lake and measured in the lake discharge; suggest that there is no significant release of phosphorus from lake sediments. This is good as recycling of lakebed phosphorus could lead to an unstoppable slide to further water quality degradation. Oxygen levels in the lake remain above those considered low enough for phosphorus to be released from the sediments. However, an increasing trend in the hypolimnetic oxygen depletion rate since 1992 has indicated an increase in Lake Brunner's productivity and trophic status. This is supported by significant trends in all the water quality parameters evaluated over this period. Increasing emphasis is now being put on analysis of the shorter, more recent 2001-2011 time frame. It is encouraging that the negative trends observed over 1992-2011 are less pronounced from 2001-2011. However, significant increases in TN, TP, and CDOM, provide evidence to suggest that some decline in Lake Brunner water quality has continued over the last decade.

References

¹ West Coast Surface Water Quality Report. 2011.

<http://www.wcrc.govt.nz/Resources/Documents/Publications/Environmental%20Management/Council%20Monitoring%20Reports/West%20Coast%20Surface%20Water%20Quality%202011.pdf>¹ West Coast

² West Coast Surface Water Quality Report. 2008.

<http://www.wcrc.govt.nz/Resources/Documents/Publications/Environmental%20Management/Council%20Monitoring%20Reports/West%20Coast%20Surface%20Water%20Quality%202008.pdf>