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Water Quality Patterns in the Motupipi River in the Tasman District 2006-2009

RESEARCH BASED SOLUTIONS

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Water Quality Patterns in the Motupipi River in the Tasman District 2006-2009

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EXECUTIVE SUMMARY

Reviews of surface water quality throughout the Tasman District have identified some concerns in the Motupipi Catchment with poor water clarity, low oxygen concentrations and high concentrations of nutrients and faecal indicator bacteria compared with other sites in the district. In an effort to find the causes of the issues that have been identified, the Tasman District Council installed a permanent monitoring station at the Motupipi at Reilly's Bridge site in December 2006. This station records dissolved oxygen (DO) saturation, conductivity, water temperature, air temperature, flow, turbidity and rainfall at 15-minute intervals.

Water quality measurements indicate that the Motupipi River is generally of poor ecosystem health. DO saturation in the Motupipi River ranged from 36% to 168% with an average of 90.9% and showed characteristic annual patterns with greatest daily fluctuations in summer and smallest fluctuations in winter. DO is fundamental to the survival of aquatic life and the 1992 ANZECC guidelines recommended that DO should not normally be permitted to fall below concentrations of 6 mg/L or 80-90% saturation. Daily minimum dissolved oxygen saturations were below 80% for three quarters of the sampling period and below 60% saturation for 12% of the sampling period, indicating substantial concerns with low dissolved oxygen levels for most of the time. Such low DO levels may be affecting aquatic life.

Between December 2006 and August 2010, temperature records showed clear seasonal patterns, with warmer temperatures in summer and cooler temperatures in winter. Temperatures ranged from 8.7 – 20.7 °C. The highest temperature recorded halfway between the daily mean and maximum was 18.8 °C and the lowest 10.3 °C with an average of 13.9 °C. Therefore, the site never exceeded the recommended temperature guidelines for aquatic ecosystem protection and water temperatures are unlikely to be affecting aquatic life in the river.

Turbidity analyses showed that recommended guidelines for contact recreation (*i.e.*, 5.6 NTU) were only exceeded for 2.5% of the time, with the majority of the records (97.5%) being between 1 and 5 NTU. The lowest daily average turbidity recorded was 0.11 NTU and the highest 36.5 NTU. Time trend analyses showed a statistically and ecologically significant decrease (improvement) in turbidity at the site over the monitoring period. Average monthly turbidity was highest in July and November 2008, following major floods and lowest in September 2010.

In addition to more traditional water quality measures, recent advances in indicator development have highlighted the value of including functional measures, such as ecosystem metabolism, for documenting the health of freshwater ecosystems. Ecosystem metabolism can be calculated from continuous DO data and is a measure of the main factors controlling dissolved oxygen dynamics in rivers and also indicates how much organic carbon is produced and consumed in river systems.

Ecosystem metabolism was successfully calculated for a five-day period for each season during the sampling period (*i.e.*, 15 seasons between December 2006 and August 2010). Daily ecosystem respiration (ER) rates ranged from 4.2 gO_2/m^2/day to 19.2 gO_2/m^2/day with an average of 11.8 gO_2/m^2/day, reflecting generally poor ecosystem health. Similarly, daily gross primary production

(GPP) rates ranged from 2.2 gO_2/m^2/day to 15.6 gO_2/m^2/day, with an average of 7.9 gO_2/m^2/day, reflecting satisfactory to poor ecosystem health.

Due to the high percentage of intensive farming in this catchment, water quality guidelines will always be difficult to meet, although considerable improvement is expected through implementing better environmental practice. Despite some better management practices being employed on most farms, there is still more that could be done to benefit water quality of the stream.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

1. INTRODUCTION

Reviews of surface water quality throughout the Tasman District have identified some concerns in the Motupipi Catchment with poor water clarity, low oxygen concentrations and high concentrations of nutrients and faecal indicator bacteria compared with other sites in the district (Young *et al.* 2010). In order to explore management possibilities for an improvement of water quality at the Motupipi River, Tasman District Council (TDC) engaged Cawthron to advise the council on options for how to best analyse continuous water quality data from the Motupipi River. The data was recorded using a permanent water quality monitoring station which was installed by the TDC at the Motupipi at Reilly's Bridge site in December 2006. This station records DO saturation, conductivity, water and air temperature, flow, turbidity and rainfall at 15-minute intervals.

Dissolved oxygen is fundamental to the survival of aquatic life and the 1992 ANZECC guidelines recommended that dissolved oxygen should not normally be permitted to fall below 6 mg/L or 80-90% saturation (ANZECC 1992). The amount of oxygen required by aquatic animals is quite variable and depends on species, size, activity, water temperature, condition, and the DO concentration itself (Boyd 1990). Thus, some species are more sensitive to low levels of oxygen than others. Concentrations of less than 80% saturation, for instance, are known to adversely affect trout (*i.e.*, feeding and growth) and less than 30% saturation (hypoxic) may result in fish deaths (ANZECC 1992; Dean & Richardson 1999). Dean & Richardson (1999) showed that minimum DO levels for some native fish species such as banded kokopu, torrentfish, common smelt and common bully were similar to those of trout, allowing the minimum DO saturation levels for trout (*i.e.*, 80% saturation; Mills 1971) to be used as guidelines for these native fish species (Dean and Richardson 1999). Furthermore, Young (2002) studied the DO tolerance of inanga juveniles and koaro, and showed that all inanga juveniles tested survived three days at 60% saturation and koaro seven days at 50% saturation. However, fish mortality clearly increased once oxygen saturation dropped below 50% for both species (Young 2002).

Water temperature also plays an important role for stream health with the main concerns being the effects of high temperatures on aquatic life. Some species will only tolerate relatively cool water and may become stressed or die if temperatures become too high. For example, laboratory studies indicate that brown trout growth is optimal at 14°C - 17°C (Elliott 1994). However, trout will cease feeding once temperatures climb above 19°C and they will begin to die once temperatures climb above 25°C for a sustained period (Elliott 1994; Jowett *et al.* 1997). Trout cannot tolerate temperatures above 30°C for even a short period.

Highly turbid water is filled with fine suspended sediments that can settle out in the bed of waterways and fill the spaces between the stones in the bed (interstices) displacing invertebrates, and also causing degradation of fish spawning grounds, and damage to fish gills. Turbidity is also highly correlated with visual clarity which strongly affects the contact recreation and visual amenity of rivers for people and the ability of fish to find their food (Davies-Colley *et al.* 2004). Fine suspended particles can also act as carriers of pollutants and/or nutrients which in high concentrations may influence water chemistry and survival of aquatic life. Turbidity in waterways should therefore be kept as low as possible.

In addition to more traditional water quality measures, research has shown that ecosystem metabolism - the combination of algal productivity (photosynthesis) and ecosystem respiration – is a useful functional indicator of river ecosystem health (Young *et al*. 2008). Ecosystem metabolism is a measure of the main factors controlling dissolved oxygen dynamics in rivers and indicates how much organic carbon is produced and consumed in river systems. Concentrations of DO in the water are critical components affecting the life supporting capacity of a river system. DO concentrations are affected by three key processes – 1) oxygen production associated with photosynthesis of algae and aquatic plants, which raises the oxygen concentrations within the water, 2) oxygen uptake associated with respiration of all river life including fish, invertebrates, algae, aquatic plants and microbes, which lowers the oxygen concentrations in the water, and 3) oxygen diffusion through the water surface, which can either raise or lower oxygen concentrations. Rates of ecosystem metabolism can be measured by monitoring the daily changes in oxygen concentration at a site. Dissolved oxygen concentrations rise during the daytime, when sunlight facilitates photosynthesis, and then decline during the night, when only respiration is occurring.

This report aims to allow TDC to effectively analyse the data collected from the permanent monitoring station and will help to refine future water quality monitoring efforts at the Motupipi at Reilly's Bridge site and potentially at any other sites in the District where permanent water quality monitoring stations are installed. The advice will be used to decide on appropriate analysis techniques for permanent water quality monitoring, thus potentially guiding enhanced land management and river health.

2. METHODS

2.1 Study sites and data quality

Environmental data were investigated for the Motupipi River at Reilly's Bridge site in the Tasman District (Figure 1). The Motupipi, with its tributaries of Watercress, Powell, McConnon, Berkett and Dry Creeks, have consistently the second highest concentrations of nutrients of any waterway in the district (median in lower catchment is 1.25 g/m3) *(Young et al.* 2010). This is one of the main reasons for the extensive growths of filamentous green algae (particularly upstream of Powell Creek) and algal blooms near the Abel Tasman Drive bridge. The major source of these nutrients is groundwater that emerges as springs (particularly the karst springs) in the mid-reaches and headwaters of the Motupipi with pasture run-off also contributing (James & Stevens 2008). The source of the nitrate in these springs is currently under investigation. The karst spring water feeding the Motupipi near Sunbelt Crescent has been aged at 6-7 years using tritium and sulphur hexafluoride dating methods (Van der Raaij & Stewart 2010). This suggests either a source relatively remote from the Motupipi River or very low groundwater permeability slowing down travel times. Due to these increased nutrient concentrations, aquatic plant growth rates and oxygen uptake rates in the Motupipi River are higher than many other streams draining intensive agriculture in New Zealand and internationally (Young 2006).

Fine sediment deposits in this stream are heavy with an average layer of 200-300 mm over the original cobble bed and a layer over 1.2 m thick for a 450 m reach downstream of Powell Creek. Stormwater from a drain originating in the Takaka township was found to be contaminated with high concentrations of copper, chromium and zinc (all over an order of magnitude higher than ANZECC guidelines for 90% level of protection). Sediment sampling in this drain was also above guidelines for zinc and chromium (zinc was above ANZECC ISQG-high; ANZECC 1992). Macroinvertebrate data indicates poor or very poor water quality in the lower and upper reaches of the main stem and lower Powell Creek catchment. The upper Powell Creek site had good macroinvertebrate condition.

The data supplied by TDC included 15-minute measurements of DO saturation (%), water and air temperature (°C), conductivity (µS/cm), turbidity (NTU), rainfall (mm) and flow (m3/s) between December 2006 and August 2010. DO concentration (mg/L) was calculated from the oxygen saturation data, water temperature and site altitude using equations from APHA (1992). Salinity was assumed to be zero at all sites on all occasions. Data analysis was dependent on the quality of the data provided by TDC. TDC staff check the oxygen loggers every 12-16 weeks and measure DO saturation and conductivity using an independent calibrated meter (YSI). Turbidity was calibrated using laboratory analysed samples.

Prior to analyses, the data was post-processed by TDC. For turbidity, this included the removal of outliers and correcting for drift in the baseline due to lens fouling. The *in-situ* conductivity meter consistently read 70 µS/cm lower than the hand-held YSI meter and was corrected by +72 µS/cm for analyses. There were no corrections applied by TDC for DO concentration, however, small gaps (< 1 hour) in the data were filled by interpolation using a moving average smooth with an interval of five measurements.

Graphs of the complete data set were inspected to determine suitable periods for ecosystem metabolism calculations. Criteria for data selection were:

- The oxygen data showed clear daily patterns (small gaps <1 hour were filled by interpolation),
- Flows were relatively stable.

The exact periods chosen varied amongst seasons which were categorised as followed:

- Summer (December, January, February)
- Autumn (March, April, May)
- Winter (June, July, August)
- Spring (September, October, November).

A detailed list of the periods used for analyses and their results can be found in Appendix 1.

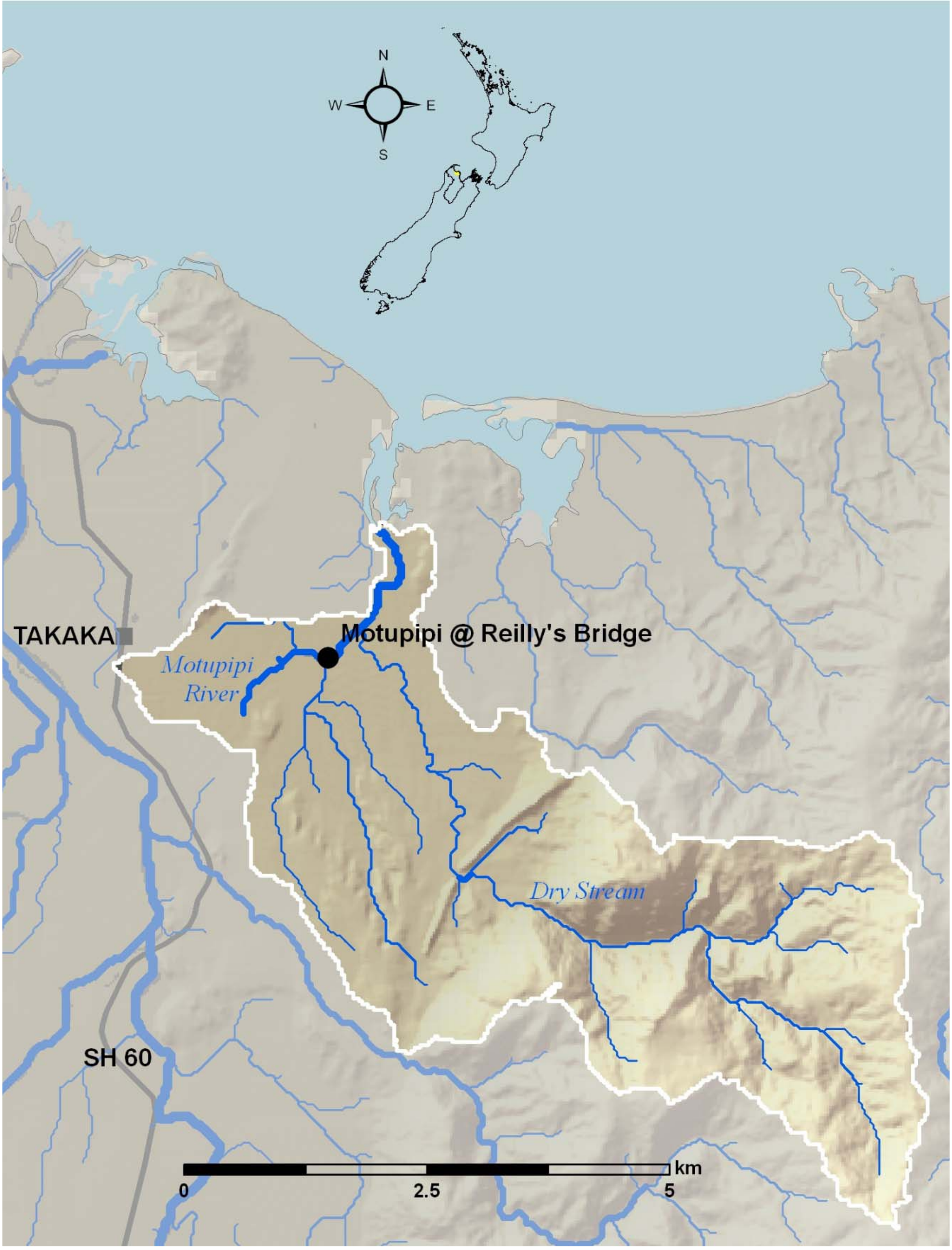

Figure 1. **Location of the permanently installed surface water quality monitoring station in the Motupipi River Catchment. The river network shown is from the River Environment Classification (REC; Snelder *et al.* 2004).**

2.2 Metabolism analysis

Before analysis, random noise in each data set was removed/reduced using a moving average smooth with an interval of five measurements. Metabolism values were then calculated using the RiverMetabolismEstimator spreadsheet model (version 1.2) developed by Young & Knight (2005). This model uses the following approach to calculate metabolism values. Mean daily ecosystem respiration (ER) and the reaeration coefficient (k) were determined using the night time regression method (Owens 1974), which uses only data collected in the dark ($< 2\ \mu mol/m^2/s$). Light data were not available, so the night time period was determined by examining the oxygen data. Night time typically is the period between the fastest recorded reduction in oxygen concentration (dusk) and the highest recorded oxygen deficit (difference between the oxygen concentration at saturation and the observed concentration in the water) which occurs at dawn. The rate of change of oxygen concentration over short intervals during the night is regressed against the oxygen deficit to yield:

$$dO/dt = ER + kD \tag{1}$$

where dO/dt is the rate of change of oxygen concentration ($g/m^3/s$), ER is the ecosystem respiration rate ($g/m^3/s$), k is the reaeration coefficient (s^{-1}), and D is the oxygen deficit (g/m^3). The slope of the regression line estimates k and the y-intercept estimates ER (Kosinski 1984).

The reaeration coefficient and ecosystem respiration rate obtained are then used to determine gross photosynthetic rate over the sampling interval using:

$$GPP_t = dO/dt + ER - kD \tag{2}$$

where GPP_t is the gross photosynthetic rate ($g/m^3/s$) over time interval (t). To compensate for daily temperature fluctuation, ER is assumed to double with a 10°C increase in temperature (Phinney & McIntire 1965), while the reaeration rate is assumed to increase by 2.41% per degree (Kilpatrick *et al.* 1989). Daily gross primary production (GPP, $g/m^3/day$) is estimated as the integral of all temperature corrected photosynthetic rates during daylight (Wiley *et al.* 1990).

This analysis gives values of production and respiration per unit volume. An areal estimate is obtained by multiplying the volume based estimates by average reach depth (m) which allows comparison among stations with different depths. Average water depth was provided by TDC staff. For each calculation the following parameters were recorded:

- Average water depth
- Gross primary productivity (GPP)
- Ecosystem respiration (ER)
- Reaeration coefficient (k)
- R2 value of the regression used to calculate ER and k

- Timing of dusk and dawn

Analysis of Variance (ANOVA) was used to compare metabolism results among seasons and years.

3. RESULTS

3.1 Flow

Flow ranged from 0.2 m^3/s (26/04/2007) to 7.2 m^3/s (24.11.08) with an average of 0.45 m^3/s (Figure 2). Highest flows occurred on 23rd November 2008 when water from the flooded Takaka River contributed to flows in the Motupipi (Figure 3). Other high flows were linked with rainfall in the Motupipi Catchment itself. Turbidity was positively correlated with flow (Figure 4), although the relationship was weak (R^2 = 0.29).

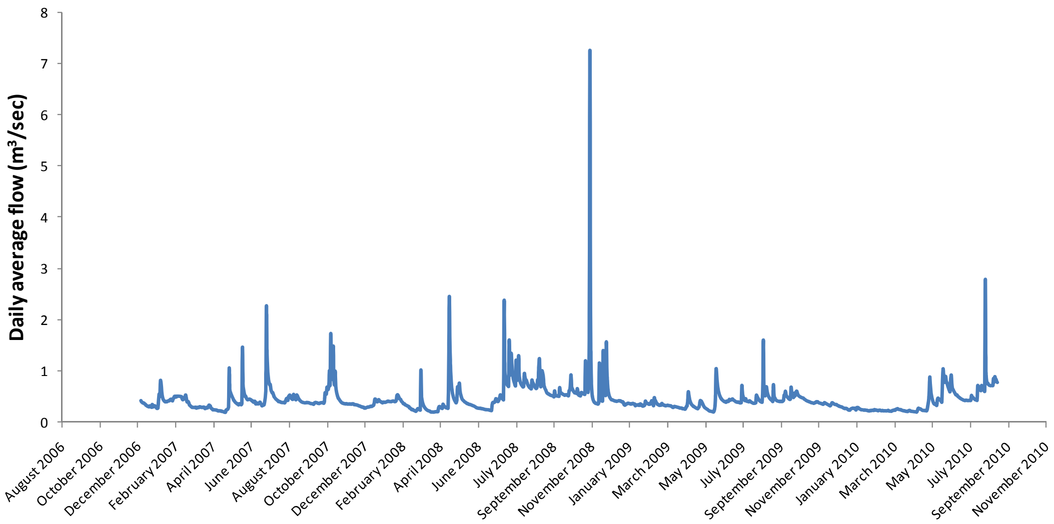

Figure 2. Daily average flow recorded between December 2006 and August 2010 at Motupipi at Reilly's Bridge.

Figure 3. **Overflow from the Takaka River to the Motupipi during a flood in November 2008.**

3.2 Turbidity

Turbidity analyses showed that recommended guidelines for contact recreation (*i.e.*, 5.6 NTU) were only exceeded for 2.5% of the time, with the majority of the records (97.5%) being between 1 and 5 NTU (Figure 5). The lowest daily average turbidity recorded was 0.11 NTU (12/08/2010) and the highest 36.5 NTU (23/07/2009). Average monthly turbidity was highest in July and November 2008, following major floods and lowest in September 2010.

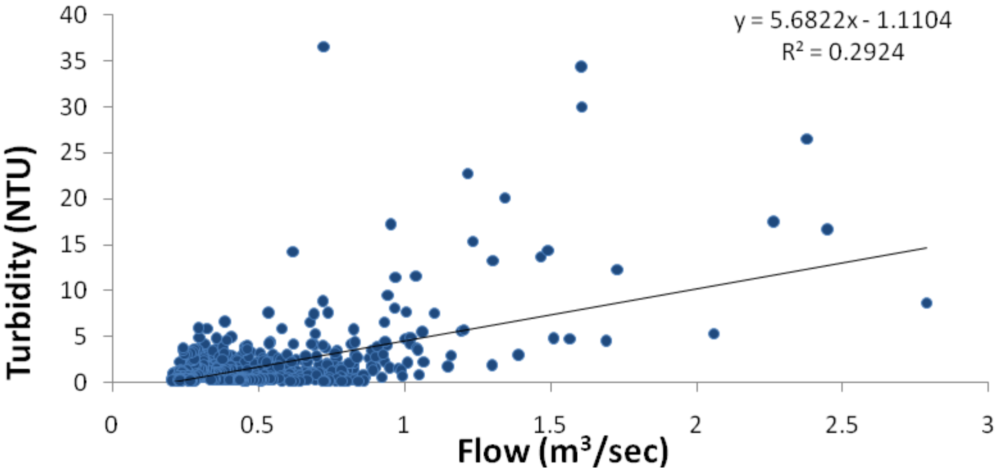

Figure 4. **Relationship between average daily turbidity and average daily flow in the Motupipi River at Reilly's Bridge.**

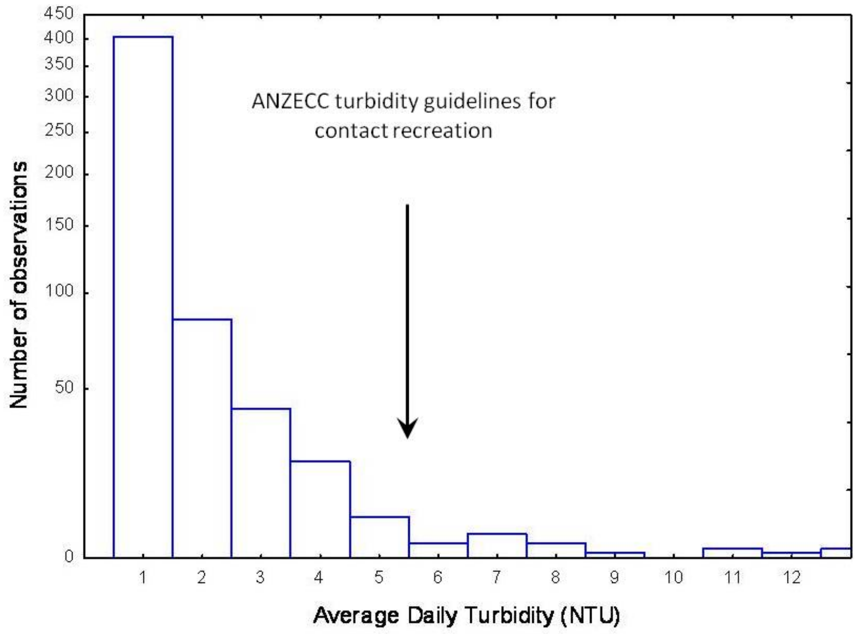

Figure 5. Frequency of average daily turbidity recorded between December 2006-August 2010. Note: The Y-axis is on a log scale.

3.3 Dissolved oxygen saturation

DO saturation ranged from a minimum of 36% (March 2008/January 2010) to 186% (September 2007) with a median of 90.8%. Annual changes in DO saturation had characteristic patterns for each season and daily fluctuations were greatest in summer and smallest in the winter (Figure 6). Daily minimum dissolved oxygen saturations were below 80% for more than three quarters (76%) of the sampling period and below 60% saturation for 12% of the sampling period, indicating substantial concerns with low dissolved oxygen levels for most of the time. DO saturation was especially low during summer, autumn and spring 2008, with minimum dissolved oxygen levels continually below 80% during these seasons. Minimum dissolved oxygen saturation levels breached the 60% DO guidelines during seven of 15 seasons over the period from December 2006, with no breaches so far recorded in 2010 (Table 1).

Statistical analyses showed significant differences in DO among seasons ($P < 0.001$) and years ($P < 0.001$).

Table 1. **Range in dissolved oxygen data at Motupipi at Reilly's Bridge, calculated between December 2006 and August 2010.**

Year	Season	DO Sat (%) Min	DO Sat (%) Max	% of daily minimum measurements <60%	% of daily minimum measurements <80%
2006	Summer	50	158	43	100
2007	Summer	44	151	78	100
	Autumn	51	134	17	97
	Winter	76	149	0	12
	Spring	63	168	0	70
2008	Summer	53	146	13	100
	Autumn	36	122	22	100
	Winter	65	121	0	87
	Spring	53	142	2	100
2009	Summer	36	142	14	100
	Autumn	60	133	0	98
	Winter	72	111	0	26
	Spring	64	139	0	79
2010	Autumn	67	150	0	76
	Winter	77	117	0	2

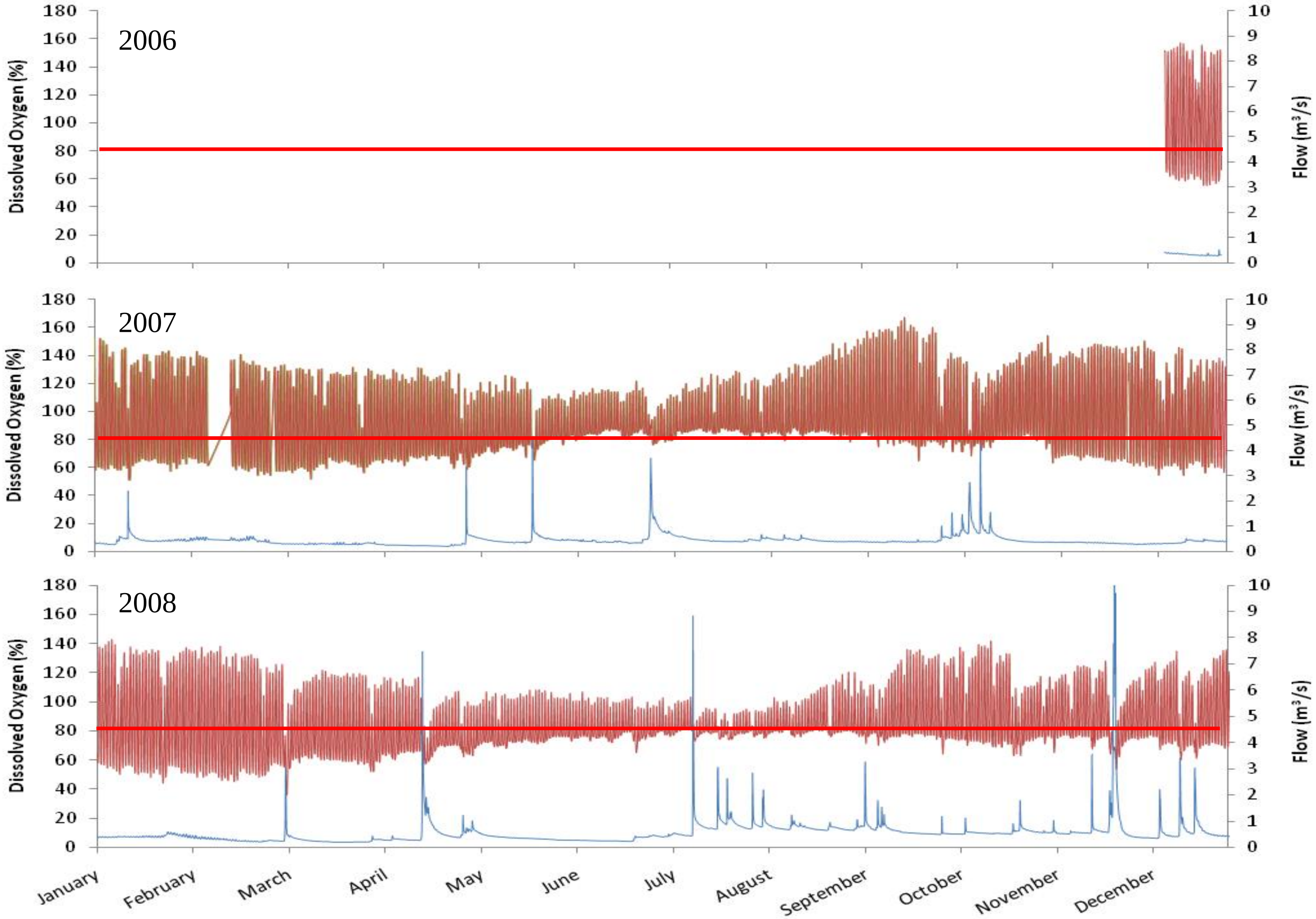

Figure 6. **Annual changes in dissolved oxygen (% saturation) and flow (m^3/s) at Motupipi at Reilly's Bridge for the years (top to bottom) 2006 - 2010. The red lines indicate dissolved oxygen saturation guidelines (i.e., everything below 80% saturation is considered poor quality.)**

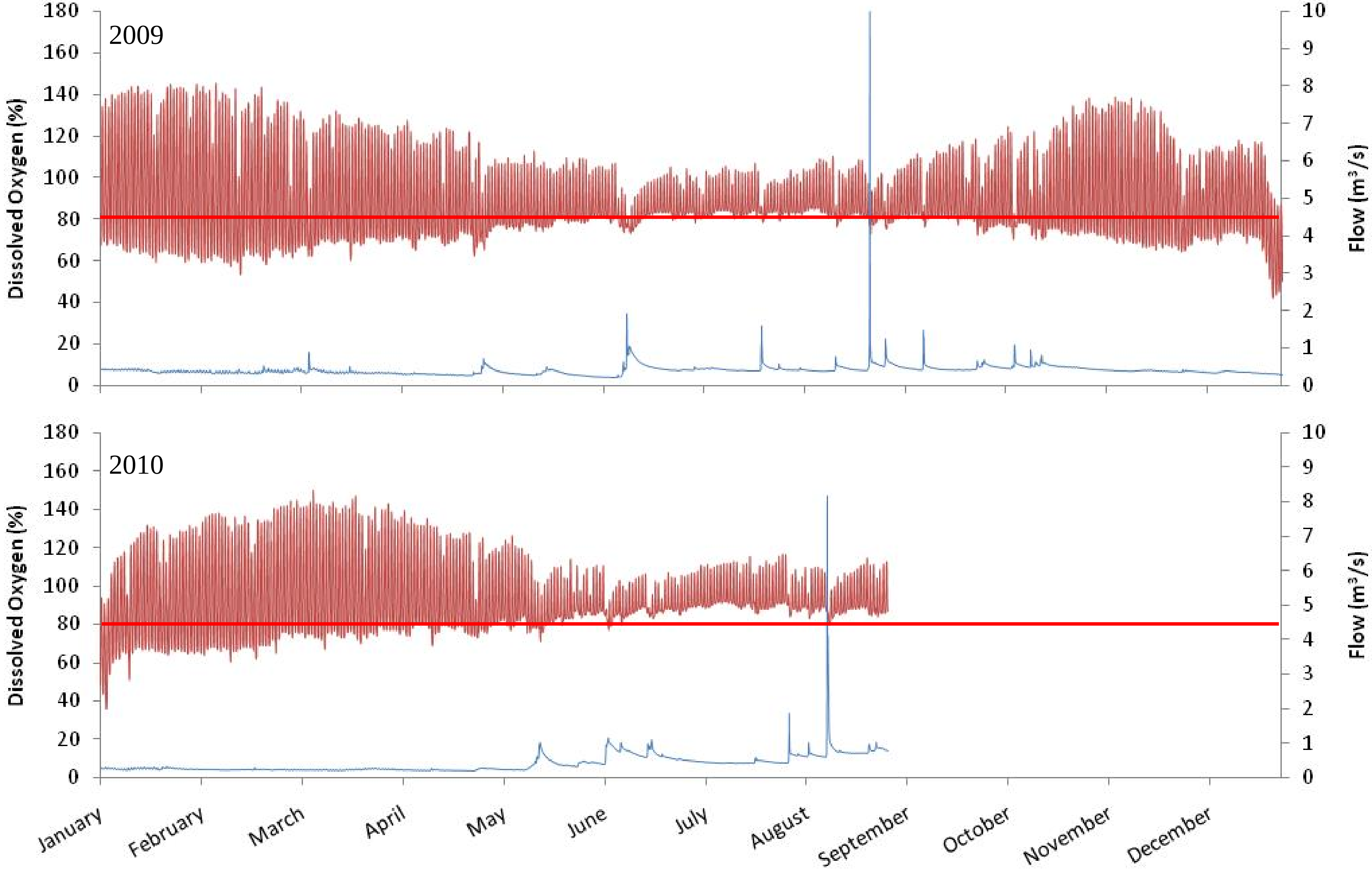

Figure 6. **Contd. Annual changes in dissolved oxygen (% saturation) and flow (m^3/s) at Motupipi at Reilly's Bridge for the years (top to bottom) 2006 - 2010. The red lines indicate dissolved oxygen saturation guidelines (i.e., everything below 80% saturation is considered poor quality.)**

3.4 Ecosystem Metabolism

Ecosystem metabolism metrics were successfully calculated for each season and year between December 2006 and August 2010 (Figure 7). Daily gross primary production (GPP) rates ranged from 2.2 gO2/m2/day (25/08/2010, winter 2010) to 15.6 gO2/m2/day (summer 2009, 25/02/2010), with an average of 7.9 gO2/m2/day, reflecting satisfactory to poor ecosystem health using the criteria from Young et al. (2008). Daily ecosystem respiration (ER) rates ranged from 4.2 gO2/m2/day (winter 2010, 25/08/2010) to 19.2 gO2/m2/day (summer 2008, 24/02/2008) with an average of 11.8 gO2/m2/day, reflecting generally poor ecosystem health (Young *et al.* 2008).

Analyses showed significant differences in GPP among seasons (F_5=28.52, $P < 0.001$) and a significant interaction between seasons and years (F_6=4.94, $P < 0.001$), indicating that differences in GPP among seasons varied from year to year. Although there was no consistent difference among years (F_3=2.63, P=0.056), 2007 and 2008 appear to have relatively high GPP values compared to 2010. It needs to be considered, however, that data for 2010 only include autumn and winter and therefore do not represent values for the entire year.

Analyses for ER showed significant differences among seasons (F_5=20.48, $P < 0.05$) and a significant interaction between seasons and years (F_6=3.27, $P < 0.05$). However, unlike GPP, there was also a significant difference among years (F_3=3.03, $P < 0.05$).

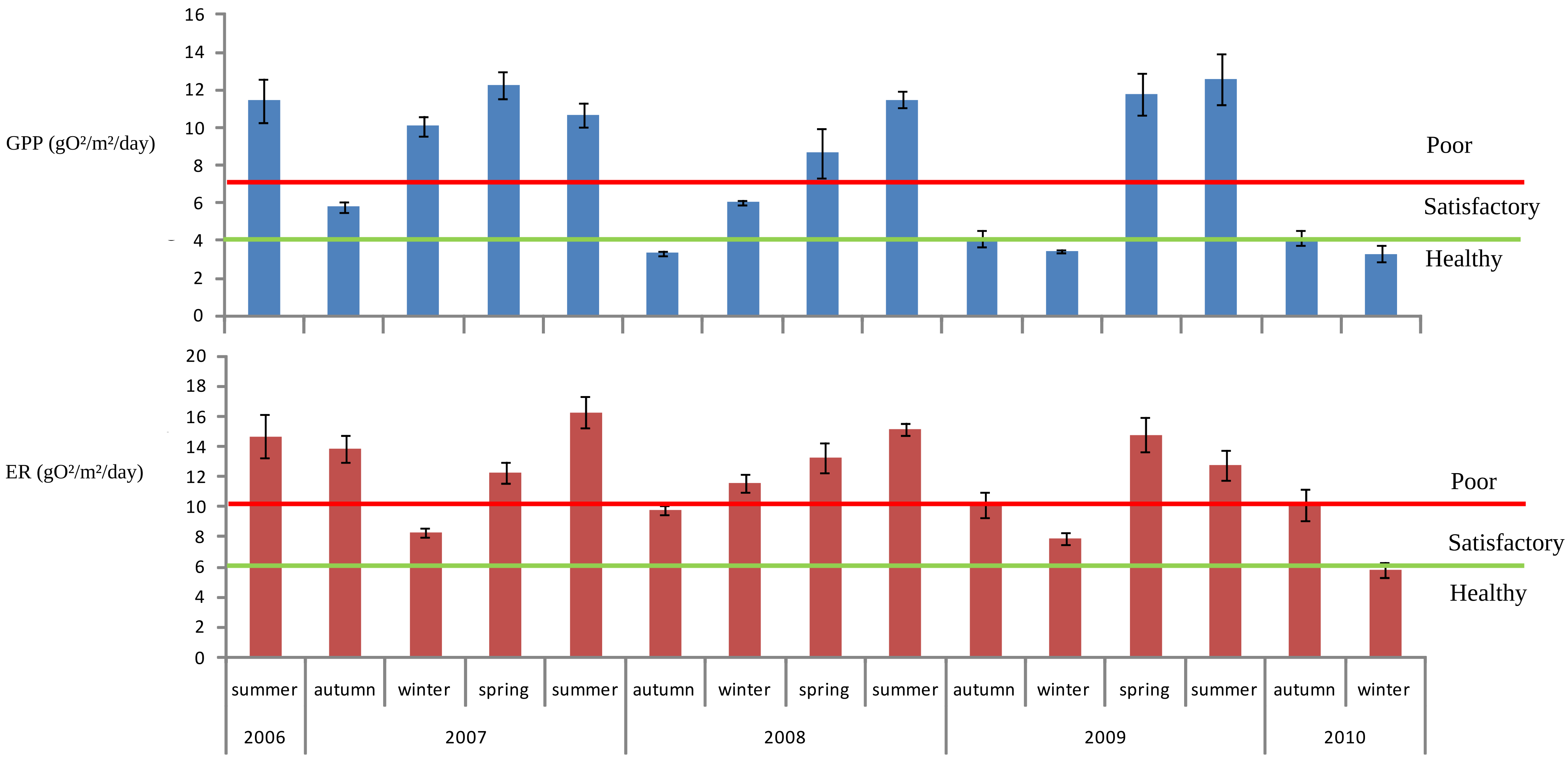

Figure 7. **Average gross primary production and respiration for Motupipi at Reilly's Bridge between August 2006 and September 2010. SE bars were calculated using seasonal average measurements for each year over the available record. Note: seasons were categorised as summer = December, January, February; autumn = March, April, May; winter = June, July, August; spring = September, October, November.**

3.5 P/R ratio

The balance between GPP and ER is a useful measure of the sources of energy driving a stream ecosystem (Odum 1956). If GPP equals or exceeds ER, then organic matter produced within the system is probably supporting the food chain, whereas if ER greatly exceeds GPP, then organic matter from upstream or the surrounding catchment is being used to maintain the ecosystem. The ratio of GPP:ER (or P/R) for the Motupipi River ranged from 0.25 (22/11/2008) to 1.28 (26/08/2007). Most of these values were within the range expected for healthy river systems according to Young *et al.* (2008) (*i.e.*, < 1.2), except in winter 2007 where the ratio exceeded the threshold (red bar in Figure 8). The P/R ratios indicate that the site was often relying on, at least, some organic matter from upstream or the surrounding catchment to support the food chain (*i.e.*, values < 1), although the relatively high ratios in winter 2007 indicate that algal and macrophyte production alone may be sufficient to support the food chain at times (*i.e.*, values >1).

The P/R ratio can be regarded as a good indicator for some stressors (*e.g.*, riparian vegetation removal, Young *et al.* 2008). However, the P/R ratio appears to be an insensitive measure of stream health for other stressors. One of the main issues with the ratio is that the same P/R value can apply to vastly different systems. For example, a P/R ratio of 0.5 could be calculated from a GPP value of 10 gO2/m2/day and an ER value of 20 gO2/m2/day (both indicative of poor health), and also a GPP value of 0.5 gO2/m2/day and an ER value of 1 gO2/m2/day (both indicative of good health). This means that the P/R ratio needs to be interpreted with caution and should always be integrated with the actual values of GPP and ER.

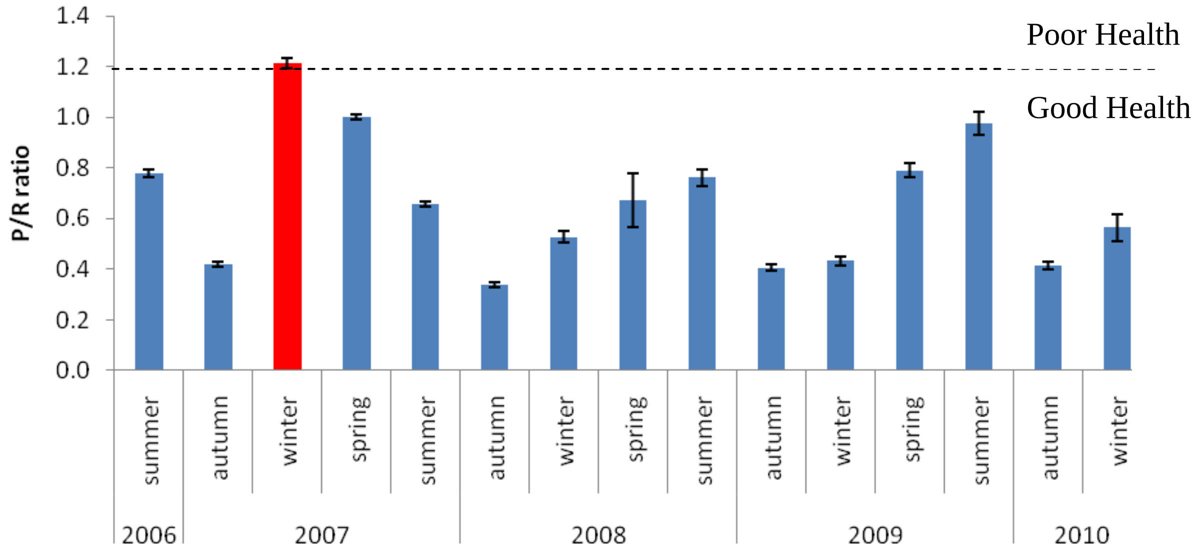

Figure 8. The average ratio of GPP:ER at Motupipi at Reilly's Bridge between December 2006 and August 2010.

The red bar indicates conditions above the 1.2 ratio threshold for healthy river systems. SE bars were calculated using seasonal average measurements for each year over the available record.

3.6 Reaeration coefficient

A useful by-product of metabolism calculations is an assessment of the reaeration coefficient, which provides an indication of the potential for gas exchange through the surface of a river. As mentioned previously, a shallow turbulent stream has a high reaeration coefficient (> 20 day-1), whereas a deep slow flowing river has a low reaeration coefficient (<3 day-1). Average reaeration coefficients ranged from 4.2 day-1 (23/02/2007) to 18.1 day-1 (28/05/2007) with a relatively high average of 11.9 day-1, reflecting the fact that the system is small and relatively shallow.

3.7 Trends over time

Trends were determined using non-parametric Seasonal Kendall trend statistics, which compute the slope (or magnitude) and significance of any trends in the data. As the name suggests, seasonal variations (*i.e.*, up to 12 seasons per year) in measurements are accounted for by this technique. These statistics have been used previously in New Zealand to analyse water quality trends in the records from the National River Water Quality Network, and are described fully in Smith *et al.* (1996) and Ballantine and Davies-Colley (2009). We used NIWA's Time Trends programme (Version 3.00) to analyse the raw data for significant trends in water quality and ecosystem metabolism.

To obtain statistically (i.e., P-value < 0.05) and ecologically meaningful data (*i.e*., Relative Seasonal Kendall Slope Estimator (RSKSE >1 % yr-1), a minimum of three years of data are recommended (Stark & Fowles 2006). Monthly average values were calculated for each parameter before analyses. Water temperature, conductivity, flow, dissolved oxygen, turbidity, ER and GPP were tested for trends, however, only turbidity showed a statistically significant decrease (P=0.02, RSKSE = -13.82%) over the last three years and ten months (Figure 9).

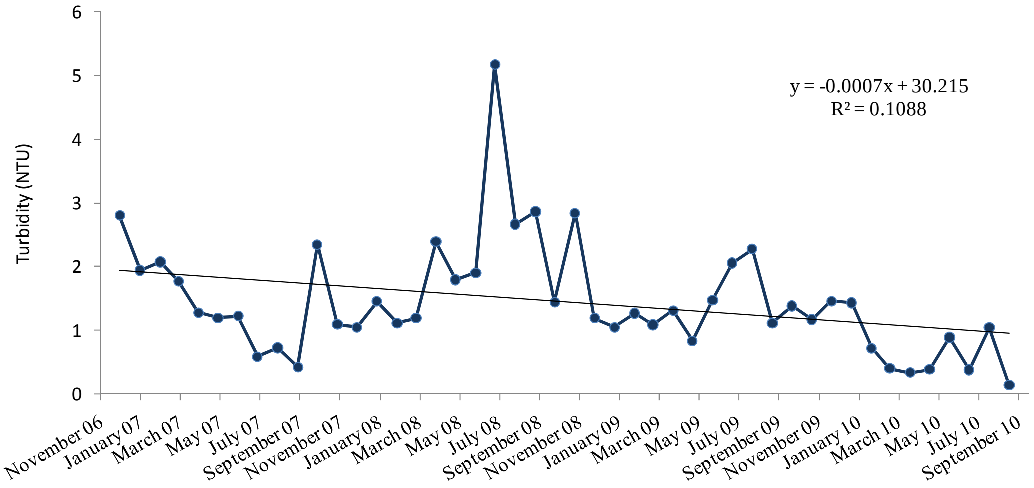

Figure 9. Trend in turbidity (monthly average) over time from 13/12/2006 to 01/09/2010 at Motupipi at Reilly's Bridge. Mean seasonal Kendall Slope Estimator per year = -13.82%.

4. DISCUSSION

Water quality measurements indicate that the Motupipi River is generally of poor ecosystem health. GPP and ER values measured since December 2006 have been indicative of poor ecosystem health for > 50% of the time, particularly in spring and summer. Catchment land use is often the main factor affecting river health (Quinn & Hickey 1990; Young *et al.* 1994; Harding & Winterbourn 1995; Quinn *et al.* 1997; Young & Huryn 1999; Parkyn & Wilcock 2004; Suren & Elliott 2004). Therefore we would predict that waterways such as the Motupipi River, which are dominated by rural land use, would have impaired health. The metabolism results for the Motupipi River site support this hypothesis, with consistently high rates of GPP and ER.

The most marked divergence from healthy conditions was expected to occur during summer and autumn when low flows, warm temperatures, plentiful sunlight and accumulation of algal biomass combine to produce high rates of metabolism. This pattern was found throughout the sampling period, where production rates in summer exceeded the poor health threshold, while autumn rates were ranked between healthy and satisfactory.

Although there were no significant trends identified for metabolism measures over the last three years and ten months, water quality analysis showed a significant decrease in turbidity. If the cause/s of the trend can be determined, then one may be able to predict the future with some confidence. Conversely, if one cannot determine why a trend has occurred, the extrapolation into the future may be most unwise, because the trend may simply be an artefact. A potential reason for the observed decrease in turbidity could be the high flood flow in November 2008. Although turbidity levels first increased due to high flow, the flushing out of fine sediments during the flood event caused turbidity levels to decrease in the long-term.

High rates of ecosystem metabolism are often associated with low dissolved oxygen concentrations, potentially reducing the life supporting capacity of an ecosystem. High algal densities caused by high nutrient concentrations in the system can, for example, cause hypoxic conditions when periphyton mats mature and decompose, resulting in life threatening conditions for some fish. DO concentrations were below the 80% saturation threshold for 76% of the sampling period, with a critically low minimum concentration of 36%. Especially during the summer periods, minimum daily DO saturation values were continuously below the 80% threshold, indicating particularly poor stream health during this time of the year, and potentially threatening aquatic life within this system.

Warm water temperatures are a common stressor in lowland rivers throughout New Zealand. However, the monitoring in the Motupipi River suggests that temperatures are within the preferred range for many sensitive species and thermal limits are never breached. The spring-fed nature of the Motupipi River is undoubtedly the cause of this moderate thermal regime. Water temperature is clearly not the cause of the degraded macroinvertebrate community in the river (Young *et al.* 2010).

Due to the high percentage of intensive farming in this catchment (almost 40% of the land area), water quality guidelines will always be difficult to meet, although considerable improvement is expected through implementing better environmental practice. Despite some better management practices being employed on most farms, there is still more that could be done to benefit water quality of the stream. An effective method is the installation of wetlands in key locations to filter run-off and seepage from the land.

5. RECOMMENDATIONS

1. Maintain the existing surface water quality monitoring station to obtain continuous water quality measurements.
2. Continue with the regular maintenance and calibration regime to ensure that high quality data is collected. Ideally this would involve monthly visits, particularly over the sensitive summer period.
3. Continue restoration efforts (*e.g.*, fencing off and replanting riparian areas) in the catchment to minimise run-off and seepage from upstream land-use.
4. Consider automated calculation of ecosystem metabolism from the study site.

6. ACKNOWLEDGEMENTS

We thank Trevor James (TDC) for initiating this study and Matt McLarin (TDC) for providing the raw data in a format that was easy to analyse. This study was funded by Envirolink Small Advice Grant (943-TSDC 76).

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8. APPENDICES

Appendix 1. Metabolism records for the Motupipi River between 2007 and 2010.

Season	Date	k	Depth (m)	ER ($gO_2/m^2/day$)	GPP ($gO_2/m^2/day$)	R^2
Summer	20/02/07	9.0	0.45	19.2	14.8	0.9
Summer	21/02/07	7.6	0.46	16.1	12.7	0.9
Summer	22/02/07	6.8	0.46	14.4	11.9	0.9
Summer	23/02/07	4.2	0.45	10.6	8.1	0.8
Summer	24/02/07	6.0	0.44	13.1	9.7	0.9
Autumn	26/05/07	13.7	0.43	14.5	5.7	0.7
Autumn	27/05/07	15.8	0.43	15.3	6.0	0.7
Autumn	28/05/07	18.1	0.43	16.0	6.7	0.6
Autumn	29/05/07	14.0	0.42	11.6	5.0	0.7
Autumn	30/05/07	14.5	0.42	11.9	5.4	0.9
Winter	22/08/07	13.5	0.36	7.9	9.1	0.8
Winter	23/08/07	13.5	0.36	7.7	9.1	0.9
Winter	24/08/07	14.7	0.35	8.3	10.1	1.0
Winter	25/08/07	14.3	0.35	8.3	10.1	0.9
Winter	26/08/07	15.4	0.35	9.4	12.0	0.9
Spring	24/11/07	9.4	0.33	13.2	13.2	1.0
Spring	25/11/07	8.3	0.33	11.9	11.6	0.9
Spring	26/11/07	9.1	0.33	12.2	12.6	0.9
Spring	27/11/07	6.9	0.33	9.9	9.8	0.9
Spring	28/11/07	10.5	0.33	14.1	14.1	0.9
Summer	24/02/08	11.7	0.31	19.2	12.6	1.0
Summer	25/02/08	10.8	0.32	16.9	10.5	0.9
Summer	26/02/08	11.5	0.32	17.4	11.4	0.9
Summer	27/02/08	9.5	0.31	14.4	10.0	0.9
Summer	28/02/08	8.8	0.31	13.5	8.8	0.9
Autumn	26/05/08	11.0	0.32	9.7	3.6	0.8
Autumn	27/05/08	12.2	0.32	10.3	3.4	0.8
Autumn	28/05/08	10.5	0.32	8.9	2.9	0.7
Autumn	29/05/08	11.3	0.32	9.6	3.2	0.7
Autumn	30/05/08	12.5	0.31	10.5	3.5	0.8
Winter	25/08/08	15.1	0.35	12.9	6.2	0.6
Winter	26/08/08	15.2	0.35	12.4	6.1	0.9
Winter	27/08/08	12.9	0.35	10.3	5.7	0.9
Winter	28/08/08	12.9	0.34	9.9	6.0	0.9
Winter	29/08/08	16.7	0.34	12.3	6.2	0.7
Spring	18/11/08	13.2	0.36	14.4	10.8	0.9
Spring	19/11/08	14.0	0.35	14.4	11.4	0.9
Spring	20/11/08	11.9	0.35	11.7	9.5	0.9
Spring	21/11/08	10.4	0.34	10.2	7.6	0.9

Season	Date	k	Depth	ER ($gO_2/m^2/day$)	GPP ($gO_2/m^2/day$)	R^2
Spring	22/11/08	11.8	0.37	15.5	4.0	0.7
Summer	23/02/09	10.6	0.37	15.0	11.7	0.9
Summer	24/02/09	10.2	0.37	14.8	12.0	0.9
Summer	25/02/09	10.8	0.37	16.4	12.4	0.8
Summer	26/02/09	9.1	0.37	13.9	11.5	0.9
Summer	27/02/09	10.6	0.37	15.5	10.0	0.9
Autumn	26/05/09	13.4	0.35	11.0	4.6	0.8
Autumn	27/05/09	14.8	0.35	12.1	5.1	0.7
Autumn	28/05/09	13.4	0.35	11.1	4.6	0.7
Autumn	29/05/09	8.6	0.34	7.4	3.1	0.9
Autumn	30/05/09	11.1	0.34	8.9	3.2	0.8
Winter	19/08/09	13.1	0.34	9.0	3.7	0.7
Winter	20/08/09	11.8	0.34	7.7	3.3	0.7
Winter	21/08/09	10.6	0.33	6.9	3.4	0.7
Winter	22/08/09	10.6	0.33	7.2	3.3	0.9
Winter	23/08/09	12.9	0.33	8.7	3.4	0.8
Spring	17/11/09	12.1	0.33	15.0	11.1	0.7
Spring	18/11/09	14.2	0.33	18.0	14.6	0.9
Spring	19/11/09	11.4	0.33	14.8	11.9	0.8
Spring	20/11/09	12.1	0.33	15.3	13.3	0.9
Spring	21/11/09	8.3	0.33	10.9	7.9	0.9
Summer	23/02/10	12.4	0.32	12.7	12.4	0.9
Summer	24/02/10	8.9	0.32	10.5	8.5	0.8
Summer	25/02/10	15.8	0.32	15.5	15.6	0.9
Summer	26/02/10	12.3	0.32	10.9	11.0	0.9
Summer	27/02/10	16.2	0.32	14.2	15.4	1.0
Autumn	19/05/10	14.6	0.40	12.0	4.3	0.8
Autumn	20/05/10	13.7	0.39	11.0	4.4	0.8
Autumn	21/05/10	16.0	0.38	11.4	5.1	0.7
Autumn	22/05/10	15.0	0.37	9.9	4.2	0.8
Autumn	23/05/10	5.9	0.37	6.2	2.7	0.7
Winter	23/08/10	16.1	0.33	6.5	4.2	0.9
Winter	24/08/10	13.3	0.33	5.4	3.6	0.8
Winter	25/08/10	8.2	0.33	4.2	2.2	0.7
Winter	26/08/10	12.3	0.36	6.9	4.3	0.6
Winter	27/08/10	11.0	0.35	6.0	2.3	0.8

Appendix 2. Average reaeration coefficient for Motupipi at Reilly's Bridge between December 2006 and August 2010. SE bars were calculated using the observed mean seasonal reaeration coefficients for each year.