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Basslink Monitoring Program

Gordon River Basslink Monitoring Annual Report

2010–11

Volume I: The Report

Prepared by

Hydro Tasmania

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Executive summary

The Gordon River Basslink Monitoring Annual Report is the product of Hydro Tasmania's Gordon River Basslink Monitoring Program. This monitoring program is required under Hydro Tasmania's Special Water Licence and seeks to identify and document changes in the Gordon River environment in response to Basslink operation. The program extends the knowledge gained during the 1999–2000 investigative years and the 2001–05 monitoring on the pre-Basslink condition, trends, and spatial and temporal variability of the middle Gordon River environment. The 2010–11 monitoring year was the ninth year of Basslink monitoring, and the fifth year of monitoring completed since the commissioning of Basslink operation in April 2006.

The principal objective of this report is to present the consolidated results of all monitoring undertaken pursuant to the Gordon River Basslink Monitoring Program during the 2010–11 reporting year.

Monitoring was completed across the full range of scientific disciplines in 2010–11.

Hydrology and water management

The 2010–11 monitoring year had a power station operating regime that continued to be influenced by Hydro Tasmania's strategy to increase general storage levels, and to ensure sufficient storage in Lake Gordon in preparation for the Poatina Power Station outage that commenced in April 2011. The overall discharge in 2010–11 from Gordon Power Station was low, with the energy generated at Gordon Power Station being 65 % of the long-term average.

The discharge from Gordon Power Station consisted of greater periods of regular hydro-peaking than in recent years, at levels corresponding to 3-turbine operation. The power station operation for the undertaking of seepage trials contributed to this greater 'peakiness' from January to March 2011.

There were a total of 21 exceedances of the ramp-down rule outside the tolerances defined in the Special Water Licence Agreement. Of these 21 exceedances, seven ramp-down rule non-conformances were recorded. Eight were defined events as listed under the Special Water Licence Agreement and six were approved when undertaking the seepage trials. There were 75 minor exceedences of the ramp-down rule that were within tolerances.

The minimum environmental flow requirements were achieved 100 % of the time.

Flow patterns at downstream sites were reflective of flows from the power station.

Water quality

Lake Gordon and Lake Pedder continued to have generally good water quality in 2010–11.

The thermal structure of Lakes Gordon and Pedder were similar to previous years. Depth profiles varied with location and between monitoring trips. Dissolved oxygen showed declines at depth at all sites in Lake Gordon during summer. Anoxic conditions were recorded for bottom waters at the Knob Basin on all sampling occasions. The power station intake was at the oxycline measured at Knob Basin on three of the sampling occasions, with reduced oxygen concentrations. Of these three occasions, the lowest oxygen concentration at the intake was recorded in April at approximately 6 mg L^{-1}.

Lower dissolved oxygen was occasionally observed in the tailrace over the last week of April, however concentrations were not low enough or of sufficient duration to be harmful to biota at any time. Concentrations of dissolved oxygen in the tailrace were highly variable as a result of changes to power station outflow and concomitant changes in aeration inside the turbines.

Dissolved oxygen and water temperatures in the Gordon River displayed broad seasonal patterns related to the thermal pattern of Lake Gordon.

Water temperatures along the river differed between sites and were higher during summer at sites further downstream due to inputs of warmer water from tributaries, as well as from warming in the Gordon River itself. However, during cooler periods of the year the trend was reversed, so that water temperatures were cooler downstream. Water temperature in the Gordon River was also sensitive to fluctuations in power station discharge.

Dissolved oxygen concentrations at the compliance site were generally high. Changes in dissolved oxygen concentration at the compliance site appear to be influenced by the rate of discharge from the power station. Higher dissolved oxygen coinciding with higher discharges is probably due to the significant aeration that the water receives as it travels the 12 km from the tailrace to the compliance site.

Fluvial geomorphology

Field observations in October 2010 were consistent with very low power station usage, and included the accumulation of organic matter on bank faces and the continued establishment and growth of mosses and seedlings in the 1–2 and 2–3 turbine bank levels. In February 2011, observations reflected the recent peaking operations of the power station, with scour evident in the 1–2 turbine bank level, and seepage derived deposition originating from lower banks at the base of root mats on some banks which support tea-tree in zones 2 and 3.

Piezometer results show there was a low risk of seepage erosion in the 2–3 turbine bank level. High ground water slopes were recorded during periods of low river level, and are likely to have contributed to the rilling and seepage processes observed on the lower banks in February 2011.

Erosion pin results grouped by zones and compared to the results from the previous monitoring period showed increases in erosion in the October results and decreases in erosion in February for all zones except zone 1, although the magnitude of change was highly variable across the zones. The largest changes were recorded in zones 4 and 5, suggesting that during this year of low power station discharge, unregulated inflows played a substantial role in the fluvial geomorphology of the river.

Zone 1 continues to be the only zone where the recorded rates of erosion are within the projected range of results based on pre-Basslink results. Zones 2–4 continue to record lower rates of erosion than predicted, with zone 5 showing slightly higher rates than predicted.

Photo-monitoring showed no change at the majority of the sites (60 %) relative to March 2010. Changes that were observed included the movement of woody debris on bank toes, and the continued adjustment of banks above the power station-controlled high-water level.

Overall, the findings from the 2010–11 monitoring year are consistent with the understanding of processes in the river and the conceptual model. There are no significant impacts related to Basslink.

Karst geomorphology

The monitoring of karst caves in 2010–11 showed some minor sediment changes in the caves. None of the informal triggers for sediment change or structural changes to the dolines were exceeded during this monitoring period.

In Bill Neilson Cave, inundation was low throughout the year, and consequently resulted in modest and generally unremarkable change in the sediments overall. The maximum level of inundation was lower than in the majority of years and is unlikely to have reached the level of the pins in the dry sediment bank for more than a couple of hours.

The pins in Kayak Kavern have demonstrated that deposition has generally occurred in winter at the majority of pins and erosion generally occurred in summer. The changes this year are considered to be consistent with other years.

In GA-X1, there was high deposition at the lowest pin in the cave during the summer months. This may be a result of the hydro-peaking operations in January and February 2011.

Erosion occurred during the summer months in Channel Cam possibly due to the power station 3-turbine peaking operation in January and February 2010.

The findings from the 2010–11 monitoring year showed no significant impacts to the karst features of the Gordon River as a result of Basslink.

Riparian vegetation

The recovery of the vegetation along the Gordon River noted since 2008 was impacted by a combination of longer periods of inundation and physical impacts associated with regular high flow events that occurred immediately prior to the monitoring event in March 2011. Sites showed an apparent increase in bare ground and potentially a decrease in bryophyte cover; however, the total vegetation cover in response to these high flow events was variable.

A number of values were recorded outside the triggers for species and ground cover abundance which were largely due to small changes in the similarity indices, attributable to the change in the presence and absence of a few species.

Diverging similarity in the lower quadrats between zones occurred, largely due to higher flows removing species that had become established over the last three years in a low flow environment. Species evenness was generally stable.

Proportional changes in life form variables (e.g. shrubs, moss, bryophytes) and ground cover between 'above' and 'high' and 'above' and 'low' quadrats resulted in these measures exceeding trigger values. This can be explained by proportionally greater impacts of high water flows in the early part of 2011 on 'low' and 'high' quadrats compared with the 'above' quadrats.

The impact of Basslink on the riparian vegetation is considered to be minimal, with the establishment and subsequent loss of vegetation in 2010–11 on banks being the result of periods of lower or higher inundation and associated physical impacts.

Macroinvertebrates

Patterns and trends in benthic macroinvertebrate metric values for 2010–11 were broadly similar to those observed in the four years pre-Basslink with the following substantial exceptions:

- community compositional similarity between Gordon and reference sites were again higher than pre-Basslink means; and
- the absolute and proportion of abundance of EPT species was substantially raised in zone 1.
- These exceptions were not as pronounced in 2010–11, as most metrics had declined compared to values in 2009–10. However, the values fell either within or above pre-Basslink ranges.

Trigger values were complied with in 2010–11, with the exception of density of EPT species being elevated and high, due to high densities of the caddis *Asmicridea* and the insect families Gripopterygidae and Hydrobiosidae, believed to be driven by the maintenance of minimum environmental flow.

Overall, for benthic macroinvertebrates, there has been general compliance with, or positive exceedance of, established triggers and evidence of lagged improvement in benthic biological condition, especially during 2008–09 to 2009–10. Changes in power station operations and the resulting flow regime in 2010–11 have led to a partial decline in biological condition in zone 1, relative to the peak in 2009–10. All indicators still fall within or above pre-Basslink ranges and may be indicative of a positive Basslink effect as a result of the environmental flow.

Algae and moss

Patterns and trends in algal cover were broadly similar to those observed in previous years:

- aquatic flora having a consistently low to moderate cover across all sites;
- moss and filamentous algae having low overall mean per cent cover across all sites;
- filamentous algae being low and locally variable in abundance;
- mean algal cover being highly variable and highest in zone 1; and
- macrophytes occurring at site 72 at low densities.

Moss cover values stayed well within pre-Basslink trigger bounds. Filamentous algae also fell within bounds for most sites, but minor exceedances at two sites resulted in a minor exceedance at zone 2 and the whole-of-river cases. These are small exceedances and not deemed significant ecologically.

Fish

Spotted galaxias were the most abundant fish in the river and tributaries over summer, and second only to brown trout in autumn, as per previous years. This reflects strong recruitment of spotted galaxias in spring/summer 2010. Climbing galaxias and jollytails were caught in relatively small numbers, which is consistent with previous years.

Brown trout were the only exotic species captured in the river during 2010–11. Brown trout catches in the upper Gordon River appear to have increased in the post-Basslink period, and may be related to improved habitat due to the environmental flow. However, these increases have not resulted in exceedences of the upper exotic trigger, which is calculated across all zones. This is the first year that redfin perch have not been captured from the river since the start of the monitoring program, and reflects the species' low abundance in the Gordon River.

Pouched lampreys' abundances were relatively low in the autumn sample, however low abundances were also noted from the reference sites, indicating a seasonal catchment trend rather than a Basslink effect. Short headed lampreys are uncommon in the river, and the 2010–11 catches were characteristically low.

Short finned eel abundances were generally similar to pre-Basslink means, with no evidence of temporary accumulation at lower reaches due to high flows as per the 2009–10 survey.

Trigger exceedences for 2010–11 occurred in the ratio of natives to exotics (community composition) and annual galaxiid relative abundance (ecologically significant species).

Within the cumulative 2006–11 triggers, exceedences of the upper bound occurred across the community composition and ecologically significant species groups (five of 10 triggers). These exceedences were driven by elevated *G. truttaceus* abundance and reflect strong recruitment of this species in the Gordon River over the post-Basslink period.

There has been no obvious negative impact on Gordon River fish as a result of Basslink.

Conclusions

Results of the 2010–11 monitoring period continue to be influenced by the flow regime experienced in the Gordon River. Discharge from Gordon Power Station continued to be generally low compared with previous years, with periods of operation at levels of the minimum environmental flow. There were significant periods of hydropeaking discharge.

Twenty three per cent of triggers were exceeded in 2010–11. However, many of the exceedences were considered to be positive or neutral changes. In particular, positive exceedences in the macroinvertebrate discipline appear to be related to the environmental flow, while low overall discharge is linked to reduced erosion. The vegetation was, overall, in good condition, which can be attributed to generally low discharge.

Overall, no net Basslink impact has been observed in 2010–11.

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Acronyms and abbreviations

AEMO	Australian Energy Market Operator – founded in 2009 with NEMMCO as a founding entity
AETV	Aurora Energy Tamar Valley
ANOVA	analysis of variance
ANZECC	Australian and New Zealand Environment and Conservation Council
AUSRIVAS	Australian River Assessment System
BBR	Basslink Baseline Report
BMP	(Gordon River) Basslink Monitoring Program
CPUE	catch per unit effort
CWD	coarse woody debris
DO	dissolved oxygen
DPIPWE	Department of Primary Industries, Parks, Water and Environment
EC	electrical conductivity
EPT	Ephemeroptera (mayflies), Plecoptera (stoneflies), Trichoptera (caddisflies)
FLOCAP	Flow calculator application to convert station power output to flow
FRP	filterable reactive phosphorus
GRBMAR	Gordon River Basslink Monitoring Annual Report
IIAS	Basslink Integrated Impact Assessment Statement: Potential Effects of Changes to Hydro Power Generation
LOAC	Level of acceptable change
mASL	metres above sea level
NEMMCO	National Electricity Market Management Company – incorporated into AEMO in 2009

NTU	Nephelometric turbidity units
O/E	is a biological index of the 'observed' to 'expected' ratio which describes the proportion of macroinvertebrate taxa predicted to be at a site under undisturbed conditions that are actually found at that site. O/E scores range between 0, with no predicted taxa occurring at the site, to around 1, with all expected taxa being observed (i.e. a community composition equivalent to reference condition).
O/Epa	the O/E value calculated using an AUSRIVAS model based on presence-absence data
O/Erk	the O/E value calculated based on rank abundance category data
RBA	rapid biological assessment - macroinvertebrate sampling protocol
TKN	total Kjeldahl nitrogen
WOR	whole-of-river

Glossary

Ambient	background or baseline conditions
Anoxic	absence of oxygen
Benthic	the bottom of a lake
Bray-Curtis index	a measure of assemblage similarity between sites/samples
Catch per unit effort (CPUE)	the catch related to a standardised measure of effort. In this case, the number of fish collected by electrofishing at a site, standardised to a shocking time of 1200 seconds
Cavitation	the formation and subsequent collapse of vapour bubbles (cavities) within water moving at high velocity. Cavitation is responsible for the pitting of turbine blades.
Colluvium	loose bodies of sediment that have been deposited or built up at the bottom of a low-grade slope or against a barrier on that slope, transported by gravity. The deposits that collect at the foot of a steep slope or cliff are also known by the same name.
Confluence	the location when two rivers or tributaries flow together
Diurnal	relating to or occurring in a 24-hour period
Dolines	are karst features which present as depressions or collapses of the land surface. Dolines are formed when a solution cavity in the underlying rock becomes enlarged enough for overlying sediment to collapse into it.
Environmental flow	water which has been provided or released for the benefit of the downstream aquatic ecosystem and broader environment
Exotic	introduced organisms or species
Full-gate	is the discharge which produces the maximum amount of energy by the turbine
Geomorphic	the study of the earth's shape or configuration

GordonRatingApp	the stand-alone application used for calculating discharge from the Gordon Power Station
GWh	gigawatt hours (10^9 watt hours) – a standard measure of energy equivalent to the production of one gigawatt of power for one hour
Hydrology	the study of the properties, distribution, and effects of water on the earth's surface, in the soil and underlying rocks and in the atmosphere
Hydro-peaking	Variable flow in power station discharge on a daily scale
Inundation	an area of vegetation or bank which becomes covered by water associated with flows from either an upstream dam or tributary input
Karst	an area of irregular limestone in which erosion has produced fissures, sinkholes, underground streams and caverns
$m^3 s^{-1}$	cubic metres per second, units for the measure of flow rate
$mg L^{-1}$	milligrams per litre, units for the concentration of a substance dissolved in a solution
$\mu g L^{-1}$	micrograms per litre
$\mu S cm^{-1}$	micro Siemens per centimetre, measure of electrical conductivity
Morphology	the consideration of the form and structure of organisms
MW	megawatts (10^6 watts) - a standard measure of power
Oxycline	level at which dissolved oxygen decreases rapidly
pH	a measure of the acidity or alkalinity of a solution, numerically equal to 7 for neutral solutions, increasing with increasing alkalinity and decreasing with increasing acidity (scale of 0-14)
Piezometer	an instrument for measuring pressure
Pielou's evenness index	a measurement of diversity in samples using abundance and species richness data developed by Pielou in 1966

Post-Basslink	the period following commissioning of the Basslink interconnector
Pre-Basslink	the period prior to commissioning of the Basslink interconnector
Riffle habitat	habitat comprising rocky shoal or sandbar lying just below the surface of a waterway
Rill	a small brook or natural stream of water smaller than a river
Tailrace	the outflow structure of the power station, from which water is discharged into the river
Taxon	a taxonomic category or group, such as a phylum, order, family, genus, or species
Temporal	change or pattern over time
Thermal stratification	change in temperature profiles over the depth of a water column

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1 Introduction and background

The purpose of this Gordon River Basslink Monitoring Annual Report (GRBMAR) is to present the consolidated results of all monitoring undertaken pursuant to the Gordon River Basslink Monitoring Program (BMP) during 2010–11. This is the fifth full year of post-Basslink operation, with monitoring conducted for all disciplines and the results assessed against the trigger values set out in the Gordon River Basslink Monitoring Annual Report 2005–06 (Hydro Tasmania, 2006) and other assessment criteria developed for specific disciplines during the course of the monitoring program.

1.1 Context

The Gordon River Basslink Monitoring Program (BMP) was established as an outcome of the Basslink approvals process. The aims of the Gordon River Basslink Monitoring Program are:

- to undertake pre-Basslink monitoring (2001–05) in order to extend the understanding gained during the 1999–2000 investigative years on the present condition, trends, and spatial and temporal variability of potentially Basslink-affected aspects of the middle Gordon River ecosystem;
- to undertake six years of post-Basslink monitoring to determine the effects of Basslink operations on the environment of the Gordon River below the power station and to assess the effectiveness of mitigation measures; and
- to obtain long-term datasets for aspects of the middle Gordon River ecosystem potentially affected by Basslink that will allow refinement of theories and more precise quantification of spatial and temporal variability, processes and rates.

The focus of the pre-Basslink monitoring program was to measure conditions under the prevailing operating regime, rather than attempting to relate them to 'natural' or 'pristine' conditions. This approach is an essential element of the monitoring program given the highly modified conditions that exist due to the presence of, and the flow regulation resulting from, the Gordon Power Scheme.

The independent investigative studies produced for the Basslink Integrated Impact Assessment Statement (IIAS) (Locher 2001) led to the formulation of the BMP. The BMP was included in the Special Licence held by Hydro Tasmania under the *Water Management Act 1999*.

The post-Basslink monitoring program has a major component that compares post-Basslink data with trigger values derived from pre-Basslink data. Presently five years of data are available post-Basslink. In this report both 2010–11 data and combined data from the 2006–11 period are assessed against trigger values.

1.2 Basslink Baseline Report

One of the requirements of Hydro Tasmania's Special Licence was to produce a Basslink Baseline Report (BBR) prior to Basslink commencement. The BBR was submitted to the Minister in December 2005 and provided a comprehensive assessment of pre-Basslink conditions in the Gordon River below the power station. The BBR described how post-Basslink conditions would be compared with the pre-Basslink ranges of variability and trends. The Basslink Baseline Report is available on Hydro Tasmania's website (www.hydro.com.au/environment/basslink-studies).

1.3 Basslink Review Report 2006–09

A further requirement of Hydro Tasmania's Special Licence was to produce a three-year review report following the collection of three years of post-Basslink data. The report was submitted to the Minister in April 2010 and provided review of the data collected to date, fulfilling its aims to:

A. present trends from the consolidated data collected subsequent to the Basslink Baseline Monitoring Report;

B. evaluate the adequacy of the Gordon River Basslink Monitoring Program, providing refinements if necessary;

C. evaluate the appropriateness and effectiveness of the mitigation measures; and

D. evaluate the appropriateness and effectiveness of any 'limits of acceptable change' (triggers).

1.4 Logistical considerations and monitoring in 2010–11

Access presents significant challenges in this part of the Tasmanian Wilderness World Heritage Area. On-site monitoring activities require helicopter support due to the density of the terrestrial vegetation, the absence of access infrastructure and the extent of the study area.

Power station outages are needed to conduct monitoring because the majority of viable helicopter landing sites are on cobble bars in the river bed that are exposed only when there is little or no discharge from the power station. Shutdowns are necessary because most of the biotic and geomorphic monitoring activities require measurements or sampling to take place within the river channel, which would not be possible under normal or high flow conditions.

To complete the required monitoring work, the Gordon River Basslink Monitoring Program has a schedule of at least four visits per year, each requiring the power station to be turned off for two to four consecutive days.

The 2010–11 river monitoring surveys were conducted on 18–20 October (macroinvertebrates, algae and moss, geomorphology, karst); 3–5 December 2010 (riparian vegetation, fish); 25–27

February (macroinvertebrates, algae and moss, geomorphology, karst) and 4–6 March 2011 (riparian vegetation, fish).

As a result of the Poatina Power Station outage, which began on 1 April 2011, it was not possible to undertake a power station outage in April and the autumn sampling was brought forward for all disciplines. The Minister was notified of this in advance, and agreed to the earlier sampling. As a result, the macroinvertebrate and geomorphology autumn sampling were slightly earlier than the March–April requirement in the Special Water Licence. While the fish and vegetation autumn monitoring was undertaken within the prescribed period (March–April) in the Special Water Licence, this sampling occasion was around a month earlier than usual.

In addition to the river monitoring surveys, seepage monitoring field trials were undertaken in early 2011. These trials were undertaken to verify the outputs of modelling undertaken to assess the likelihood of seepage occurring in the upper banks under a range of bank saturation conditions and ramping rates. The aim of the trials was to aid in the development of a more appropriate ramp-down rule. The dates of these monitoring trials were 22–23 January, 23–25 February and 7–8 March 2011. The results of the field trials are presented in Appendix 5.

1.5 Geographic datum

Map coordinates given in this document use the 1966 Australian Geodetic Datum (AGD) as this corresponds with the topographic maps currently available for the area. A later datum, the Geocentric Datum for Australia (GDA), has recently been adopted for new maps. Site references using the AGD will be approximately 200 m different (-112 m east and -183 m north) from those using the GDA.

1.6 Document structure

This document is the tenth of the Gordon River Basslink Monitoring Annual Reports to be produced, and is organised into ten chapters plus an executive summary.

This first chapter discusses the requirements, context, operational considerations and constraints of the program. Chapters 2–9 report on the monitoring work that was undertaken during 2010 - 11, and present the consolidated results of each of the individual monitoring elements. These are:

- Hydrology and water management (Chapter 2);
- Water quality (Chapter 3);
- Fluvial geomorphology (Chapter 4);
- Karst geomorphology (Chapter 5);
- Riparian vegetation (Chapter 6);
- Macroinvertebrates (Chapter 7);
- Algae and moss (Chapter 8);

- Fish (Chapter 9); and
- Discussion of trigger results (Chapter 10).

The results from the 2010–11 monitoring are reported in each of these chapters. With the increased understanding of the processes of the Gordon River, it was recognised in the Basslink Review Report 2006–09 (Hydro Tasmania, 2010a) that trigger values are just one important measure in understanding the response of the river to hydrological changes. This is the second report where assessment is provided with a greater emphasis on ‘multiple lines of evidence’ where appropriate. Each discipline chapter also contains a section on comparisons with trigger values. Where available, two comparisons against the trigger values were made; one assessing the 2010–11 results and one comparing the combined results for all the post-Basslink data (2006–11) against the triggers. Trigger reporting was undertaken as in the 2009–10 annual report.

When a result fell outside the trigger levels, the terminology ‘a trigger has been exceeded’ has been used in this report. However, it should be noted that an ‘exceedance’ can either be above or below the trigger levels. It should also be noted that a trigger exceedance can be considered an ecological benefit, for example lower levels of exotic fish. Interpretation of the trigger exceedances will be discussed in the individual chapters and explored in more detail in Chapter 10.

A series of nine appendices is included in Volume II as follows:

- Power station discharges graphed per month (Appendix 1);
- Fluvial geomorphology erosion pin and scour chain data (Appendix 2);
- Fluvial geomorphology erosion pin descriptions and graphed data (Appendix 3);
- Fluvial geomorphology photo-monitoring and site descriptions (Appendix 4);
- Ramp-down trials January–March 2011 (Appendix 5)
- Karst erosion pin data (Appendix 6);
- Riparian vegetation photo-monitoring (Appendix 7);
- Bank profiles and ground cover variables (Appendix 8);
- Fish monitoring data (Appendix 9); and
- Formal trigger levels (Appendix 10).

1.7 Authorship of chapters

The information presented in chapters 2–10 was extracted from field reports produced by the various scientists employed to conduct the monitoring, as shown in Table 1-1. The efforts and original contributions of these researchers are duly acknowledged.

This document was collated by Malcolm McCausland of Entura, with internal review from Will Elvey, Ray Brereton (Entura), Marie Egerrup, Alison Howman, Peter Connolly, Gerard Flack and Greg Carson (Hydro Tasmania), and significant assistance from the researchers. Donna Porter assisted with editing and production.

Table 1-1 Chapter numbers, titles and original authors from whose reports the information in chapters 2–10 was extracted

Chapter	Chapter title	Author(s)
2	Hydrology	Malcolm McCausland and Mark Willis (Entura)
3	Water quality	Tim Shepherd and Malcolm McCausland (Entura)
4	Fluvial geomorphology	Lois Koehnken (Technical Advice on Water)
5	Karst geomorphology	Jenny Deakin (consultant)
6	Riparian vegetation	Stephen Casey (Entura)
7	Macroinvertebrates	Peter Davies and Laurie Cook (Freshwater Systems)
8	Algae and moss	Peter Davies and Laurie Cook (Freshwater Systems)
9	Fish	David Ikedife (Entura)
10	Discussion of trigger value results	Lois Koehnken (Technical Advice on Water), Peter Davies (Freshwater Systems), David Ikedife and Stephen Casey (Entura)

1.8 Site numbers

Throughout this report, monitoring locations are identified by site number. These represent the approximate distance upstream from the Gordon River mouth at the south-eastern end of Macquarie Harbour. The monitoring work is conducted between sites 39 (immediately downstream of the Franklin confluence, at the upstream tidal limit) and site 77 (the power station tailrace).

Some disciplines, such as fluvial geomorphology and riparian vegetation, use zones rather than the standard site numbering system. This is because their work is associated with longer reaches of river bank than are suitable for the 'site' nomenclature. The fish monitoring uses both systems. Site numbers define the specific monitoring location and fish zones define the river reach to which the sites belong.

Map 1-1 Gordon River Basslink monitoring area

2 Hydrology and water management

This section of the Gordon River Basslink Monitoring Annual Report provides an overview of the hydrological data from the Gordon River downstream of the Gordon Power Station for the July 2010 to June 2011 period. Conformance with the two mitigation measures, environmental flow and ramp-down rule, are presented.

2.1 Factors affecting Gordon Power Station discharge

The Gordon Power Station running regime has always been heavily influenced by a number of factors. A timeline of some of the major factors is presented in Figure 2-1. The normal factors include:

- inflows to Hydro Tasmania catchments (volume, distribution and sequence);
- overall storage position, in particular, the storage positions of Great Lake and Lake Gordon;
- energy demand in Tasmania; and
- power station outages.

At present, the ability to import and export energy in response to National Electricity Market price signals influences the Tasmanian hydro generation system including the Gordon Power Station. An additional factor exerting further influence on the running regime of the Gordon Power Station is the entry into the market of the Aurora Energy Tamar Valley (AETV) Power Station.

Based on modeling undertaken prior to Basslink commissioning it was expected that the Gordon Power Station running regime would become extremely ‘peaky’ creating numerous high flow ramping events as Hydro Tasmania responded to market opportunities. In the first three years post-Basslink, the anticipated degree of increased peaking operation was not observed. A number of factors played differing roles in this operation, and quantification of the individual factors was and continues to be difficult (Hydro Tasmania, 2010b). The type of operation observed in 2010–11 has been ‘peaky’ and more similar to that originally anticipated and is discussed in Section 2.5.3.

In all but three of the last 16 years, Tasmanian electricity demand was higher than the annual yield (Figure 2-2). The post-Basslink years began with a continuation of a downward trend in overall storage position until 2007–08 (Figure 2-3). Implementation of the storage rebuild strategy in June 2008, made possible by the commissioning of Basslink, resulted in increasing storage levels, as Hydro Tasmania provided less hydro generation to the market. Consequently there was significant net import of power from 2007–08 and 2008–09. In 2009–10, there was lower net import of power to Tasmania as a result of an increase in the system-wide hydro generation in response to higher inflows and greater gas generation by AETV. In 2010–11, this trend continued, with increasing hydro generation made possible by the higher inflows and higher storage levels. There was also an increase in gas generation and a small net export of power via Basslink. In 2010–11 the net generation (hydro, gas, wind) in Tasmania has been very similar to demand (i.e. small net export).

Despite increased system-wide generation, Gordon Power Station generation (848 GWh) remained lower than previous years at 65 % of the long-term annual average (1996–2011). A major factor in the lower generation in 2010–11 has been the need to continue to store sufficient energy in preparation for a lengthy power station outage at Poatina Power Station that began in April 2011. Since the start of this outage period, Gordon Power Station has been relied upon to provide a greater proportion of state-wide energy demand. Due to the lower use of Gordon Power Station in 2010–11 (up until April 2011), there has been an increasing disparity in storage levels between Lake Gordon and Great Lake (Figure 2-3).

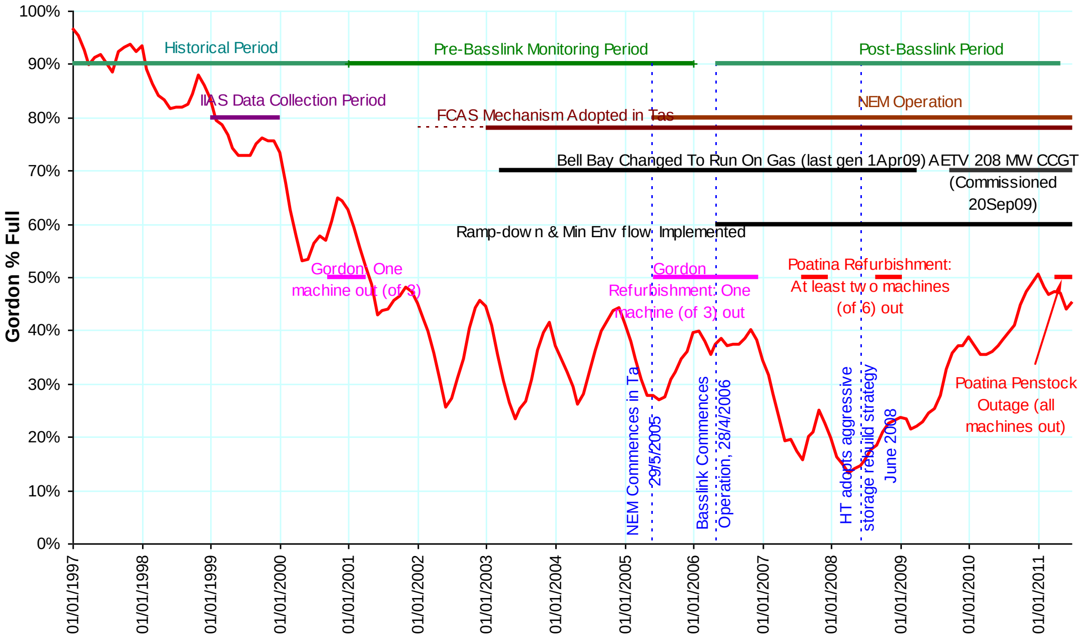


Figure 2-1 Timeline of significant factors affecting Gordon Power Station operation (including storage levels) relative to Basslink monitoring periods

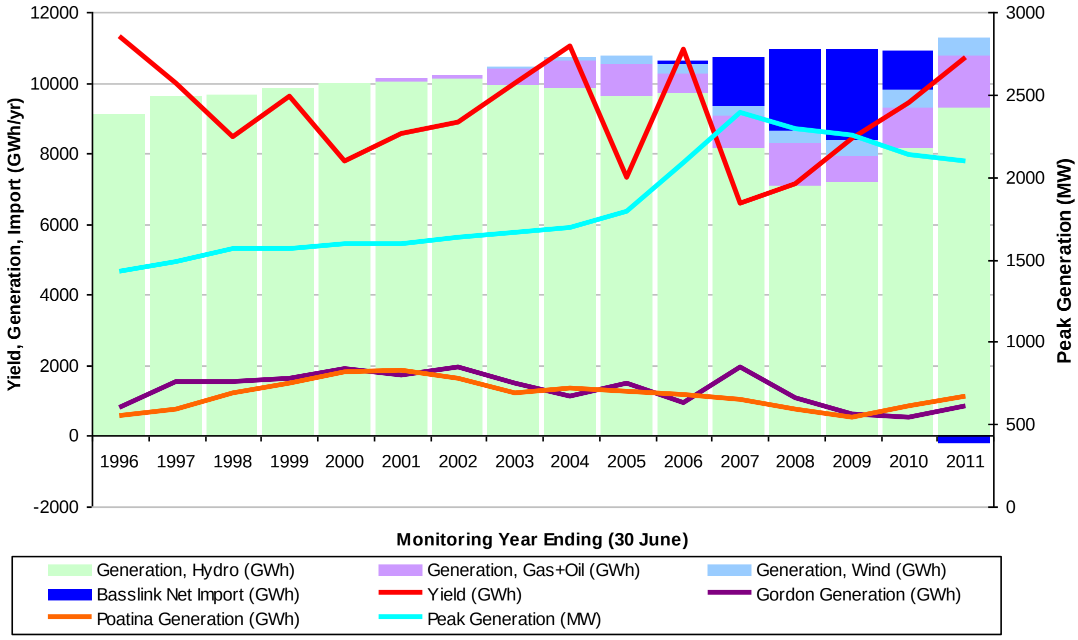


Figure 2-2 Annual hydro generation and yield, Basslink import, wind and gas generation, Gordon and Poatina generation in GWh and peak demand in MW for financial years from 1995–96 to 2010–11. Yield presents system inflows converted to GWh

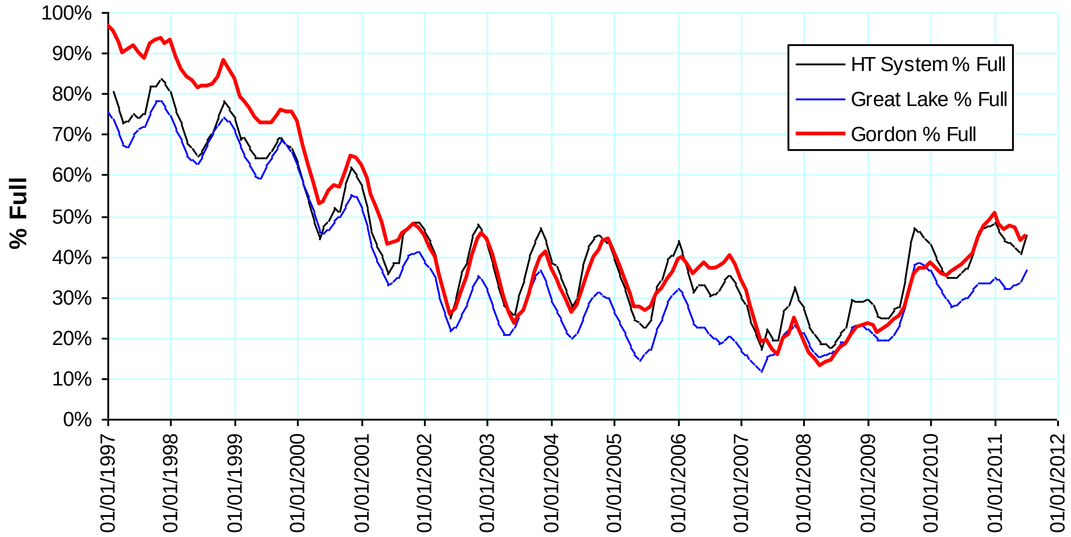


Figure 2-3 System, Lake Gordon and Great Lake water level presented as per cent full for the last 14 years

2.2 Power output to flow ratings

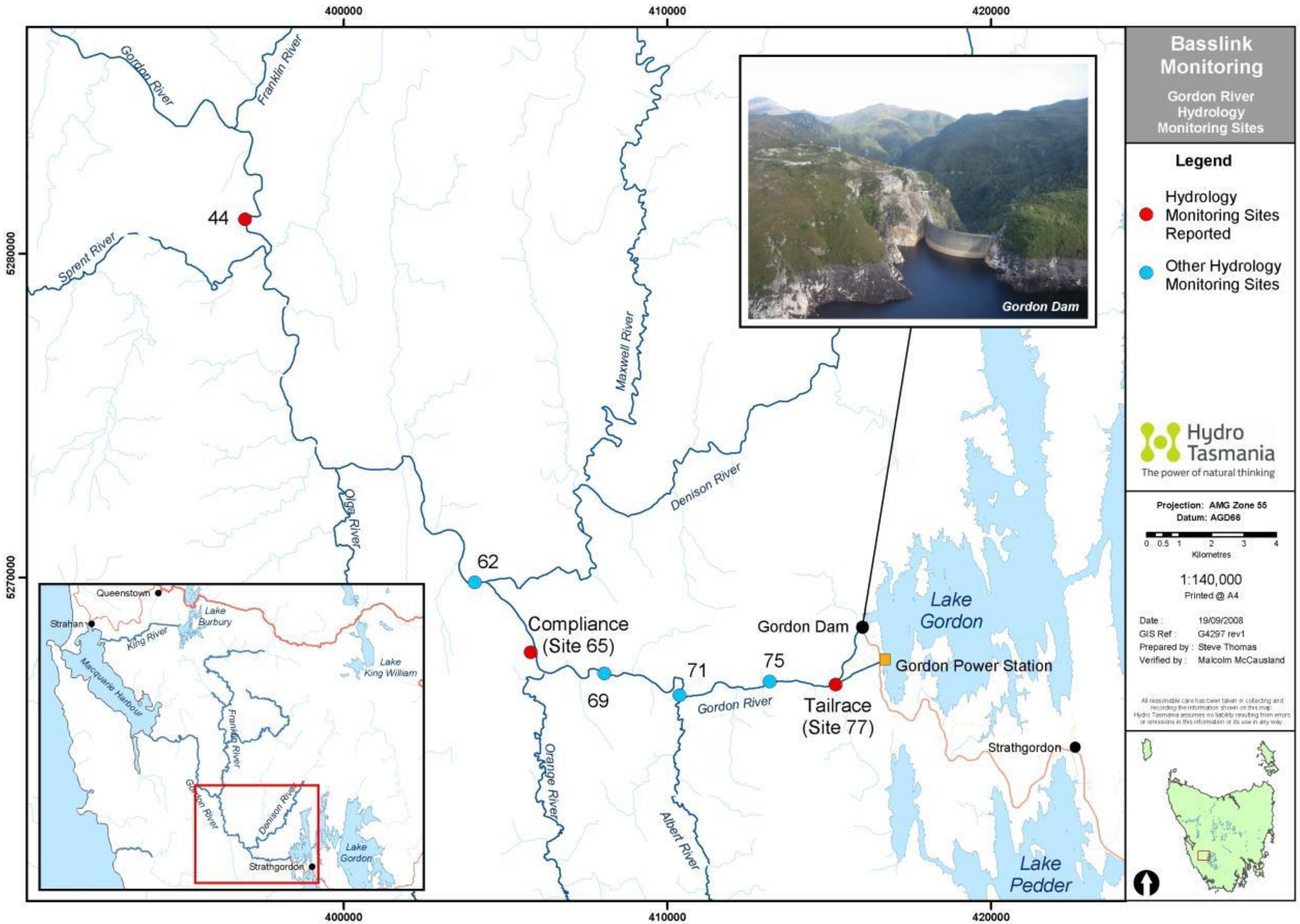
Due to the difficulty in accurately measuring flow in the tailrace, flow records have been converted from power station output (MW) using a stand-alone rating application (GordonRatingApp) developed during 2010–11. This application mimics the real-time application (FLOCAP) used by the operators for determining ramp-down compliance. It is the most accurate method of determining flow from the Gordon Power Station, and is presented in all analyses in this report. This application utilises the following input data to determine discharge from Gordon Power Station:

- Machine 1 power output;
- Machine 2 power output;
- Machine 3 power output;
- storage water height; and
- machine power-discharge rating

The application is run periodically, and has the capability to write the data to the hydrological data base for each five-minute interval.

2.3 Site locations

The gauging stations used to record river levels during 2010–11 were sites 44, 62, 65, 69, 71 and 75. Power station discharge derived from the three-dimensional rating is used to estimate the flow in the tailrace (site 77). The sites reported in this chapter (and those for which data were collected but not reported here) are shown in Map 2-1. The sites reported in this chapter are Gordon above Franklin (site 44), Gordon above Denison (site 65; also known as the flow compliance site) and the Gordon Power Station tailrace (site 77).



Map 2-1 Gordon River Basslink hydrology monitoring sites

2.4 Data analysis

2.4.1 General flow analysis

For 2010–11, the estimated power station discharge at site 77 (the tailrace), site 65 (compliance site) and site 44 (Gordon above Franklin) hourly flow data, median monthly flow and annual duration curves were plotted and are discussed in section 2.5. These three sites are considered representative of the various river sections below the power station. Data from sites 75, 71, 69, 62 were recorded hourly but are not presented in this report. These are a resource available to researchers in the interpretation of their data when necessary. Additional duration curves for the pre-Basslink, post-Basslink and historical periods, as well as each of the individual post-Basslink years, are presented for power station discharge data.

Analyses at sites 77, 65 and 44 have provided the comparison of data from the 2010–11 year to the long-term average at that site. It could be argued that only data from the pre-Basslink period (2001–05) should be used to ensure a strict comparison with the baseline period, however longer datasets are considered a more representative comparison. The long-term average is calculated by using all available data at a site, which means that the date range for the long-term average figures will change for each site depending on when data records commenced.

2.4.2 Flow change frequency analysis

Analysis of changes in flow in the 2–3 turbine operating presented in the 2009–10 Annual Report (Hydro Tasmania, 2010b) have been updated to include the most recent data. This information shows how individual periods vary with regard to flow changes above 180 $m^3 s^{-1}$. The information assists with the interpretation of data in the discipline sections, in particular chapter 4 Fluvial geomorphology. Flow change frequency analysis was conducted on the actual data to determine the frequency with which different flow changes occurred, i.e. between one hour's average and the next hour's average[1].

The calculation of the one-hour lag difference was conducted applying the following rules:

- missing data was eliminated;
- only data where the start flow was above 180 $m^3 s^{-1}$ was selected; and
- data was ranked and plotted.

2.4.3 Low range discharge 'peakiness' analysis

An analysis of the frequency of flow variation or 'peakiness' was undertaken for low range discharges for the Gordon Power Station discharge and for the Gordon above Denison site. This was undertaken with specific relevance to the understanding of the influence of this variable flow

[1] This method cannot be used to determine conformance with ramp-down rule.

regime on the macroinvertebrates at the lower flow ranges. This examined the number of occasions when:

- flow reduced below 25 $m^3 s^{-1}$; and
- subsequently increased to greater than 100 $m^3 s^{-1}$ within a two-hour period.

The number of instances where this flow pattern is observed is presented for each year for which hourly data is available for the Gordon Power Station and Gordon below Denison site and for each month in 2010–11.

2.4.4 Ramp-down rule

A ramp-down rule mitigation measure is in place under the terms of Hydro Tasmania's Special Water Licence Agreement. The ramp-down currently defined under the terms of the Special Water Licence Agreement is:

- if water is discharged from the Gordon Power Station at a rate above 180 cumecs for greater than 65 minutes, then the reduction in that discharge to less than 150 cumecs must:
    - (a) occur at a rate of no more than 30 cumecs in any 60 minute period; or
    - (b) where that reduction has not commenced from the highest discharge, hold discharges at 150 cumecs until the end of the Ramp Compensation Period (defined below).

There are allowances made within the licence for breaches of the rule as follows:

- allowable tolerances are defined as periods where:
    - (a) flow is reduced to 145 $m^3 s^{-1}$ for no longer than 25 minutes;
    - (b) flow is reduced to 136 $m^3 s^{-1}$ for no longer than 15 minutes; and
    - (c) where the ramping rate is no more than 35 $m^3 s^{-1}$ for one 60 minute period.
- the Ramp Compensation Period is defined as the period ending at the latest point in time calculated by reducing discharges by 30 $m^3 s^{-1}$ in any 60 minute period, for each dispatch interval (five minute period), in the three hours prior to a reduction.

2.4.4.1 Methods of analysis for ramp-down rule exceedances and non-conformance

The analysis of ramp-down rule exceedance events performed for 2009–10 was used again for the 2010–11 analysis with a small variation. Calculation of the ramp-rate was done for the five minute averaged data, rather than one minute data. This method analysed data generated by the most accurate flow rating (see Section 2.2, the GordonFlowApp).

The method adopted for analysis of the ramp-down rule uses the following logic to determine whether a non-conformance has occurred:

- review the power station flow, if the flow drops below 150 $m^3 s^{-1}$, then record an event;
- look backwards from the event and check to see if the flow was continuously above 180 $m^3 s^{-1}$ for 65 minutes (60 minutes + the time deviation tolerance) in any period in the last four hours and five minutes (the maximum ramping time is three hours if going from maximum discharge of 240 $m^3 s^{-1}$ to 150 $m^3 s^{-1}$);
- at the time of the event (i.e. flow going below 150 $m^3 s^{-1}$ having previously exceeded 180 $m^3 s^{-1}$ for 65 minutes) look back through the flows that occurred in every five minute period preceding the three hours and compare that flow with the flow that occurred an hour before that (i.e. the flow at two hours prior to the event is compared with the flow at three hours prior to the event). If the comparison shows that the difference is greater than 30 $m^3 s^{-1}$, this is noted as a potential exceedence, however if the difference is greater than 35 $m^3 s^{-1}$ then this is flagged as an exceedance for further investigation;
- only the largest flagged non-conforming ramp rate prior to the event is investigated;
- allowable tolerances have been included in the model and are used to exclude minor exceedances where applicable;
- if an exceedance is reported then another exceedance is not reported if it occurs within three hours, as the model may report the same change in flow condition responsible for a previously reported exceedance if the flow remains below 150 $m^3 s^{-1}$;
- non-conforming ramp-rates are assessed against the ramp compensation and are excluded if a ramp compensation of appropriate length is instigated; and
- all exceedances are assessed and categorised according to magnitude and reason for the exceedance and reported on. However, only those falling outside measurement tolerances (>35 $m^3 s^{-1}$) or caveats (system, load, ramp compensation or market event) are reported as non-conformances.

Results are presented in section 2.5.3.7.

2.5 Results

2.5.1 Data availability

Data was collected for the majority of the time at all the flow measurement sites. There were some periods of missing data in excess of two days at some sites, which are indicated in Table 2-1. Two significant periods of data were missing from site 69 (15 days in January 2011) and site 44 (22 days in June 2011). The reasons for these missing data are due to the use of the incorrect logger scheme in the first instance (site 69), and instrument failure in the second instance (site 44).

Table 2-1 Data availability for water level sites on the Gordon River 2010–11

Site no.	Site name	Periods of missing data	Reason	Comment
75	Gordon River at G4	none to last download	---	Data manually downloaded. Currently available to 5 December 2010
71	Gordon River below Albert (G5A)	none	---	Nil
69	Gordon River above 2nd Split (G6)	6–21 January 2011	logger scheme (program) incorrect	Nil
65	Gordon above Denison (compliance site)	none	---	Nil
62	Gordon River below Denison	none to last download	---	Data manually downloaded. Currently available to 6 March 2011
44	Gordon River above Franklin	8–30 June 2011	float hanging above true water level	Nil

2.5.2 General analysis

2.5.2.1 System yield

The inflows to Hydro Tasmania's state-wide system during the 2010–11 was greater than 2009–10 and the highest since 2005–06. The total system inflows (system yield) of 10731 GWh were 116 % of the long-term median (1976–2011). The continued above average inflow in 2010–11 was the major factor that allowed for greater overall generation across the system, and contributed to continued ability to increase storage in Lake Gordon.

Figure 2-4 shows the total system yield during 2010–11 compared with the long-term (1976–2010) median, 20th and 80th percentile inflows. Highest inflows occurred during August and September 2010 and June 2011. Inflows in September 2010 and June 2011 were well in excess of the 80th percentile, while August 2010 was close to the median. In addition inflows for each of the months from November 2010 to March 2011 were at, or above, the 80th percentile.

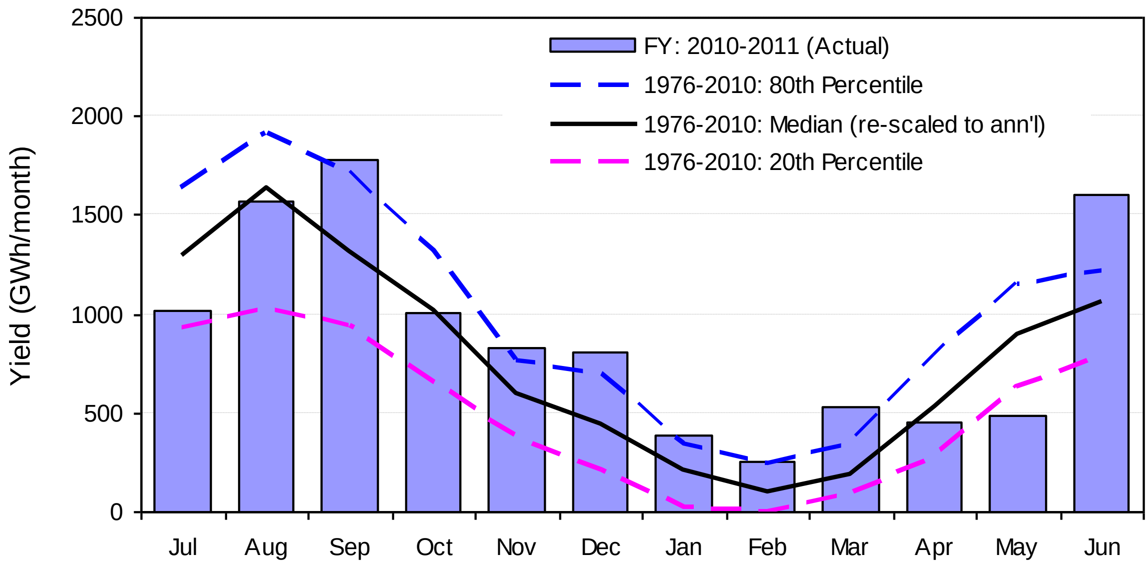


Figure 2-4 Monthly total system yield for 2010–11 compared to the long-term median, 20th and 80th percentiles for 1976–2010

2.5.2.2 Strathgordon rainfall

The Strathgordon meteorological station has rainfall records dating back to 1970. These allow the calculation of long-term mean monthly values and comparisons with the monthly rainfall totals recorded for 2010–11.

Figure 2-5 shows the total monthly and long-term average rainfall values. In 2010–11, Strathgordon received 2454 mm, which is very similar to the long-term mean of 2452 mm, and the same as the long-term median (2454 mm). The 2010–11 annual patterns of rainfall in Strathgordon were similar to the patterns of system inflows; three months (September 2010 and February and June 2011) were classified as wet (with values greater than the 80th percentile of the long-term values). Only one month (April 2011) was classified as dry (with values less than the 20th percentile of the long-term values). Of the remaining eight months, two had above average, and six had below average rainfall.

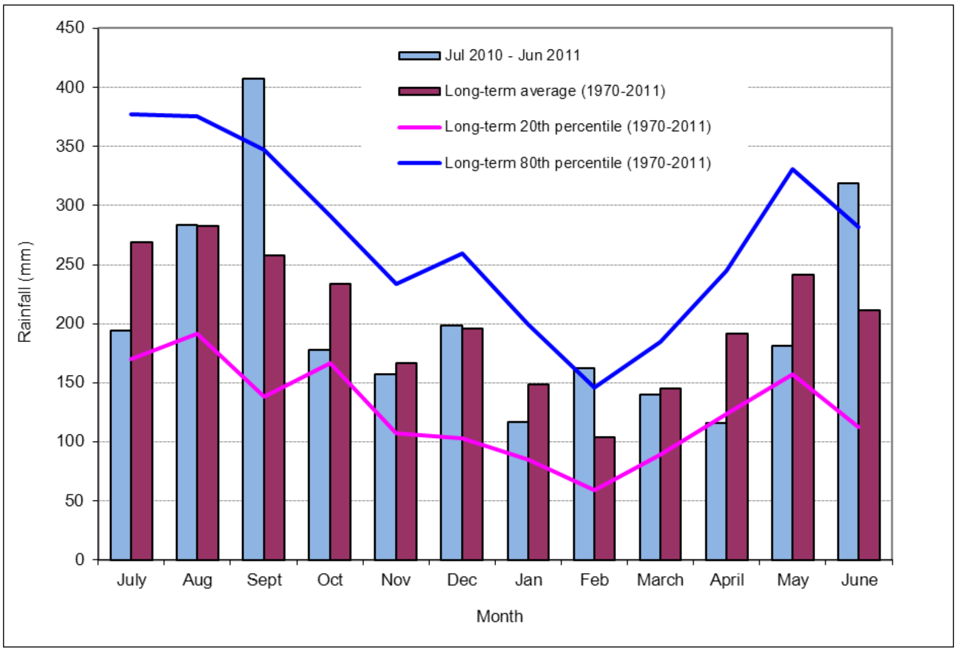


Figure 2-5 Total monthly rainfall values recorded at Strathgordon for 2010–11 compared with the long-term average (1970–2011)

2.5.3 Gordon Power Station

2.5.3.1 Discharge and power station operation

As previously discussed, the discharge pattern for the Gordon Power Station is driven by a number of factors, including market factors as a result of the Tasmanian energy demand and Basslink, and other factors such as inflows. Figure 2-6 shows the discharge from the power station for 2010–11. For a more detailed view of the graph month by month, please refer to Appendix 1. A summary of significant points of interest in the 2010–11 discharge data is as follows:

- there were a number of distinctive operating patterns throughout 2010–11;
- in July and August 2010, the operation was typified by a regular peaking pattern between low (20–30 $m^3 s^{-1}$) and mid-high (150–230 $m^3 s^{-1}$) discharges;
- in the period from September to December 2010, the discharge pattern was characterised by low flow between 20–50 $m^3 s^{-1}$ with peaks in flow that were up to 150 $m^3 s^{-1}$ in September, but which generally showed a decrease in size in October to December. Also in this period there was a lengthy maintenance outage in October;
- regular hydro-peaking to higher discharges (210–240 $m^3 s^{-1}$) was the dominant feature in January and February 2011. This was undertaken largely to assist in saturating banks for the undertaking of seepage monitoring trials;
- March 2011 returned to a similar pattern observed in July and August, having generally low flow, with peaks no greater than 170 $m^3 s^{-1}$;
- generally high discharges of up to 250 $m^3 s^{-1}$, and hydro-peaking occurred from April to June 2011. This high flow was influenced significantly by the maintenance outage at Poatina Power Station, as well as low inflows in May 2011; and
- the net market energy output in 2010–11 from Gordon Power Station increased from the previous year to 848 GWh, but was still significantly lower than the average annual generation (1996–2011) of 1335 GWh (Figure 2-2).

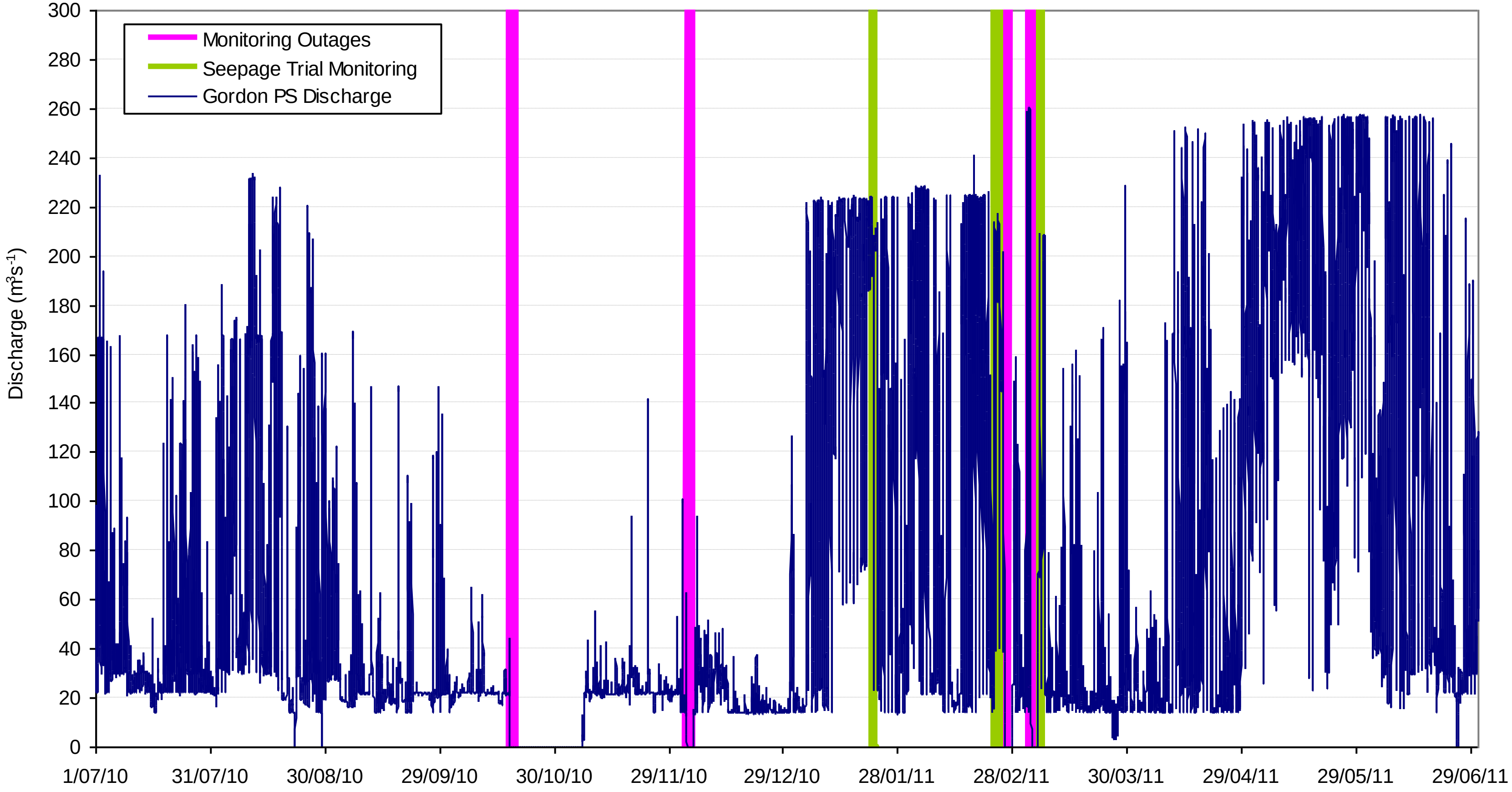


Figure 2-6 Gordon Power Station discharge (hourly data) from July 2010 to June 2011. Vertical lines indicate monitoring events and seepage trial monitoring

Table 2-2 and Table 2-3 show the percentage of time zero, one, two and three turbines were running annually and on a monthly basis, respectively, along with a description of shorter term influencing factors (Table 2-3). The monthly breakdown of power station operating pattern throughout the year provides an indication of the downstream hydrological regime, as efficient discharge for operating one, two or three turbines is 70, 140 and 210 $m^3 s^{-1}$, respectively. The use of the third turbine is generally related to higher discharge, however since joining the National Electricity Market, there has been greater use of three turbines at low to moderate discharge. This data indicates that in 2010–11, there was increased use of the third turbine compared to last year, as well as increase use of just one turbine.

Table 2-2 Percentage of time that each configuration of turbines was in operation during 2010–11 and historically

Configuration	Percentage of time operating					
	Jul 10 – Jun 11	Jul 09 – Jun 10	Jul 08 – Jun 09	Jul 07 – Jun 08	Jul 06 – Jun 07	Sep 96 – Jun 11
0 turbines running	6.9	2.6	3.1	7.5	3.6	13.4
1 turbine running	42.0	33.1	34.3	22.7	9.0	22.4
2 turbines running	24.5	49.9	38.1	30.8	40.1	33.4
3 turbines running	26.6	14.4	24.5	39.1	47.3	30.8

Table 2-3 Summary information on discharge, weather conditions, market volatility and outages for 2010–11. Dry months are classified as months with values lower than the 20th percentile of the long-term values, and wet months are classified as months with values higher than the 80th percentile of the long-term values. Market volatility is based on daily average price and 30 minute prices

Period	0-turbine operation % time	1-turbine operation % time	2-turbine operation % time	3-turbine operation % time	Strathgordon rainfall	Market volatility, inflows and outages	Basslink Net Import (GWh)
July 2010	0	41.3	46.1	12.6	<average	Low market volatility, Increased Poatina running in preparation for penstock outage	-31
August 2010	1.1	21.0	54.0	23.9	average	Low market volatility, High running on Poatina, High inflows in later half of month	-119
September 2010	0	66.7	31.8	1.5	wet	Low market volatility, Above average inflows	-222
October 2010	44.0	50.5	5.5	0	<average	Low market volatility, Below average inflows, Gordon maintenance outage 18 Oct – 7 Nov	-90
November 2010	18.5	72.8	8.8	0	<average	Low market volatility, Above average inflows, High Poatina running Gordon maintenance outage 18 Oct – 7 Nov	-60
December 2010	5.4	88.8	5.4	0.4	average	Low market volatility, Above average inflows	-14
January 2011	0	23.1	18.7	58.2	<average	Increased volatility, Above average inflows, Derwent scheme outages	-22
February 2011	7.0	18.3	23.8	50.9	wet	Low market volatility, Above average inflows	28
March 2011	6.5	59.7	26.3	7.5	<average	Low market volatility, Above average inflow	97
April 2011	0	45.6	28.3	26.1	dry	Below average inflows Poatina outage	99
May 2011	0	0	6.5	93.5	<average	Below average inflows Poatina outage	125
June 2011	0.7	14.9	38.9	45.6	wet	Above average inflows Poatina outage	-7

2.5.3.2 Power station outages

There were six power station maintenance outages in 2010–11. Five of these were only a few hours' duration. There was one major power station maintenance outage, which took place on 18 October to 7 November 2010.

Basslink monitoring power station outages took place on:

- 18–20 October 2010;
- 3–5 December 2010;
- 25–27 February 2011; and
- 4–6 March 2011.

2.5.3.3 Seepage trials

With the endorsement of DPIPWE and the Minister, seepage trials to investigate the impacts of bank saturation and varying ramp-down rates were undertaken in 2011. The aims of these trials were to:

- compare the impact of 30 m^3 s^{-1} per hour and 45 m^3 s^{-1} per hour discharge ramp-down rates on the occurrence of seepage erosion in saturated river banks;
- determine the critical in-bank water level associated with sediment flows in the 2–3 turbine region of the banks; and
- examine the impact of unramped reductions in flows in unsaturated banks.

The power station discharge was impacted by these trials in January and February 2011. In order to undertake the trials it was necessary to increase the saturation levels in the river banks. The power station was operated to achieve greater saturation, as well as balance the operational and financial implications of this high discharge. In addition, there were a number of rapid ramp-downs undertaken during these trials. The dates of the seepage monitoring trials in 2011 were:

- 22–23 January;
- 23–25 February; and
- 7–8 March.

2.5.3.4 Median monthly discharge

Figure 2-7 shows the median monthly discharge from the power station for 2010–11 compared with long-term values (since September 1996) and all of the post-Basslink period. This figure illustrates that median discharge was generally lower than usual for most of the reporting year. There were, however, significant increases in the median flow in the months of January and May 2011. The increase in January was similar to the long-term median, and slightly higher than the post-Basslink median, while the increase in May 2011 was significantly higher than both the long-term and the post-Basslink medians, and was influenced both by the Poatina Power Station outage and low system inflows.

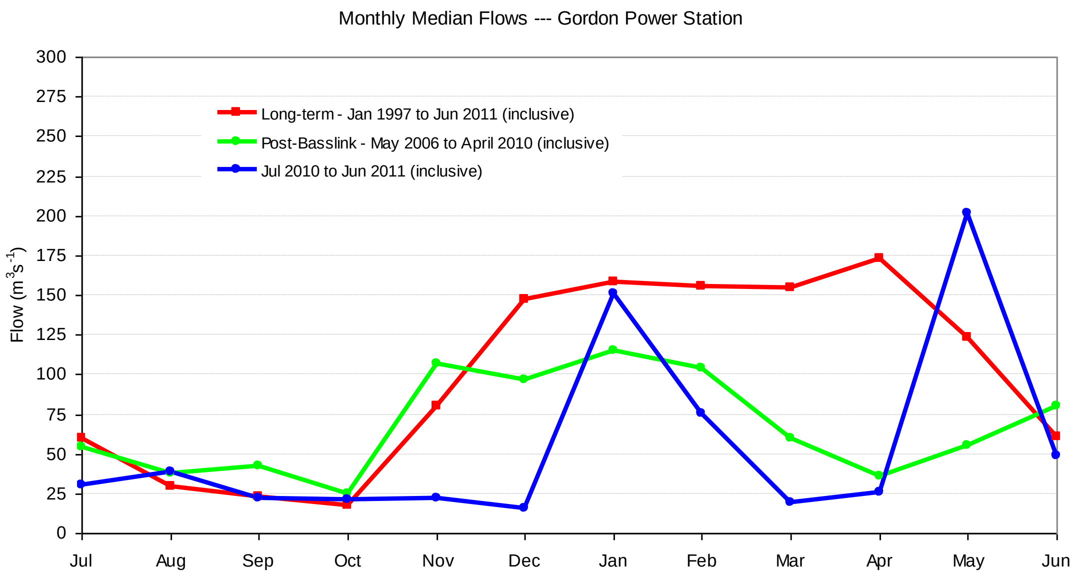


Figure 2-7 Median monthly discharge from the Gordon Power Station (site 77) for 2010–11 compared with long-term median values and previous post-Basslink years

2.5.3.5 Flow duration curves

Figure 2-8 to Figure 2-11 show the duration (percentage exceedance) curve for the power station discharge for:

- annual data;
- winter period (May–October);
- summer period (November–April); and
- years one to five of post-Basslink annual data.

Various duration curves have been plotted against these periods (each period has been devised such that it is divisible by 12 months):

- long-term period (1 July 1997–30 June 2011);
- the historical period (1 January 1997–31 December 2000), incorporating the period when IIAS data were collected;
- the pre-Basslink period (1 January 2001–31 December 2005), when pre-Basslink data were collected;
- the post-Basslink period (1 May 2006–30 April 2010) prior to ; and
- 2010–11 financial year (1 July 2010–30 June 2011).

The annual 2010–11 discharge was low for much of the year, relative to long-term, historical and all previous post-Basslink years. Significant periods of low discharge in 2010–11 were again a feature, with 55 % of all flows being less than 30 m^3 s^{-1}. In comparison, only 31 % of discharges over the long-term record are less than 30 m^3 s^{-1}. The median discharge in 2010–11 was 27 m^3 s^{-1} compared to the historic, pre-Basslink (2001–05), long-term and post-Basslink median discharges of 120 m^3 s^{-1}, 119 m^3 s^{-1}, 91 m^3 s^{-1} and 44 m^3 s^{-1}, respectively. There were 14 % of flows in 2010–11 that exceeded 180 m^3 s^{-1}. It was lower than long-term (20 %), historical (22 %), and pre-Basslink (30 %) flow durations >180 m^3 s^{-1}.

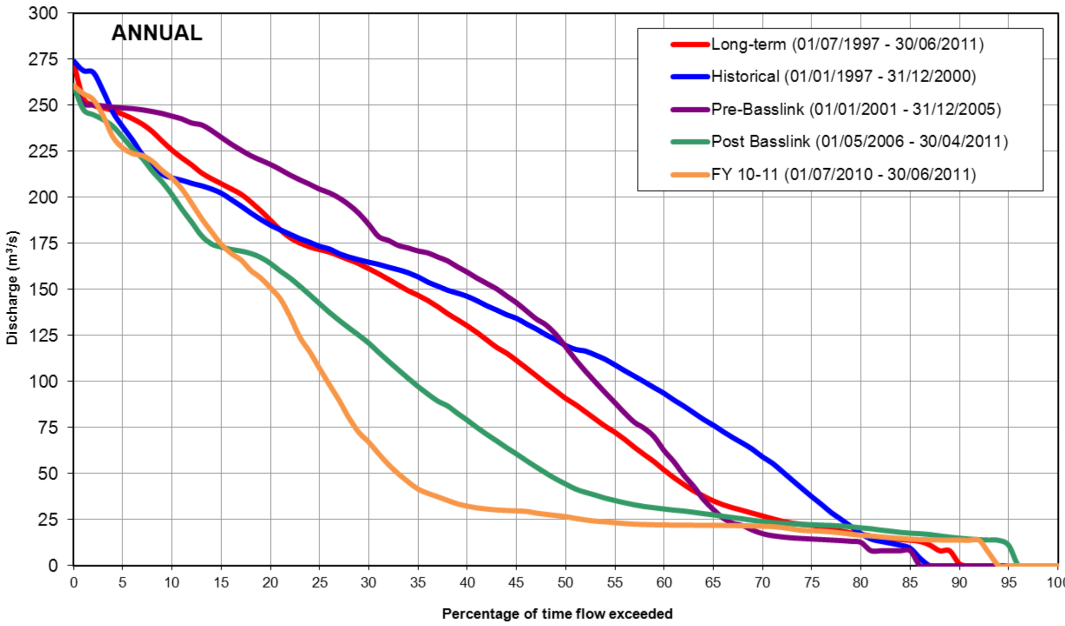


Figure 2-8 Duration curves for discharge from the power station tailrace using annual data for selected periods

The 2010–11 winter duration curve was fairly similar to that of the duration curves for all periods to which it is compared. Differences in the winter duration curves are the slightly greater proportion lower flows in 2010–11 (64 % of flows <50 m^3 s^{-1}) compared to other periods (e.g. 53 % of long-term flows were <50 m^3 s^{-1}). The median flow value was 30 m^3 s^{-1} compared to a long-term winter median of 40 m^3 s^{-1} (Figure 2-9). There was slightly more time where discharges were >180 m^3 s^{-1}; 14 % in 2010–11 compared to 12 % for the long-term. This was greater than the combined post-Basslink years (2006–11), which had only 6 % of flows >180 m^3 s^{-1}.

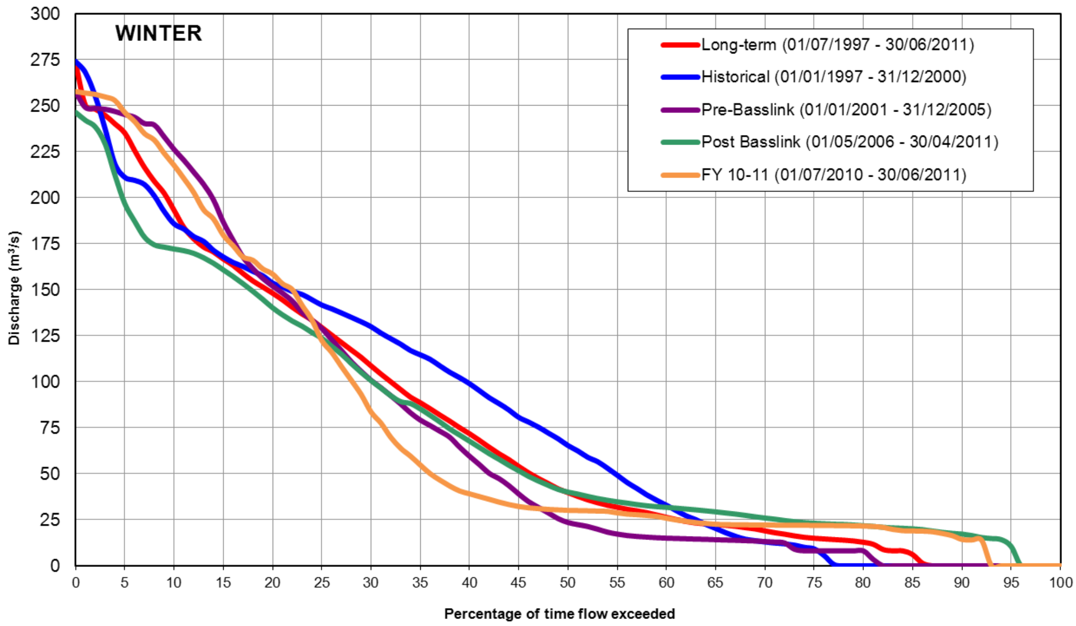


Figure 2-9 Annual duration curves for discharge from the Gordon Power Station using winter data (for the months of May to October inclusive) for selected periods

The 2010–11 summer discharge flow duration curve differs from curves for other periods (Figure 2-10). The significantly lower discharge over summer 2010–11 relative to the long-term is evident over most flow ranges. Discharges >180 m^3 s^{-1} accounted for 13 % of flow, which was significantly lower than the long-term of 31 % of flows being >180 m^3 s^{-1}. Similarly, median values were lower than other periods, with the 2010–11 and long-term median discharges being 22 m^3 s^{-1} and 146 m^3 s^{-1}, respectively.

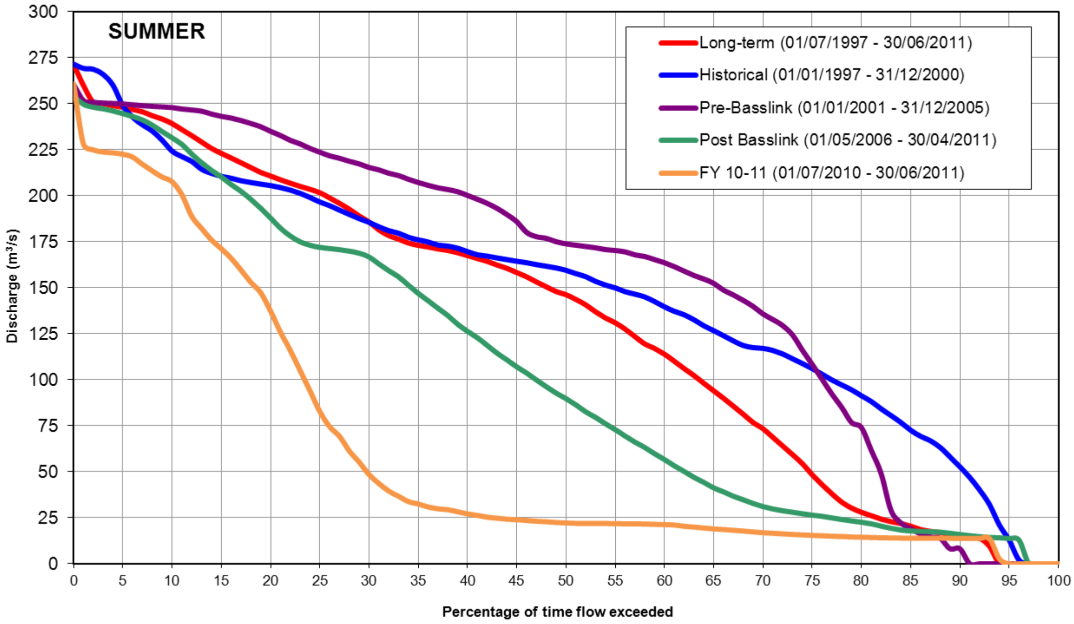


Figure 2-10 Annual duration curves for discharge from the Gordon Power Station using summer data (for the months of November to April inclusive) for selected periods

Each of the post-Basslink years have their flow duration curves represented in Figure 2-11 to compare the current year to each of the previous post-Basslink years. As the post-Basslink period began on 1 May 2006, the annual periods for each of the post-Basslink duration curves are from May to April. Hence, the curve for 2010–11 differs from the annual curve in Figure 2-8 as it represents a slightly different 12-month period. In comparison to each of the post-Basslink years, year five (May 2010–April 2011) had a similar flow duration curve to the previous two years (2008–09 and 2009–10), particularly in the high proportion of low flows. In 2010–11, there has been an increase from 2008–09 and 2009–10 of the proportion of higher discharges. This is seen in the proportion of discharges >150 $m^3 s^{-1}$, which in 2010–11 were 13 %, while in 2008–09 and 2009–10 the proportion of these flows were 7 % and 5 %, respectively.

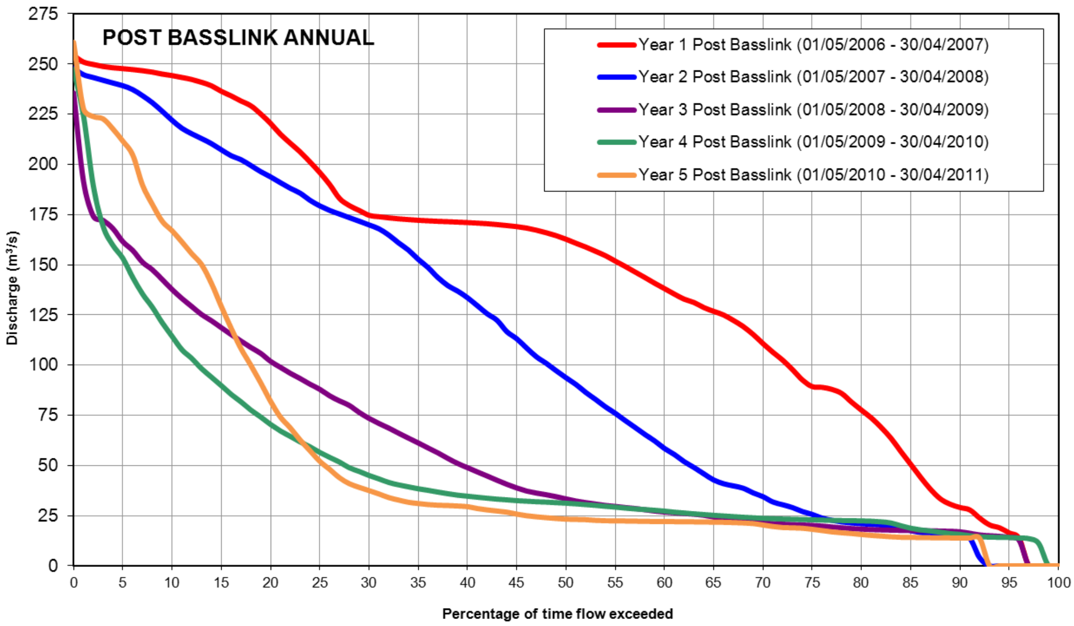


Figure 2-11 Annual duration curves for discharge from the Gordon Power Station for the first five years post-Basslink

2.5.3.6 Flow change frequency analysis

The results of the flow change frequency analysis are shown in Figure 2-12 and Figure 2-13. The data for 2010–11 indicates that there were a similar amount of hours of rapid flow reduction at high discharge as previously observed in 2006–07 (Figure 2-12). The six months up to April 2011 had greater numbers of hours of rapid flow reduction than the period up to October 2010. The six-month periods where flow reductions >30 $m^3 s^{-1}$ in the high discharge range (>180 $m^3 s^{-1}$) indicate that 1 April to 1 October 2010 had 43 hours and 1 October 2010 to 1 April 2011 had 71 hours when this occurred. This is an increase on the last three years, with the October 2010 to April 2011 result being similar to that observed in the six-month period preceding April 2007.

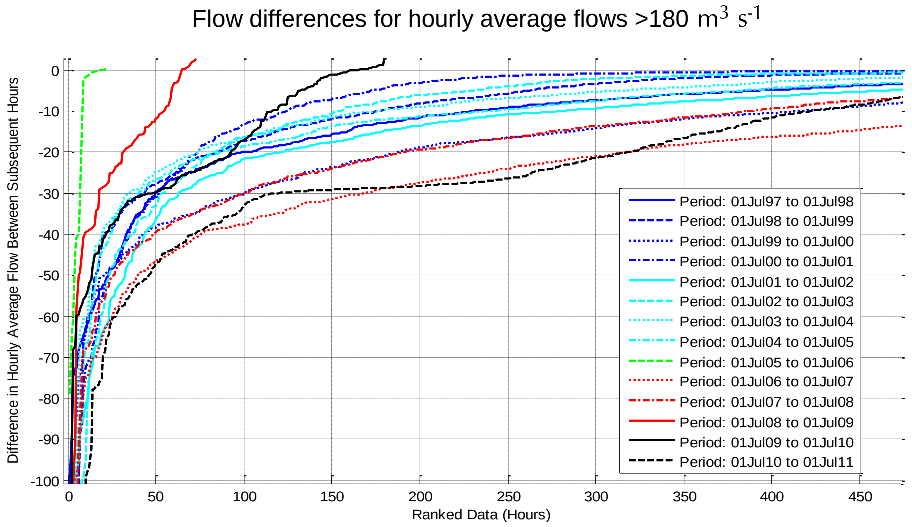


Figure 2-12 Flow change frequency plot showing the ranked rate of flow reductions data occurring while power station discharge was greater than 180 m^3 s^{-1} for 1997–98 to 2010–11

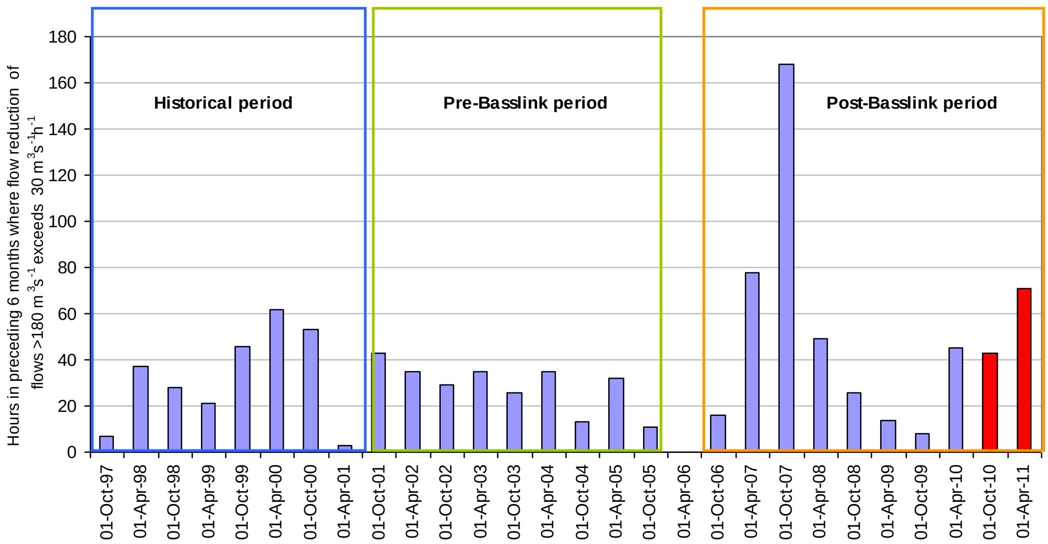


Figure 2-13 Number of hours for each prior six-month period where flow reductions from >180 m^3 s^{-1} exceed 30 m^3 s^{-1} per hour

2.5.3.7 Flow increase ('peakiness') analysis

Figure 2-14 presents analysis of flow increase or low flow range 'peakiness'. This analysis presents data for the number of occasions when flows have increased rapidly (within 2 hours) from low flows in the vicinity of the environmental flow (<25 m^3 s^{-1}) to greater than 100 m^3 s^{-1}. In all years for which hourly data are available, 2010–11 had the greatest number of events where rapid increases following low discharge occurred (100 instances), which was more than double the incidence in the next highest year in 2009–10 (54 instances).

Rapid flow increases were most common from July and August 2010, and January, February, April and June 2011 (Figure 2-14 and Figure 2-15), and coincided with the greater flow peakiness seen in the hydrograph (Figure 2-17).

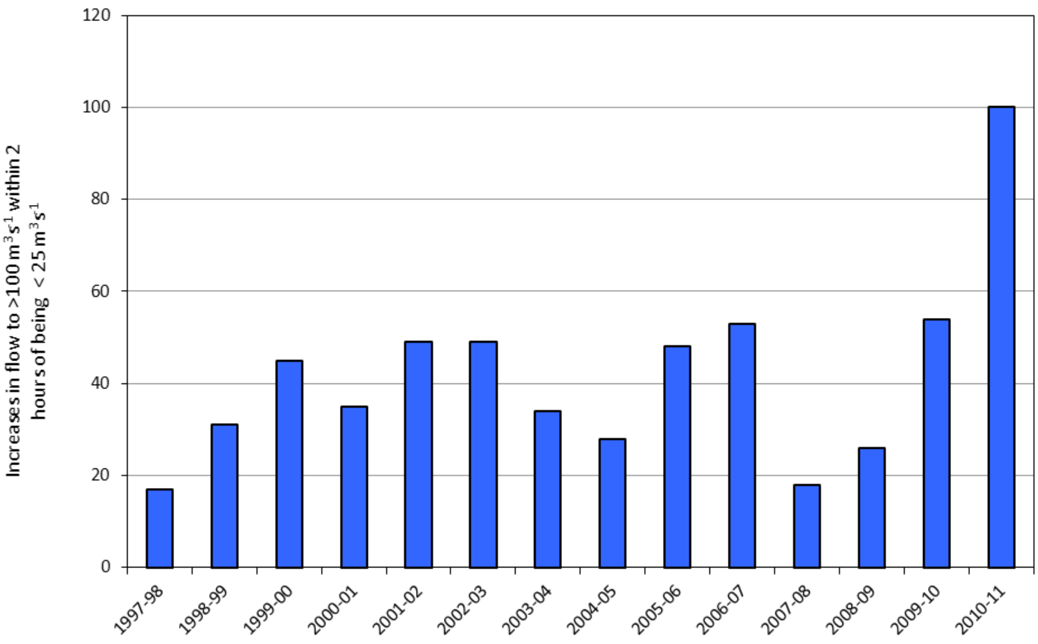


Figure 2-14 Rapid flow increases (<25 to >100 $m^3 s^{-1}$ in two hours) at the Gordon Power Station discharge for each year where hourly data are available

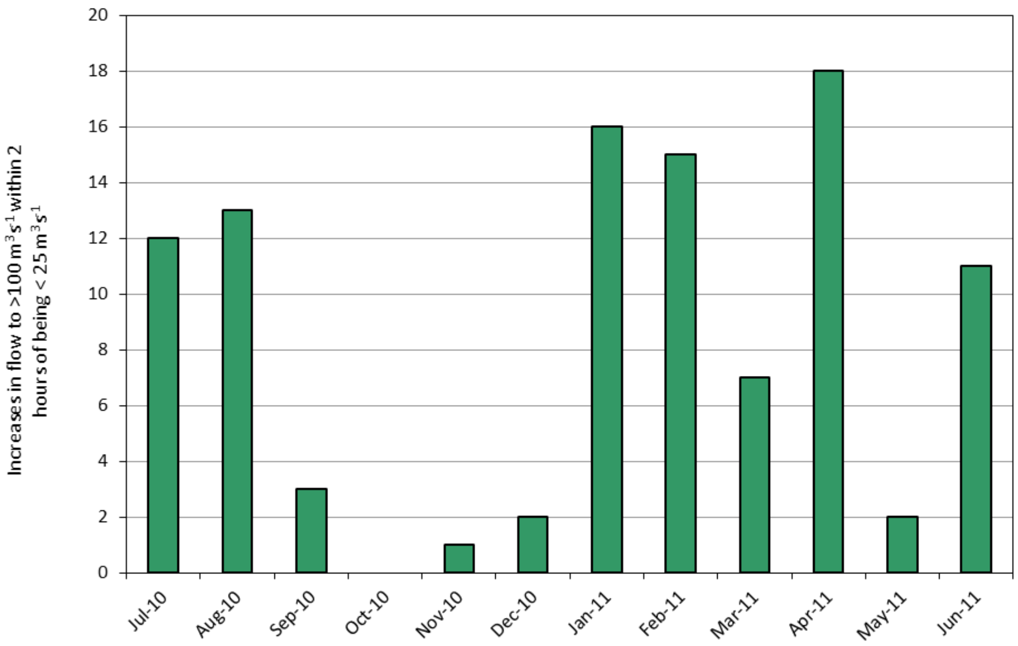


Figure 2-15 Rapid flow increases (<25 to >100 $m^3 s^{-1}$ in two hours) at the Gordon Power Station discharge for each month during 2010–11

2.5.3.8 Conformance with ramp-down rule

A total of 75 potential exceedences of the ramp-down rule were recorded in 2010–11. Of these, 21 exceedances of the ramp-down rate were outside the tolerances defined in the Special Water Licence Agreement. Eight of the exceedences (Figure 2-16) were system events as listed under the Special Water Licence Agreement, which caused the discharge of Gordon Power Station to change rapidly to ensure system stability. There were no exceedences due to market events in 2010–11. A further six events were high ramp-downs undertaken under an approved exemption from the ramp-down rule, as part of the seepage monitoring trials in February and March 2011.

A total of seven non-conformances with the ramp-down rule occurred in 2010–11.

Three of the non-conformances were due to temporary failure of electronic control systems (ramp-down tool, communications failure with AEMO). Three of the remaining non-conformances occurred when the opportunity to ramp was missed and the implementation of the ramp compensation or revised ramp profile was inadequate to stay within the requirements of the rule. The remaining non-conformance had a ramp profile followed, however, was marginally outside the tolerances, at 35.06 m^3 s^{-1} per hour.

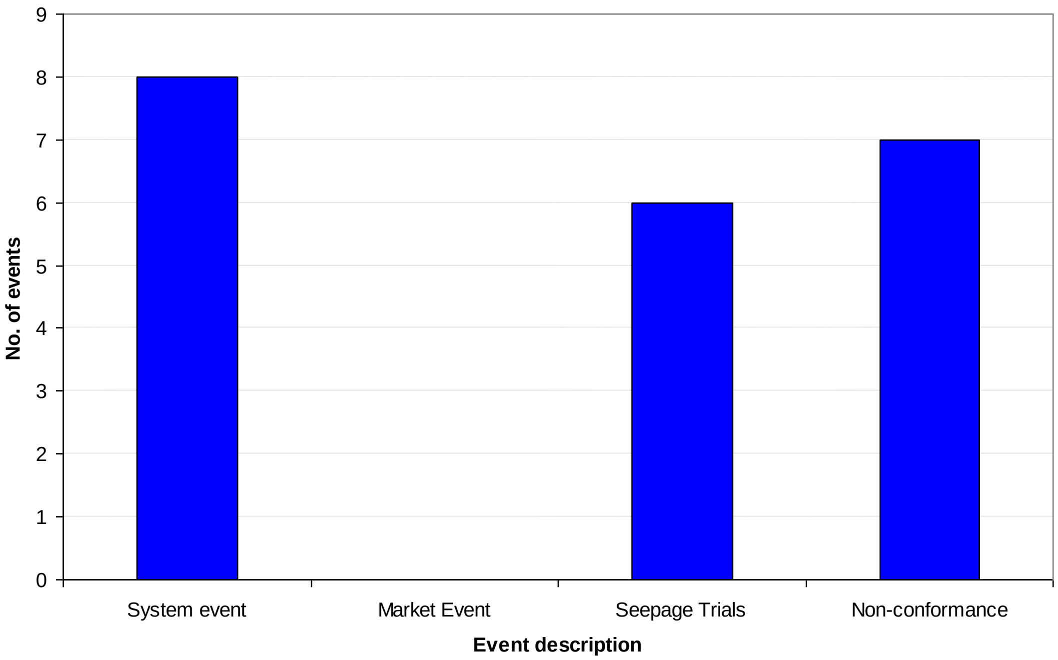


Figure 2-16 Exceedances of ramp-down rule during 2010–11 that were outside of the measurement tolerances

2.5.4 Gordon above Denison (site 65 – environmental flow compliance site)

Site 65 is located in the Gordon River downstream of the power station, approximately 2 km upstream of the Denison confluence. This site was installed in late 2003 in preparation for Basslink commencement. This site monitors the minimum environmental flow required under the Special Water Licence.

2.5.4.1 Flow

Figure 2-17 shows the flow recorded at site 65 for 2010–11. This data indicates close concordance with power station discharge (Figure 2-17) to which peak values (the result of high flows from tributary streams, such as the Albert and Orange Rivers) are added. It should be noted that in some cases, when there is little natural inflow, peaks in flow at site 65 are lower than those from the power station. It is considered than the flow attenuation that occurs between the discharge point at the power station and the 12 km distance to the compliance site is responsible for causing a reduction in the size of flow peaks.

A backwater effect has been observed at this site. When the Denison River floods and Gordon discharge is low, Denison River water may backflow up past site 65. The result of this effect at site 65 would be an over-estimation of the flows during the period of Denison River flooding. The primary function of this site is to monitor the minimum environmental flow, so the backwater effect will not interfere with this function as it only occurs during periods of high tributary flow (i.e. when the minimum environmental flow is met by tributary inputs).

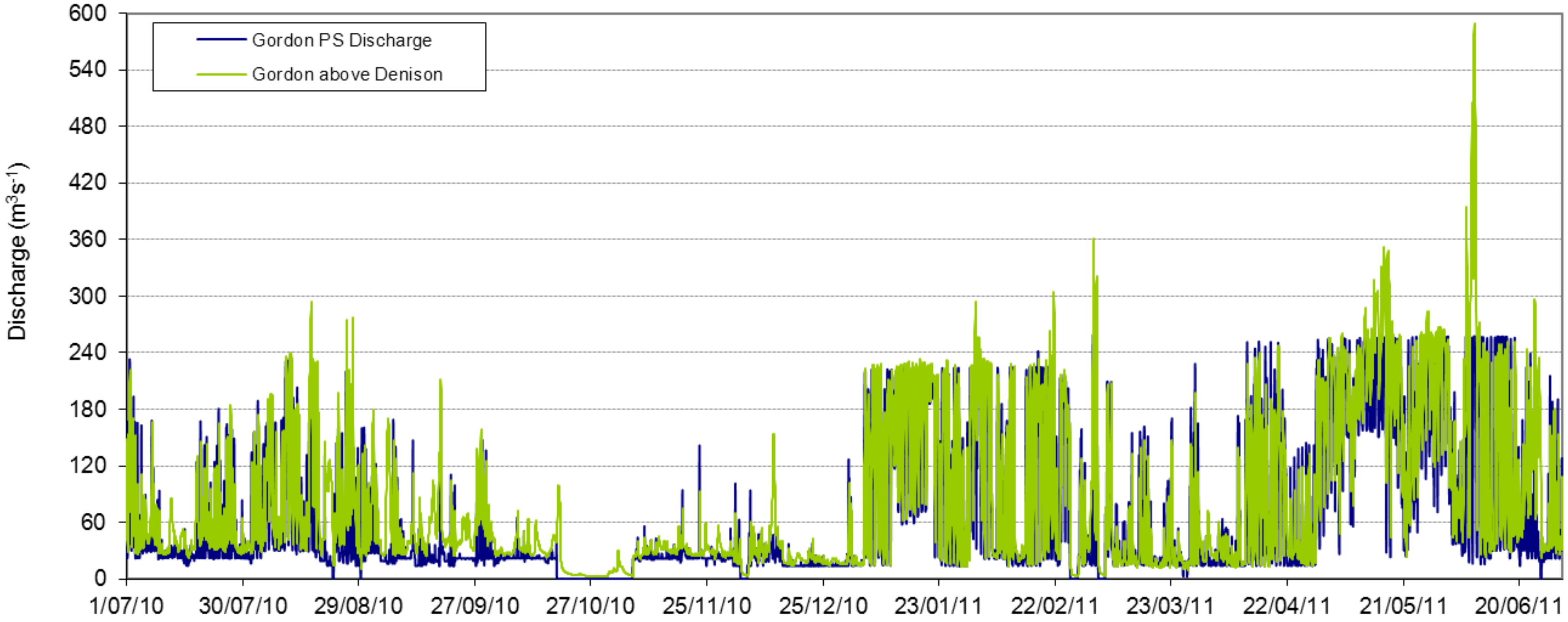


Figure 2-17 Flow recorded (hourly data) at site 65 (Gordon above Denison) showing full scale of flows, from July 2010 to June 2011

2.5.4.2 Median monthly flows

The median monthly flow for site 65 (Gordon above Denison) is shown in Figure 2-18. Comparison with historic average (2003–11) patterns shows most median flows were lower than usual, with the exceptions being January 2011, May 2011 and June 2011. January 2011 and June 2011 values were close to the long-term median value, however, in May 2011 median values were more than double those of the long-term.

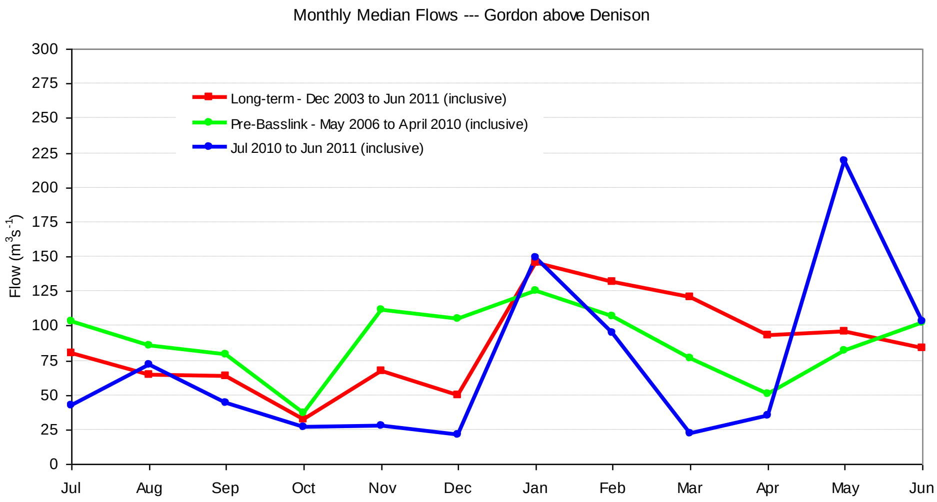


Figure 2-18 Median monthly flow at site 65 (Gordon above Denison) for 2010–11 compared with long-term median values and previous post-Basslink years

2.5.4.3 Duration curves

The duration curve for site 65 is shown in Figure 2-19. Comparison with the long-term curve shows a lower flow for the 2010–11 year in most percentiles, as a result of lower power station discharge.

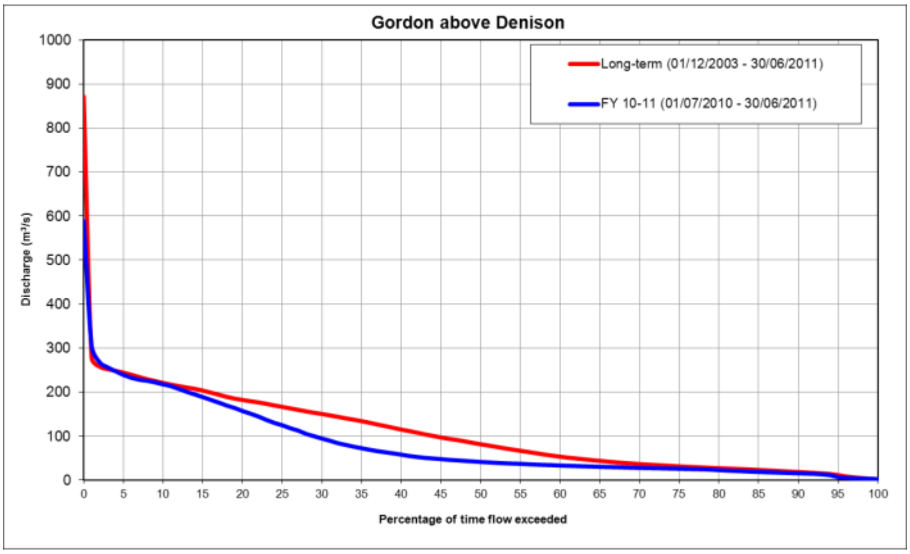


Figure 2-19 Flow duration curve for Gordon above Denison for 2010–11 compared with long-term and previous post-Basslink years

2.5.4.4 Environmental flow compliance

For the period from December through to May the minimum environmental flows required are 10 m^3 s^{-1}, and for the period from June through to November the minimum environmental flow required is 20 m^3 s^{-1}.

An analysis of hourly flows at site 65 shows that for the winter periods (July–November 2010 and June 2011), the minimum flow requirement of 20 m^3 s^{-1} was met 100 % of the time. The minimum summer (December 2010–May 2011) flow requirement of 10 m^3 s^{-1} was also met 100 % of the time (Table 2-4). Note that times of shutdown of the Gordon Power Station due to maintenance, AEMO conformance testing, and/or monitoring have been excluded from the analysis, as per the licence conditions.

As for the previous monitoring period (2009–10) the 100 % compliance in 2010–11 is attributed to setting power station output at Gordon Power Station to a level corresponding to a discharge 10–40 % greater (14 m^3 s^{-1} in summer and 22 m^3 s^{-1} in winter) than that required downstream at the compliance site when natural inflow is low. This is done to avoid potential non-conformances that could be caused as a result of automatic governor adjustment of power output and subsequent discharge. These measures have been very successful in ensuring compliance with the minimum environmental flow.

Table 2-4 Environmental low flow non-conformance events at site 65

Period	Minimum environmental flow	Compliance rate
Winter 2010 (partial)	20	100 %
Summer 2011	10	100 %
Winter 2011 (partial)	20	100 %

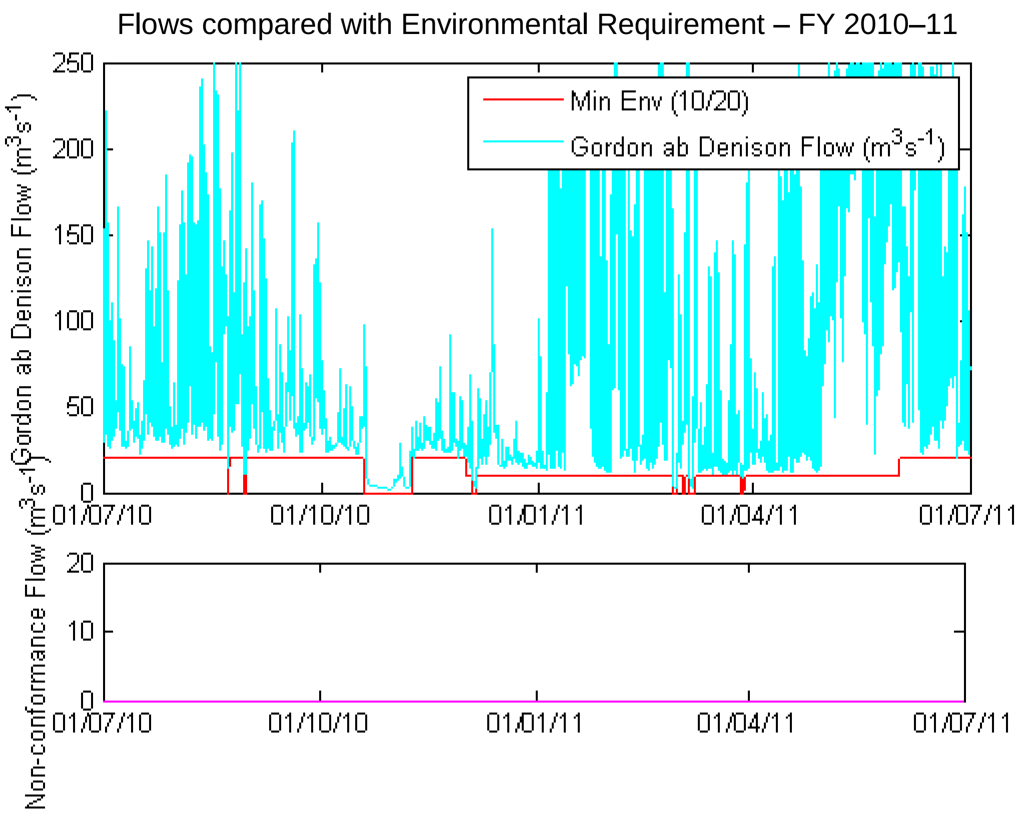


Figure 2-20 Flow recorded (hourly data) at site 65 (Gordon above Denison), from July 2010 to June 2011, and analysis of non-conforming flows

2.5.4.5 Flow increase analysis

Figure 2-21 presents analysis of flow increase or low flow range 'peakiness' at the Gordon above Denison site. This indicates, for the post-Basslink period, the number of occasions when flows have increased rapidly (within two hours) from low flows in the vicinity of the environmental flow (<25 $m^3\ s^{-1}$) to greater than 100 $m^3\ s^{-1}$. In the post-Basslink period, 2010–11 has had the greatest number of instances (39), more than double the incidence in the next highest year in 2009–10 (15 instances). The downstream attenuation of flows and tributary inputs is evident in these plots, which indicate that the annual number of events is less than half of that recorded for the Gordon Power Station (Figure 2-14).

In 2010–11, rapid flow increases were most common from January to April 2011 (Figure 2-22), and coincided with the greater flow peakiness seen in the hydrograph (Figure 2-17) and lower natural tributary inflows.

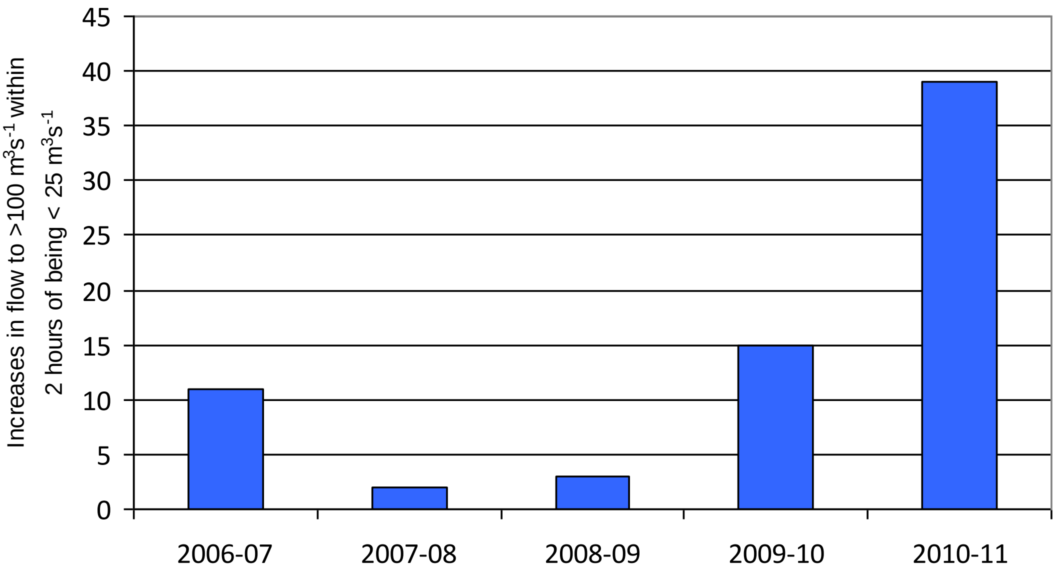


Figure 2-21 Rapid flow increases (<25 to >100 $m^3\ s^{-1}$ in two hours) at the Gordon above Denison for each post-Basslink year

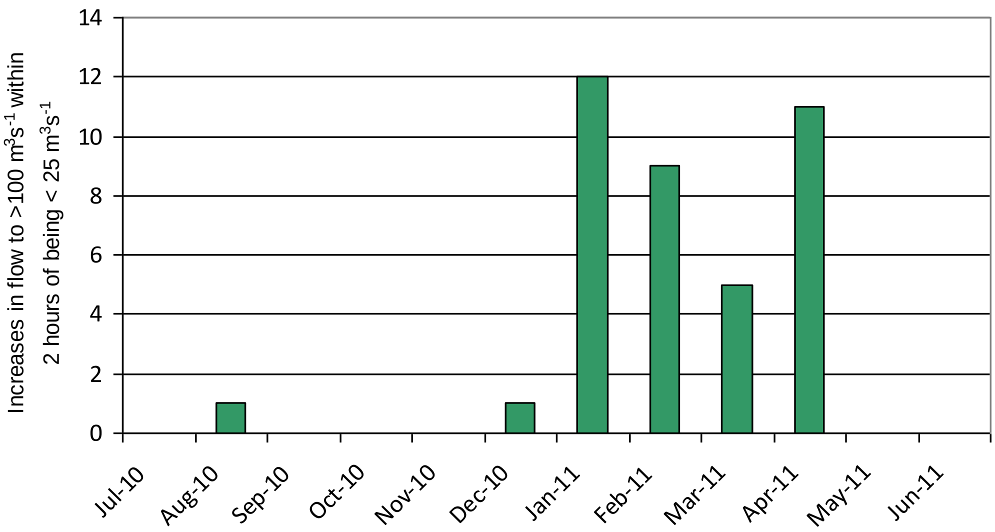


Figure 2-22 Rapid flow increases (<25 to >100 $m^3 s^{-1}$ in two hours) at the Gordon above Denison for each month during 2010–11

2.5.5 Gordon above Franklin (site 44)

The Gordon above Franklin site (site 44) is the furthest downstream monitoring site reported here. Power station releases travel 33 km down the Gordon River before passing the gauge at site 44. The measured flow at this point is a combination of the power station discharge as well as the input from a number of significant tributaries, including the Albert, Orange, Denison, Maxwell, Olga and Sprent rivers. The Franklin River joins the Gordon downstream of site 44 and therefore is not included in the gauged data. Data from site 44 provides an indication of the influence of tributary streams and flow attenuation of the power station discharge on hydrology of the lower reaches of the river.

2.5.5.1 Flow

Figure 2-23 shows the hourly flows at site 44 for 2010–11 compared with discharge from the Gordon Power Station. Data is missing for the period 8–30 June 2010.

Power station discharge is superimposed onto this plot for comparison. The flow rating at this site is based on only a small number of gaugings undertaken during monitoring periods. Of these, few gaugings have been taken at high flows, and it is acknowledged that the flow estimation, particularly at higher flows, is an under-estimate. Despite the inaccuracy of the rating, it can be determined that power station discharge formed the major component of the flow at site 44, with the high peak discharges resulting from flow from tributary streams, such as the Denison River. Large peaks in natural flow of up to 500 $m^3 s^{-1}$ were evident from August to October 2010. Fewer similar sized peaks were from December 2010 through until early March 201. It was not until May and June 2011 that flows increased significantly above Gordon Power Station discharge as a result of tributary inflows primarily from the Denison River. The maximum recorded flow of 883 $m^3 s^{-1}$ was recorded in early June.

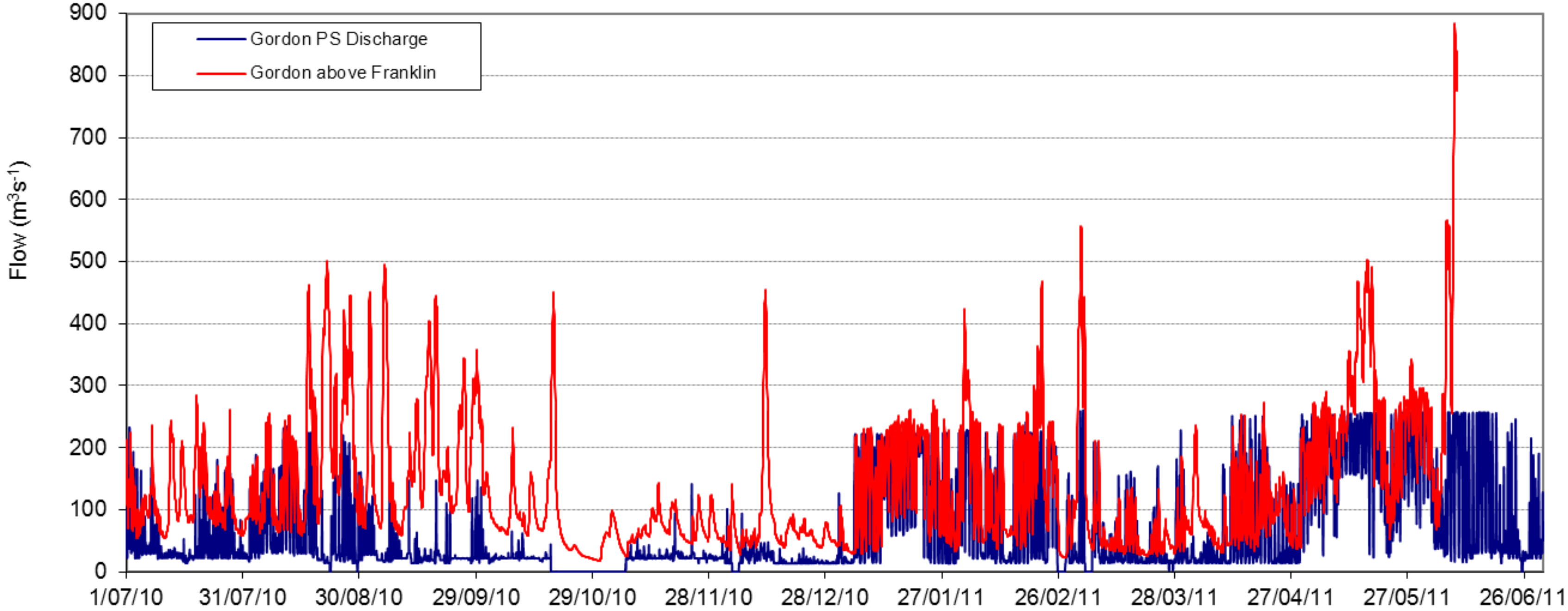


Figure 2-23 Flow recorded (hourly data) at site 44 (Gordon above Franklin) and Gordon Power Station discharge derived from the simplified three-dimensional rating during 2010–11

2.5.5.2 Median monthly flows

Figure 2-24 shows the median monthly flow for the data at site 44 over the 2010–11 year, compared with the long-term post-dam (since January 1978) patterns. Eight months were lower than the long-term median. The most notable of these were December 2010 and March and April 2011, which were significantly below the long-term medians as a result of seasonally low power station use. Of the four months with medians greater than the long-term, May 2011 was significantly greater, and was heavily influenced by both higher than usual operation, and some significant inflows. June 2011 has a period of missing data, and could not be accurately reported as a median.

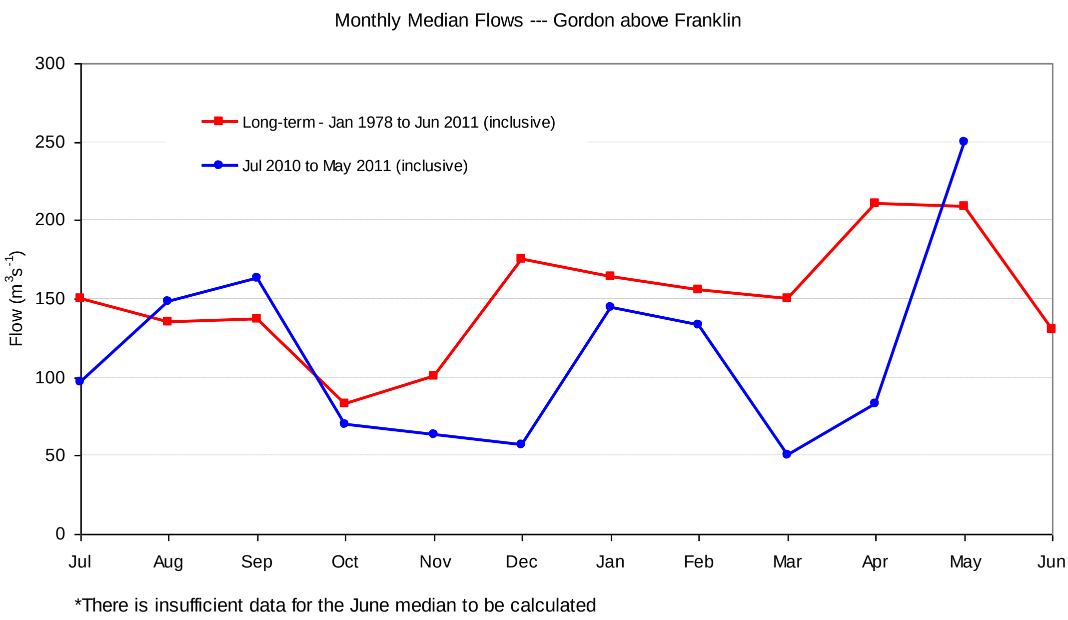


Figure 2-24 Median monthly flow at site 44 (Gordon above Franklin) for 2010–11 and the long-term monthly median values

2.5.5.3 Duration curves

The duration curve for site 44 is shown in Figure 2-25. Comparison with the long-term curve is indicative of generally lower flows for the year, which were dominated by the influence of the lower flows from the power station. It should also be noted that this curve is constructed in the absence of data for June 2011.

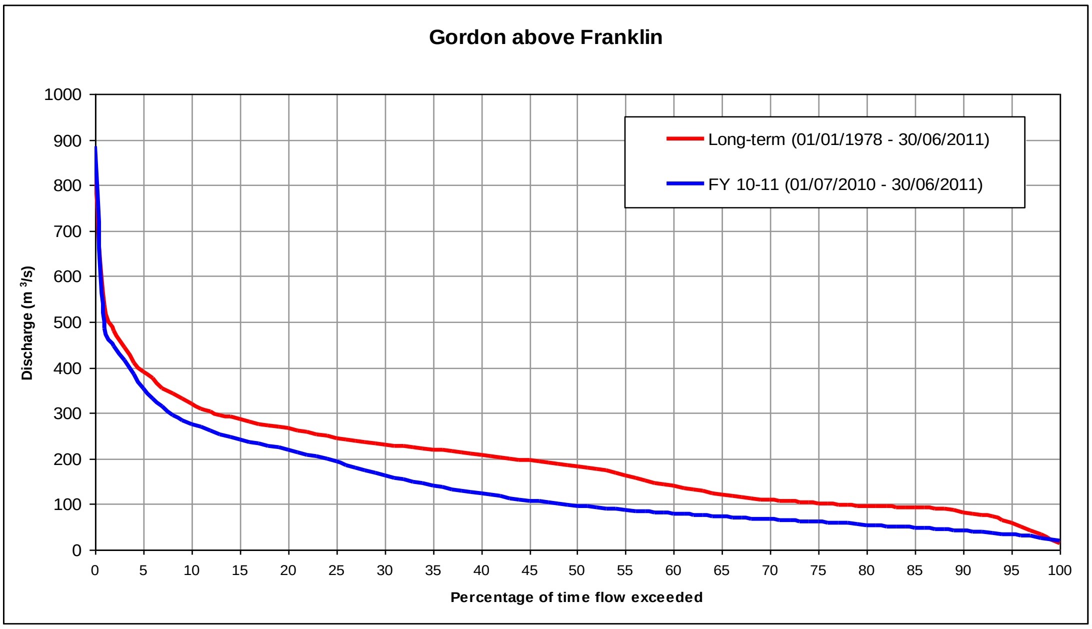


Figure 2-25 Duration curve for flow at site 44 (Gordon above Franklin)

2.6 Conclusions

The 2010–11 power station operating regime was influenced by the strategy to increase general storage levels, and to ensure sufficient storage in Lake Gordon in preparation for the outage at Poatina Power Station that commenced in April 2011. The outage at Poatina in the period after April was a significant influence on the increased running of Gordon Power Station between April and June 2011. The low system inflows in May 2011were also a significant factor in the high running at Gordon Power Station in this month.

The discharge from Gordon Power Station consisted of greater periods of regular hydro-peaking than in previous years, at levels corresponding to 3-turbine operation. The greatest number of low to high discharge peaking events in all of the post-Basslink years were measured at the Gordon above Denison site.

A total of 21 exceedances of the ramp-down rule outside the tolerances defined in the Special Water Licence were recorded in 2010–11. Of these, eight were defined system events as listed under the Special Water Licence Agreement, and six were approved when undertaking the seepage trials. There were seven non-conformances recorded in 2010–11.

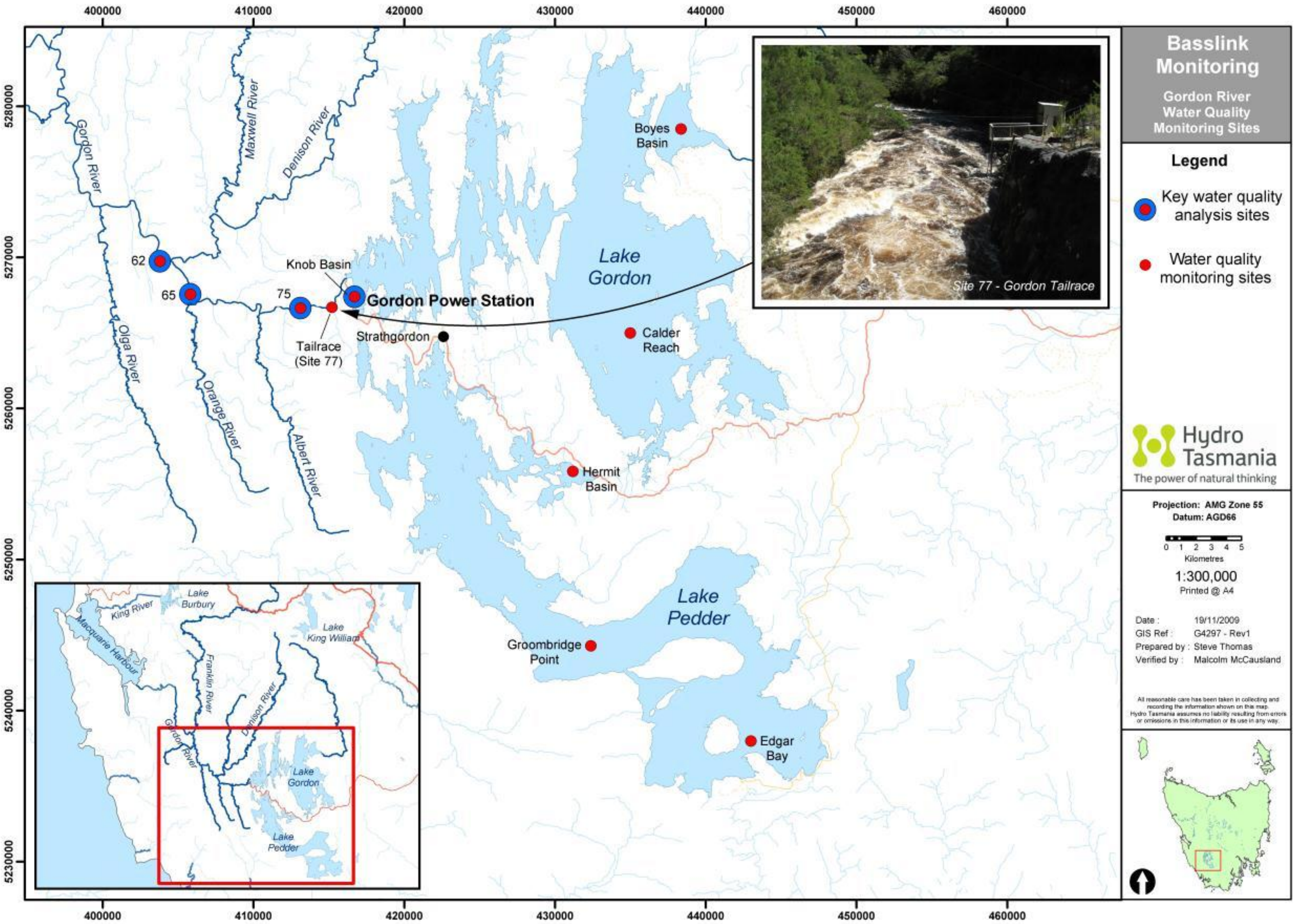
The minimum environmental flow was achieved 100 % of the time.

Flow patterns at downstream sites were reflective of flows from the power station. Notable high daily flow peaks observed in August and September 2010 and June 2011 were the result of high rainfall at these times.

3 Water quality

Water quality parameters were measured in Lake Gordon and Lake Pedder, and in the Gordon River downstream of the power station between July 2010 and June 2011. The water quality monitoring sites are shown in Map 3-1.

Lake Gordon is a major source of water for the middle reaches of the Gordon River; the quality of water in the river is influenced by the conditions at the power station intake and the flow regime in the river. There are no specific trigger values for water quality, however water quality information is collected and reported as a possible input variable that may relate to the results of biological monitoring in the Gordon River. Therefore, the intent of the Basslink Water Quality Monitoring Program is to document the water quality in both the storages (Lake Gordon and Lake Pedder) and in the Gordon River to assist in the interpretation of biological monitoring data from the middle Gordon River.



Map 3-1 Map of the locations of water quality monitoring sites in Lakes Pedder and Gordon and the Gordon River

3.1 Methods

3.1.1 Lake Gordon and Lake Pedder

During 2010–11, quarterly water quality monitoring was conducted in Lakes Gordon and Pedder on 15–16 July 2010, 18–19 October 2010, 17–18 January 2011 and 7–8 April 2011. Sampling sites in Lake Gordon were Knob Basin (approximately 100 m from the power station intake), Calder Reach and Boyes Basin (adjacent to the upper Gordon River inflow). Sampling sites in Lake Pedder were at Groombridge Point, Hermit Basin and Edgar Bay.

Chemical analyses were carried out on surface water samples collected from each site. The following parameters were analysed, for each water sample, by Analytical Services Tasmania and Inland Fisheries Service Biological Consultancy (chlorophyll-*a* analysis only):

- total phosphorus and filterable reactive phosphorus (FRP);
- nitrite, nitrate, total Kjeldahl nitrogen (TKN) and ammonia;
- chlorophyll-*a*;
- metals (iron, manganese, zinc, cadmium, copper, aluminium, cobalt, chromium, nickel and lead);
- sulphate;
- alkalinity; and
- dissolved organic carbon.

Additionally, *in situ* depth profiles of basic physico-chemical parameters (water temperature, dissolved oxygen, electrical conductivity and pH) were taken at approximately 2 m vertical intervals at each of the Lake Gordon sampling sites and Groombridge Point in Lake Pedder.

3.1.2 Gordon River

Water quality monitoring data were collected from four sites on the Gordon River, downstream from the Gordon Power Station:

- Gordon Power Station tailrace (site 77);
- Gordon River at site 75 (G4 – Albert Rapids), located 2 km downstream of the tailrace;
- Gordon River at site 65 (upstream of the Denison confluence – compliance site), located 12 km downstream of the tailrace; and
- Gordon River at site 62 (downstream of the Denison confluence), located 15 km downstream of the tailrace.

Water temperature was logged at all sites, with dissolved oxygen also recorded at sites 65 (compliance site) and 77 (tailrace). The data from sites 65 and 77 is retrieved by telemetry, while data from sites 62 and 75 must be downloaded manually during field visits. For this reason, the data from sites 62 and 75 is analysed and presented from April 2010 to April 2011, while data from sites 65 and 77 is presented from April 2010 to June 2011.

3.1.3 Logistical issues

No water temperature data is available for the following sites:

- site 62 (downstream of Denison River) for the period from 4 December 2010 through to 1 July 2011 due to corruption of data. The corrupt data was discovered following its field download on 6 March. The next field trip in October 2011 will be used to repair this site; and
- site 65 (upstream of Denison confluence – compliance site) for the period from 3 December 2010 through to 26 February 2011. This data was lost as the instrument installed had the incorrect SDI address (i.e. human error).

No dissolved oxygen data is available for the following sites:

- site 77 (tailrace) for the period 17 October to 6 November, as the instrument was out of the water while the power station maintenance outage took place; and
- site 65 (upstream of Denison confluence – compliance site) for the period from 3 December through to 5 December 2010.

Chlorophyll-*a* data were of poor quality at the Boyes Basin and Calder Reach sites on Lake Gordon, and Groombridge Point in Lake Pedder. It appears that sample contamination during extraction or instrument error may have been the cause.

3.2 Results and discussion

3.2.1 Lake Gordon water quality

Profiles of water temperature, pH and dissolved oxygen for Boyes Basin, Calder Basin and at Knob Basin, in the vicinity of the intake, are shown in Figure 3-1 to Figure 3-3.

3.2.1.1 Boyes Basin

Boyes Basin is the shallowest of the three sampling sites in Lake Gordon, with water depths ranging between 29 m and 34 m during the year (Figure 3-1). It is the closest site to the upper Gordon River, which is one of the major inflows to the lake. In July 2010, temperatures through the water column ranged from 9.5 °C at the surface to 6.5 °C at 29 m. A thermal transition layer (thermocline) was evident at around 21–25 m. A higher oxygen level and lower electrical conductivity below the thermocline in July 2010 suggests that the thermocline was the result of recent cool inflows of water from the upper Gordon River. By October 2010, the thermocline had begun to dissipate, with temperatures throughout the water column increasing and a surface temperature of 10.6 °C. In January 2011, a thermocline was again evident, with temperatures significantly decreasing at approximately 12 m. A gradient was present throughout the water column, with a surface temperature of 17.5 °C declining more than six degrees to 11.2 °C at 24.5 m. There was evidence of an oxycline at 12–24 m depth where dissolved oxygen decreased from 8.8 to 5.8 mg L^{-1} and then continued to decrease with depth down to around 3 mg L^{-1} at 25 m. In April 2011, water temperatures had cooled significantly (i.e. approximately 2 °C) to a depth of 16 m, beyond which temperatures were slightly higher than those recorded in January. There was a difference of 2.8 °C in temperature between the surface (15.2 °C) and the bottom (12.4 °C) samples, and dissolved oxygen was relatively uniform throughout the water column.

Throughout the year pH values ranged from 6.2 to 6.9. The highest pH values (up to 6.9) were recorded in 20–24 m deep waters in October 2010. The lowest pH (6.2) was recorded in January 2011 for waters up to 25 m deep, with concentrations increasing from 6.2 to 6.7 at 25 to 12.5 m. Some pH variability with depth corresponded with vertical variation in oxygen concentration and is indicative of the different chemical conditions through the water column. In shallow waters (up to 8 m) the pH gradient was relatively uniform throughout the year.

Dissolved oxygen in Boyes Basin was generally high (greater than 80 % saturation or 8 mg L^{-1}) throughout the water column. Dissolved oxygen was greatest in surface waters in October, when the associated increase in surface pH is an indicator of higher primary production occurring as surface water temperatures increase. Low dissolved oxygen concentrations (e.g. down to 31.3 % or 3.5 mg L^{-1}) were only recorded in January at depths greater than 20 m.

Electrical conductivity (EC) at Boyes Basin tended to increase slightly throughout the winter–summer period, from ~41 µS cm^{-1} in July 2010 to ~44 µS cm^{-1} in January 2011. Concentrations decreased slightly to ~43 µS cm^{-1} in April 2011. However there was significant variability in the profiles in July (decreasing from 42 to 32 µS cm^{-1}) at depths of 18 to 29 m.

Turbidity was between 0.7 and 5.3 NTU (Table 3-1), consistent with the range previously recorded. Chlorophyll-*a* concentrations ranged from 0.48 to 5.6 µg L^{-1} (Table 3-1).

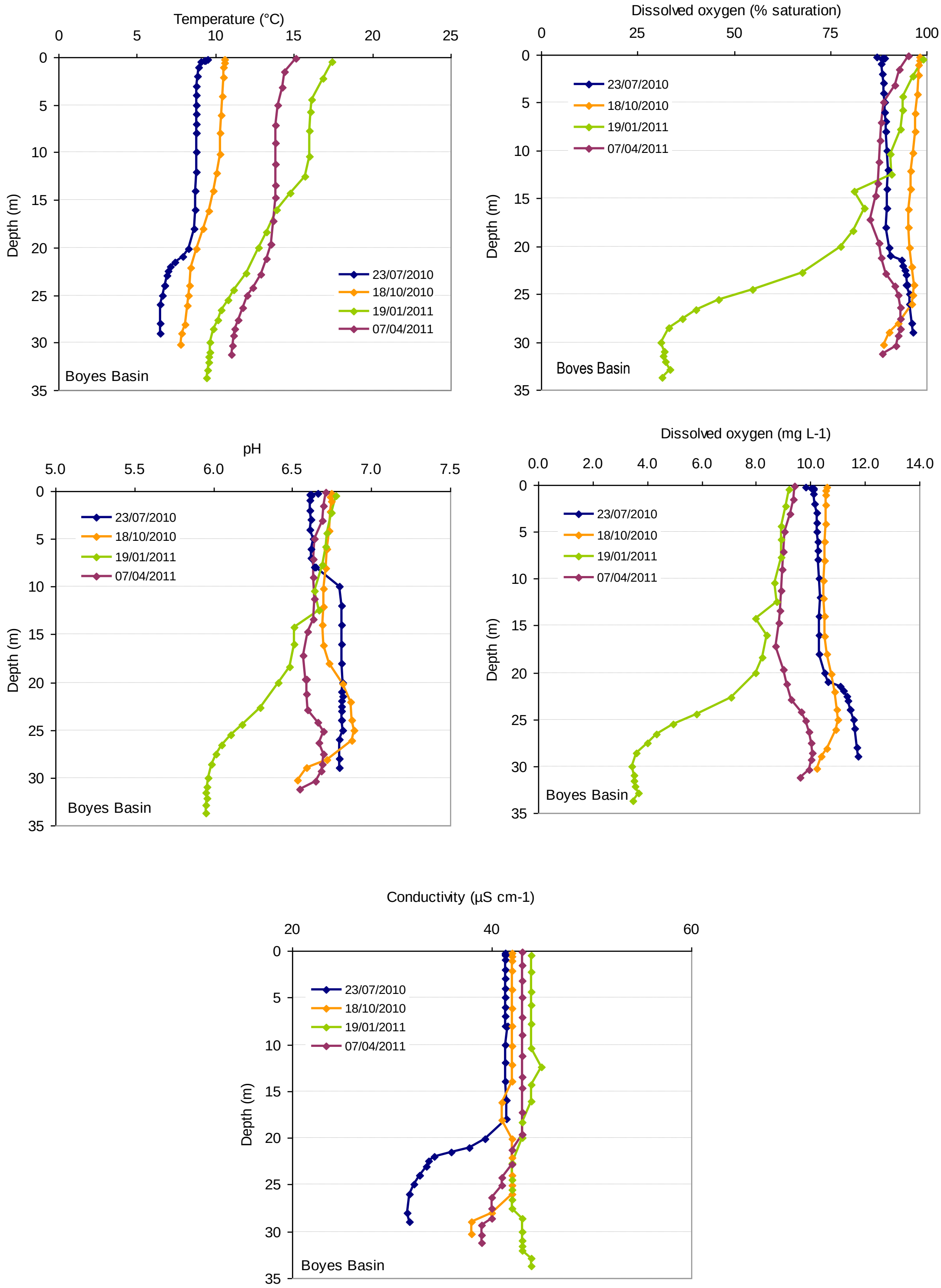


Figure 3-1 Depth profiles for temperature, pH, conductivity and dissolved oxygen at Boyes Basin in Lake Gordon

3.2.1.2 Calder Reach

Calder Reach underwent a typical seasonal temperature cycle with surface water temperatures increasing from July through to April and ranging from near-isothermal conditions in July and October 2010 to a stratified water column in January and April 2011 (Figure 3-2). A thermal gradient was evident in January 2011 with water temperatures decreasing gradually from 16.7 °C at the surface to 10.7 °C at 23 m. In April 2011 thermal stratification occurred at 23.9 m depth with temperatures falling by almost 3 °C (from 13.58 to 10.61 °C), and then continuing to decline gradually with depth, to a minimum of 9.3 °C at 39 m. A similar pattern was observed for dissolved oxygen concentrations, which decreased to 42 % saturation (4.9 mg L^{-1}) at 40 m in January, and 23 % saturation (2.6 mg L^{-1}) at 40 m in April 2011. Dissolved oxygen concentrations were high and uniform throughout the water column in July and October 2010.

There was little difference in pH (6.79–6.75) for up to 44 m of water in July 2010 and October 2010 at Calder Reach. In January 2011, pH decreased from 6.79 at the surface to 6.31 at 23 m. The pH of the surface mixed layer was highest in April 2011 (Figure 3-2), whereby pH decreased from 6.99 at the surface to 6.65 at 23 m and decreased further to 5.97 at 45 m.

The cause of the lower dissolved oxygen in the deepest waters in January and April 2011 is bacterial consumption of oxygen without replenishment due to stratification. Similarly the corresponding decline in pH is most likely related to the increase in concentration of carbon dioxide from bacterial respiration, which drives the pH down.

Conductivity at the Calder Reach site was similar on all sampling occasions (40.8–43 µS cm^{-1}) and uniform throughout the water column, as noted in previous reports. Turbidity ranged from 0 to 5.3 NTU. Chlorophyll-*a* was generally low (<2.1 µg L^{-1}), but increased slightly from October 2010 through to April 2011 (Table 3-1).

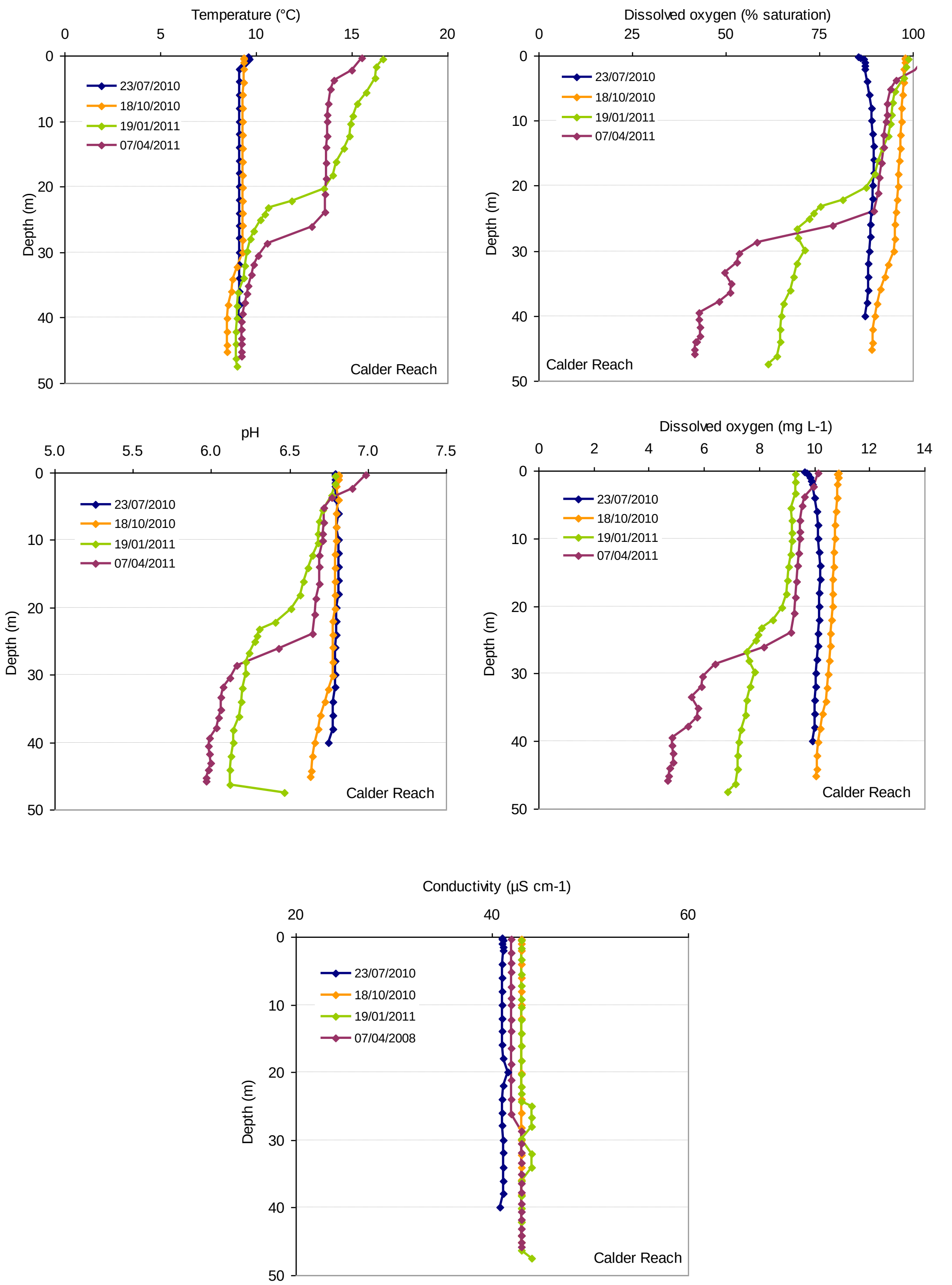


Figure 3-2 Depth profiles of temperature, pH, conductivity and dissolved oxygen at Calder Reach in Lake Gordon.

3.2.1.3 Knob Basin (intake) site

A typical annual cycle of water quality profiles was observed at Knob Basin during 2010–11. The water temperature was cool (7.7–9.4 °C) and uniform throughout the water column in July and October 2010. In January 2011, surface water temperatures had increased to 15.9 °C while water temperatures in the vicinity of the intake (intake depth range 250–255 mASL) remained low at ~10 °C. In April 2011, there was evidence of shallow surface warming and thermal stratification at 20 m at which depth temperatures fell from 13.5 °C to 10 °C in the vicinity of the intake. On all sampling occasions water temperatures below 40 m depth remained within the range of 7.7–8.9 °C (Figure 3-3).

Anoxic conditions were recorded for bottom waters at Knob Basin (deeper than 50–60 m) on all sampling occasions, as expected based on previous work, and due to the lack of mixing and bacterial respiration.

In July 2010, surface waters were reasonably well oxygenated (~82 % saturated or 9.3 mg L^{-1}) to 8 m deep and slightly less oxygenated (~ 77 % saturated or 8.7 mg L^{-1}) from 8 m to the distinct oxycline at 38–46 m; a depth range that is 10–21 m deeper than the power station intake. At the oxycline, dissolved oxygen concentrations fell from 77 % to 21 % saturation (8.7–2.4 mg L^{-1}). Below this depth, from 46 to 80 m, typical anoxic conditions were observed. In October 2010 and January 2011 the oxycline was not as distinct. Dissolved oxygen levels declined gradually with depth to 50 m and concentrations at the intake range were similar for October 2010 and January 2011 (7.3 mg L^{-1} and 6.8 mg L^{-1}, respectively). In April 2011, surface waters were well oxygenated, but an oxycline had developed at 22 m (associated with the thermocline) resulting in reduced oxygen concentrations of 50–53 % saturation (5.5–6 mg L^{-1}) at the intake range. This can allow water with lower dissolved oxygen to be drawn into the power station and discharged into the tailrace and is the possible cause of slightly lower minimum DO (~6 to 7 mg L^{-1}) observed in the tailrace over the last week of April (Figure 3-7).

Conductivity at Knob Basin ranged from 38 to 48 µS cm^{-1} over the full profile depth, with increased conductivity observed at depth in response to anoxic conditions in July 2010, October 2010 and April 2011 and, to a lesser degree, in January 2011. The higher conductivity observed in deeper waters is most likely related to the ionisation of metals and nutrients under the influence of anoxic conditions.

There was some variation in pH with depth. In July 2010, pH in the surface waters increased with depth before stabilising and then increasing yet again at a depth of 52 m (i.e. 6.69 at 52 m to 7.35 at 54 m). In October 2010, January 2011 and April 2011, pH decreased with depth down to approximately 60 m where bottom water concentrations increased slightly. In April 2011, the pH dropped slightly below the oxycline (i.e. 6.24 at 22 m and 5.91 at 24 m). Decreases in pH can be due to increased concentrations of carbon dioxide from bacterial respiration. Conversely, increases in pH near the surface can be due to primary production and a decline in carbon dioxide.

Turbidity (<1.7 NTU) and chlorophyll-*a* were low (<2.3 µg L^{-1}) throughout the year (Table 3-1).

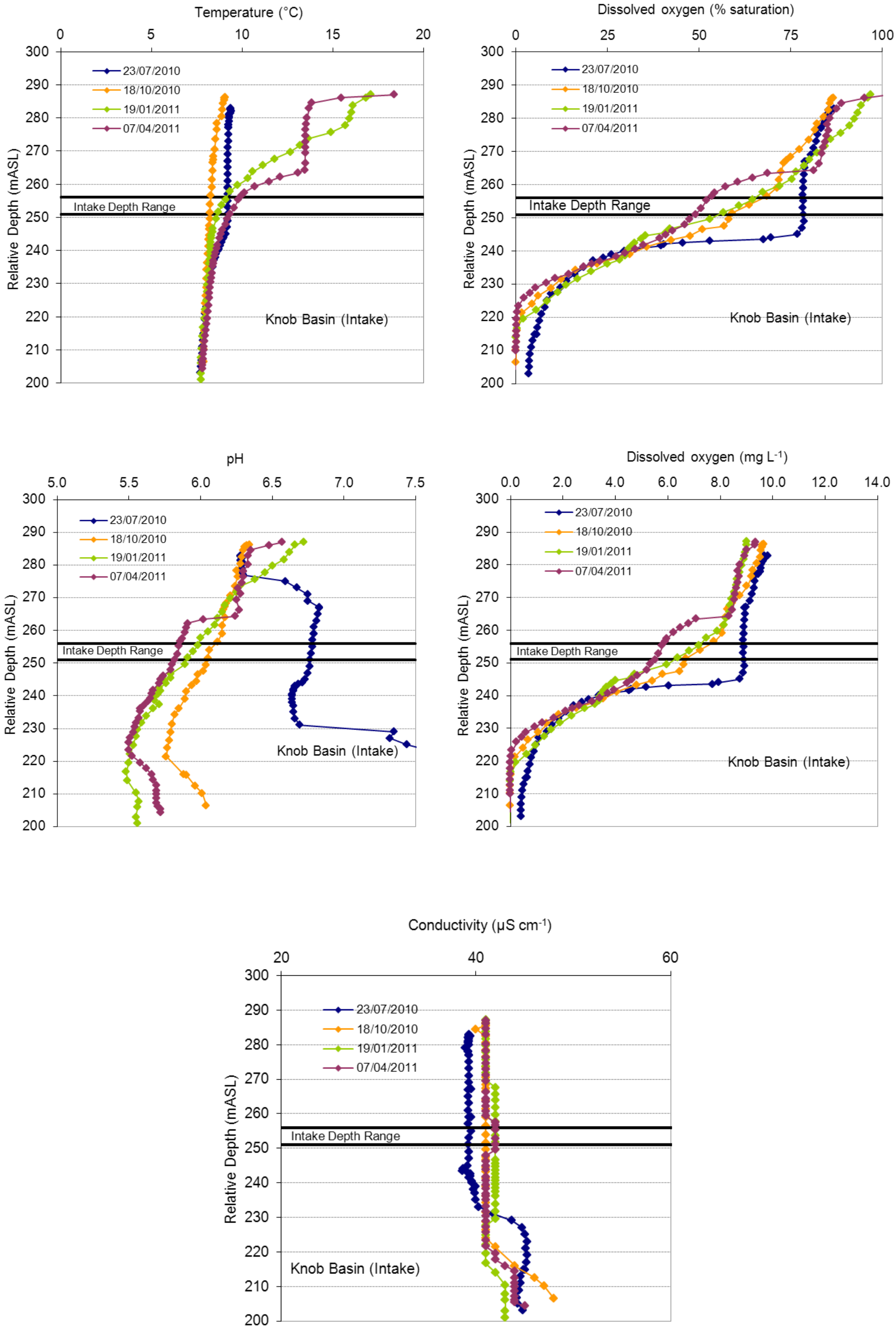


Figure 3-3 Depth profiles for the intake site located at Knob Basin in Lake Gordon for temperature, pH, conductivity and dissolved oxygen. Depths are represented as relative depth in mASL to demonstrate the potential fluctuations in water quality at the power station intake. The depth range of the power station intake is indicated by two heavy black lines

3.2.1.4 Lake Gordon surface water quality

The surface water quality data are presented in Table 3-1. The results are typical of fresh waters in Tasmania's south-western region, relatively high dissolved organic carbon and slightly acidic pH. Sulphate concentrations were within the range reported in previous years, while the low alkalinity measures continue to indicate that the water in Lake Gordon is 'soft' (i.e. low in carbonates).

Concentrations of nutrients were within ranges recorded for samples from previous years, with low concentrations of total phosphorus, total Kjeldahl nitrogen and filterable reactive phosphorus, and low to moderate concentrations of ammonia/ammonium[2] and nitrate.

Chlorophyll-*a* concentrations were relatively low across all sites in comparison to those recorded in 2009–10 (e.g. Boyes Basin = 2.57 µg L^{-1} in October 2010 c.f. 9 µg L^{-1} in October 2009) (Hydro Tasmania 2010b). It is common for chlorophyll-*a* concentrations to be highest at Boyes Basin, and it is hypothesised that, as this site is in the vicinity of the inflowing upper Gordon River, there is a source of nutrients delivered by the river that has the potential to support a higher phytoplankton biomass. Any bioavailable nutrients may be rapidly utilised in the warmer shallower waters of Boyes Basin (and therefore difficult to detect by the current nutrient sampling program). At the other sites chlorophyll-*a* concentrations were generally less than 1 µg L^{-1} but increased to 2.1 µg L^{-1} in April 2011 at Calder Reach, and 2.3 µg L^{-1} in April 2011 at Knob Basin.

Metals concentrations in Lake Gordon were low except for aluminium, zinc and copper, which were higher than the ANZECC (2000) toxicity guidelines[3] on at least one occasion. However, elevated aluminium concentrations are typical of the naturally acidic waters of storages in western Tasmania and the toxicity of aluminium is known to be reduced by the presence of humic substances (ANZECC 2000), an effect likely to occur in Lake Gordon due to its high humic content.

Except for the single elevated copper concentration of 3 µg L-1 recorded for Boyes Basin in October 2010, all other copper concentrations were low (near the detection limit of 1 µg L-1) (Figure 3-4). Elevated zinc levels were recorded from Calder Reach in April 2011 and have been previously reported from Calder Reach in July 2008 and from Knob Basin in April 2009 (Figure 3-4).

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[2] The analytical method for the determination of ammonia transforms ammonium to ammonia and is therefore representative of the combined concentration of free ammonia and ionised ammonium. However, under the pH and temperature conditions in Lake Gordon, greater than 99 % of the measured ammonia is present in the water as ammonium, and therefore concentrations of ammonia should be considered to be primarily representative of concentrations of ammonium

[3] Trigger values: 55.0 µg L^{-1} for aluminium (at pH >6.50); 1.4 µg L^{-1} for copper; 8.0 µg L^{-1} for zinc

Table 3-1 The range of nutrients, metals, sulphate, alkalinity, dissolved organic carbon and chlorophyll-*a* levels recorded from surface waters at monitoring sites in Lake Gordon during 2010–11. Figures in bold indicate exceedence of ANZECC toxicity guidelines

Parameter	Boyes Basin	Calder Reach	Knob Basin (Intake)
Specific conductivity ($\mu S\ cm^{-1}$)	41.3 – 44	41 – 43	39.3 – 41
Turbidity (NTU)	1.6 – 3.9	2 – 5.3	0.7 – 1.7
Chlorophyll-*a* ($\mu g\ L^{-1}$)	1.2 – 5.6	0.48 – 2.1*	0.1 – 2.3*
Dissolved organic carbon ($mg\ L^{-1}$)	6.3 – 7.6	6.0 – 7.1	6.0 – 8.0
Sulphate ($mg\ L^{-1}$)	1.1 – 1.2	1.1 – 1.3	1.1 – 1.2
Alkalinity ($mg\ L^{-1}$)	<2.0 – 4.0	3.0 – 4.0	3.0
Total phosphorus ($mg\ L^{-1}$)	<0.005 – 0.011	<0.005 – 0.009	<0.005 – 0.013
Filterable reactive phosphorus ($mg\ L^{-1}$)	<0.002 – 0.006	<0.002 – 0.006	<0.002 – 0.007
Ammonia ($mg\ L^{-1}$)	0.010 – 0.029	0.016 – 0.036	0.015 – 0.029
Nitrate ($mg\ L^{-1}$)	0.031 – 0.049	0.045 – 0.056	0.040 – 0.055
Nitrite ($mg\ L^{-1}$)	<0.002 – 0.004	0.002	0.002 -- 0.004
Total Kjeldahl nitrogen ($mg\ L^{-1}$)	0.16 – 0.24	0.16 – 0.21	0.16 – 0.29
Aluminium ($\mu g\ L^{-1}$)	**142 – 190**	**143 – 240**	**106 – 158**
Arsenic ($\mu g\ L^{-1}$)	<1	<1	<1 -- 1
Cadmium ($\mu g\ L^{-1}$)	<0.1	<0.1	<0.1
Chromium ($\mu g\ L^{-1}$)	<1.0	<1.0	<1.0
Cobalt ($\mu g\ L^{-1}$)	<0.5	<0.5	<0.5
Copper ($\mu g\ L^{-1}$)	<1.0 - **3**	<1.0	<1.0
Iron ($\mu g\ L^{-1}$)	524 – 605	501 – 684	401 – 681
Lead ($\mu g\ L^{-1}$)	<0.5	<0.5 – 1.2	<0.5 – 1.2
Manganese ($\mu g\ L^{-1}$)	6.0 – 7.8	5.0 – 7.3	7.4 – 18.7
Silver ($\mu g\ L^{-1}$)	<0.5	<0.5	<0.5
Nickel ($\mu g\ L^{-1}$)	<0.5 – 0.8	<0.5 – 0.8	<0.5 – 0.6
Zinc ($\mu g\ L^{-1}$)	<1.0 – 2.0	<1.0 – **9.0**	<1.0 – 5.0

* January 2011 chlorophyll-*a* data of poor quality and are not included in the above ranges

3.2.2 Lake Pedder water quality

Lake Pedder is relatively shallow (15–16 m depth) and well mixed, with depth profiles of temperature at the Groombridge Point site displaying isothermal conditions in July 2010 and October 2010 and surface warming in January 2011 and April 2011 (Figure 3-4). The temperature profiles also demonstrate a gradual warming of the water body from 8.3 °C in winter to 16.6 °C in summer. Dissolved oxygen and conductivity were uniform throughout the water column (Figure 3-4 and Table 3-2), which is consistent with previous monitoring results, but there were changes in pH with depth in July 2010. Surface water quality measurements from the Edgar Bay and Hermit Basin sites were generally within similar ranges to those from Groombridge Point (Table 3-2). Water samples from the surface at the Groombridge Point site were analysed for a range of parameters as outlined in section 3.1 (Table 3-3). As in previous years, water quality was good in Lake Pedder. Conductivity, turbidity, chlorophyll-*a*, nutrient and metal concentrations were generally low (with the exception of aluminium, which is typical of these waters). Dissolved oxygen concentrations in Lake Pedder were high in surface waters and pH was slightly acidic. Dissolved organic carbon concentrations were high and similar to those measured in Lake Gordon (Table 3-3). Chlorophyll-*a* levels were moderately high on occasions at Edgar Bay (July 2010 – 7.49 µg L^{-1}, October 2010 – 5.16 µg L^{-1}) and Groombridge Point (July 2010 – 6.44 µg L^{-1}).

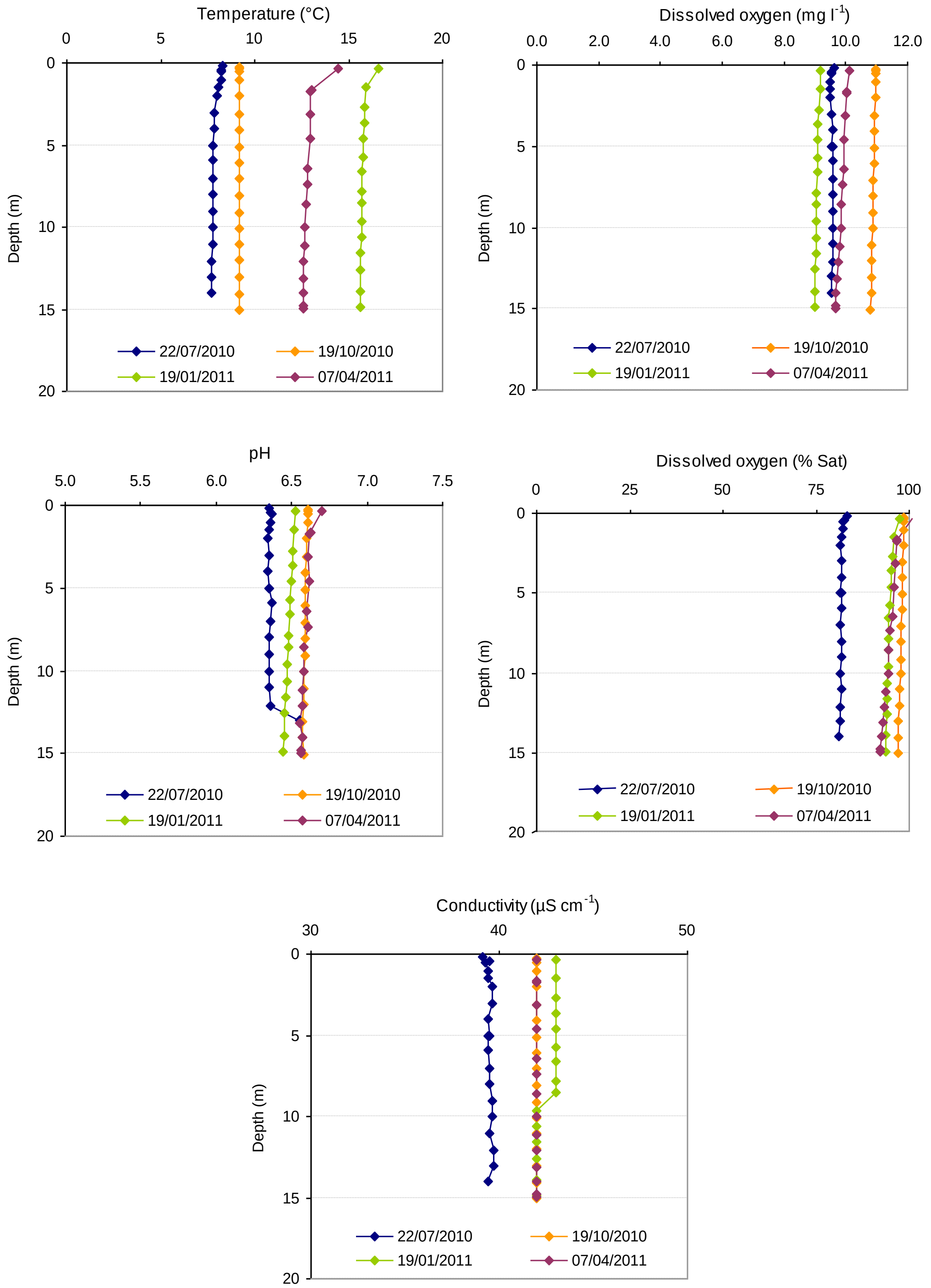


Figure 3-4 Depth profiles of water temperature, pH, conductivity and dissolved oxygen at Groombridge Point in Lake Pedder for 2010–11

Table 3-2 Water quality parameter ranges measured at the three monitoring sites in Lake Pedder during 2010–11

Parameter	Edgar Bay (surface)	Hermit Basin (surface)	Groombridge Point (surface)	Groombridge Point (15 m)
Chlorophyll-*a* (μg L^{-1})	2.04 – 7.49	1.43 – 3.62	2.26 – 6.44*	–
Dissolved oxygen (mg L^{-1})	9.13 – 10.83	9.15 - 10.86	9.17 – 10.97	8.99 – 10.8
Dissolved oxygen (% saturation)	81.4 – 101.7	82.3 – 99.2	83.2 – 100.7	81.2 – 96.9
pH	6.52 – 6.77	6.23 – 6.99	6.35 – 6.7	6.44 – 6.57
Turbidity (NTU)	0.7 – 1.5	0.6 – 1	0.5 – 1.3	0 – 1.3
Conductivity (μS cm^{-1})	40.9 – 44	38.2 – 42	39.1 – 43	39.9 – 42
Water temperature (°C)	7.79 – 16.34	8.61 – 16.38	8.27 – 16.58	7.66 – 15.65
* January chlorophyll-*a* data of poor quality and are not included in the above ranges				

Table 3-3 Nutrients, metals, sulphate, alkalinity, and dissolved organic carbon levels at Groombridge Point, Lake Pedder during 2010–11. Figures in bold indicate elevated concentration potentially in exceedence of ANZECC toxicity guidelines

Parameter	Range
Sulphate (mg L^{-1})	1.1 – 1.2
Alkalinity (mg L^{-1} as $CaCO_3$)	<2.0 -- 2.0
Dissolved organic carbon (mg L^{-1})	4.4 – 6.9
Total phosphorus (mg L^{-1})	<0.005 – 0.021
Filterable reactive phosphorus (mg L^{-1})	<0.002 – 0.008
Nitrite (mg L^{-1})	0.002 – 0.004
Nitrate (mg L^{-1})	0.034 – 0.042
Total Kjeldahl nitrogen (mg L^{-1})	0.27 – 0.29
Ammonia (mg L^{-1})	0.009 – 0.017
Aluminium (µg L^{-1})	**75 – 118**
Cadmium (µg L^{-1})	<0.1
Arsenic (µg L^{-1})	<1
Chromium (µg L^{-1})	<1
Cobalt (µg L^{-1})	<0.5
Copper (µg L^{-1})	<1 – 1.0
Iron (µg L^{-1})	242 – 299
Lead (µg L^{-1})	<0.5
Manganese (µg L^{-1})	3.0 – 3.3
Nickel (µg L^{-1})	<0.5
Silver (µg L^{-1})	<0.5
Zinc (µg L^{-1})	1.0 – 4.0

3.2.3 Water quality in the Gordon River

3.2.3.1 Water temperature

The hydrological regime and conditions in Lake Gordon tend to govern water temperature in the Gordon River at, and immediately below, the power station (Figure 3-5 and Figure 3-6). For 2010–11, the temperature of water released into the river (site 77) was influenced by lake level, degree of thermal stratification and power station discharge.

A seasonal pattern was observed at sites 77, 75, 65 and 62. Winter/spring mean temperatures in 2010 were marginally warmer than those recorded in 2009 (9 °C compared with 8–9 °C), but at all sites mean summer/autumn water temperatures were around two degrees cooler (10.5 °C in 2010–11 compared to 12 °C in 2009–10). The seasonal temperature regime was primarily influenced by the temperature of water at the power station intake in Lake Gordon and ambient air temperature (Figure 3-5). Seasonal trends in water temperatures in Lake Gordon are affected by overall lake level and thermal mass of the water body.

Differences between the water temperatures at the different sites on the river can be related to their distance downstream from the power station. For warmer parts of the year the coolest water was found in the tailrace, while the warmest was often found below the confluence with the Denison River at site 62 (Figure 3-5, Figure 3-6). The increase in temperature downstream is related to a combination of the influence of ambient air temperature and the greater proportion of water contributed from tributaries. In addition to the higher temperature at site 62, there was a greater degree of diurnal water temperature variation at both this site and site 65 (Figure 3-6b), which was increased by a combination of low power station discharge and high ambient air temperature. There is also greater relative contribution of water from tributaries that are more responsive to daily temperature fluctuations at lower power station discharges. During the cooler months (May–August) the temperature trend along the river was largely reversed so that water was generally cooler further downstream due to the cooling effect of ambient air temperature, and the greater influence downstream of cooler water sourced from tributaries (Figure 3-6a).

Some sudden increases and decreases in water temperature were observed throughout the year (Figure 3-6). These rapid temperature changes were mostly the result of the complete cessation of power station discharge flows due to outages to undertake monitoring for the Gordon River Basslink Monitoring Program. For example, Figure 3-6b shows the increase in water temperature at sites downstream during a cessation of power station discharge during October 2010. These figures demonstrate the degree of temperature control that even low power station discharges (~20 $m^3 s^{-1}$) provide.

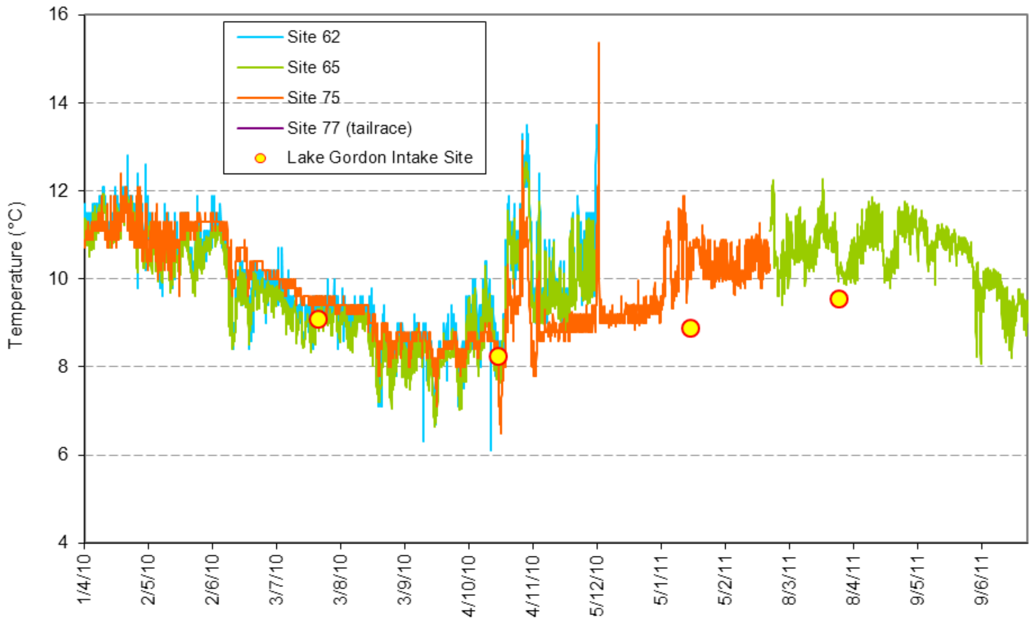


Figure 3-5 Water temperature data recorded for sites 77 and 65 from April 2010 to June 2011, and water temperature data from sites 62 and 75 recorded from April 2010 to April 2011

Figure 3-6 Water temperature at Gordon River sites 77, 75, 65 (12 km downstream) and 62 (15 km downstream) and the corresponding tailrace discharge for (a) late August to late September 2010 and (b) October to early December 2010

3.2.3.2 Dissolved oxygen

Dissolved oxygen concentrations at the tailrace (site 77) and compliance site (site 65) for July 2010 to June 2011 are shown relative to the dissolved oxygen measurements at the intake level in Figure 3-7.

Dissolved oxygen data is missing for the period during the monitoring outage from 17 October to 6 November 2010 due to there being no discharge and the probe being out of the water. The lowest dissolved oxygen level recorded in 2010–11 was 5.65 mg L^{-1} in late April. The regular fluctuation in oxygen levels means that these lowest levels were not sufficiently low for a long enough period to be considered harmful to biota in the Gordon River below the tailrace.

The mean hourly concentration of dissolved oxygen at the compliance site was 11.98 mg L^{-1}, with a standard deviation of 0.57 mg L^{-1}, and range of 10.28–13.62 mg L^{-1}. The mean hourly concentration of dissolved oxygen in the tailrace was 11.36 mg L^{-1} with a standard deviation of

2.21 mg L^{-1} and a range of 5.65–15.25, which was similar to the range reported last year and driven by large daily fluctuations. This daily variability is primarily the result of the changing loading of the power station and its subsequent effect on dissolved oxygen concentrations.

Figure 3-8 shows examples of daily variability for April 2011. Under low to mid-range turbine operations, air injection occurs automatically to prevent cavitation in the turbines and has the effect of increasing the concentration of dissolved oxygen in the discharge waters. Low dissolved oxygen concentrations in the daily range at high turbine load, when air injection is not required, therefore reflects the concentration of dissolved oxygen in Lake Gordon at the intake site (Figure 3-3 and Figure 3-7). In addition to the daily variation, some seasonal variation in dissolved oxygen (for example the lower dissolved oxygen concentrations in January) occurred in response to changing stratification relative to the intake in Lake Gordon.

There appears to be little relationship between variation in concentrations in dissolved oxygen in the tailrace and the compliance site, with the exception of the October outage. In this instance, the reduced flow resulted in a decrease in dissolved oxygen at both sites. The concentration of dissolved oxygen at site 65 responds primarily to flow rate: increases seen in dissolved oxygen at the compliance site at higher flows suggest that dissolved oxygen is influenced by the degree of aeration provided by the river between the tailrace and site 65. This relationship was most obvious during variations in power station discharge (Figure 3-8). There were no specific seasonal trends in the dissolved oxygen data at the compliance site (site 65).

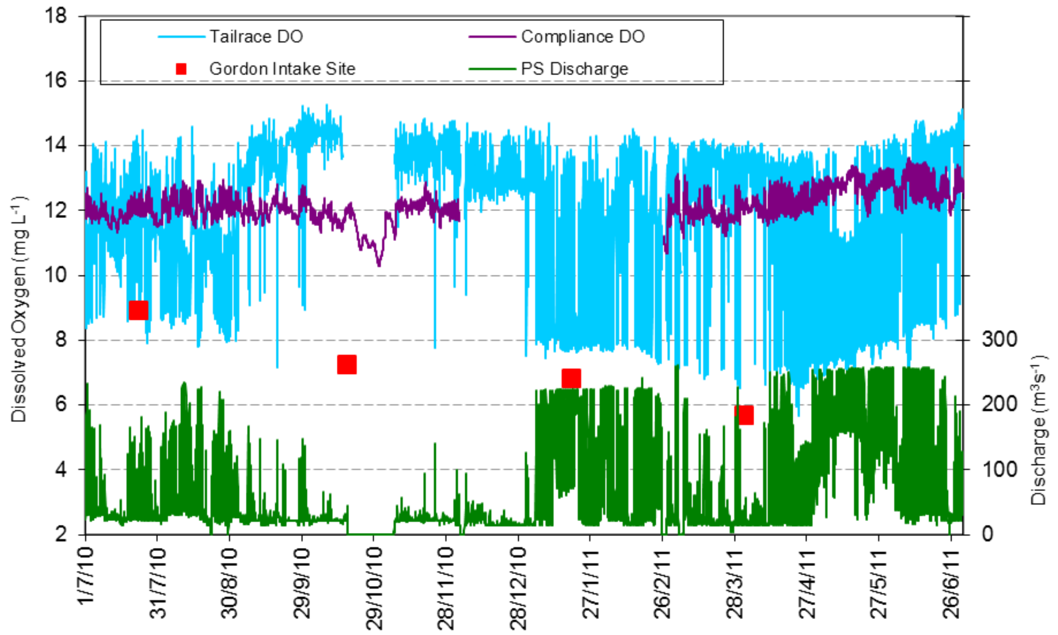


Figure 3-7 Dissolved oxygen levels at site 77 (tailrace) and site 65 (compliance site) for 2010–11 in comparison to dissolved oxygen levels at the same depth of the intake (256 mASL: 24–29 m deep dependant on lake level) in Lake Gordon at the Knob Basin site. Power station discharge is presented to compare its influence on dissolved oxygen concentration at each site

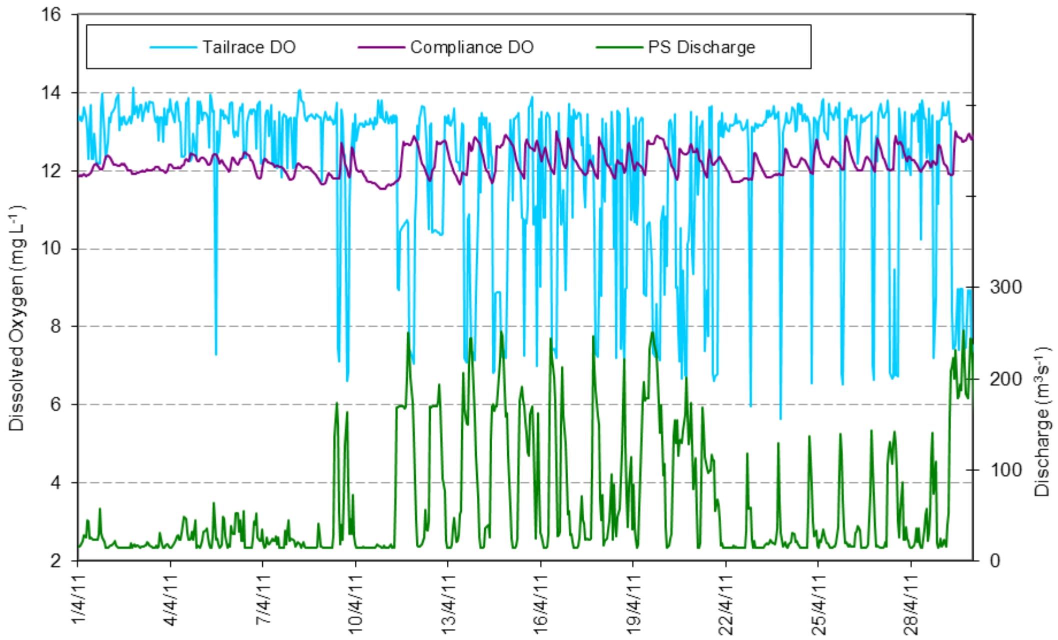


Figure 3-8 Dissolved oxygen concentrations at site 77 (tailrace) and site 65 (compliance site) relative to power station discharge 1–30 April 2011

3.3 Conclusions

The physico-chemical conditions recorded for both lakes Gordon and Pedder were considered typical for lakes in the region. Surface water quality was generally good in both lakes and was characterised by low nutrient, turbidity and dissolved metals. Zinc and copper levels were occasionally elevated at some sites, and high concentrations of aluminium were recorded at all sites (the latter due to the naturally low pH).

The thermal structure of lakes Gordon and Pedder were also similar to previous years. Depth profiles varied with location and between monitoring trips. Dissolved oxygen showed declines at depth at all sites in Lake Gordon. Anoxic conditions were recorded for deeper waters at the Knob Basin (at least 10 m deeper than the intake) on all sampling occasions and in April at Calder Basin. The power station intake was within the depth range of the oxycline measured at Knob Basin on three of the sampling occasions. As a result of this reduced dissolved oxygen concentrations (5.5–6 mg L^{-1}) were recorded at the intake range only in April 2011.

Water quality in Lake Pedder was good overall and remained well mixed at the Groombridge profile sites during 2010–11.

Water temperatures in the Gordon River differed between sites due to the effects of tributary inflows.

Water temperature in the Gordon River was also sensitive to fluctuations in power station discharge. All sites were sensitive to reductions in discharge, with significant increases or decreases in temperature observed under the influence of ambient air temperatures and greater relative volume of water from tributaries at low power station discharge.

Dissolved oxygen concentrations in the tailrace were highly variable as a result of changes to power station discharge and the resultant changes in aeration in the turbines. The dissolved oxygen at full-gate power station operation was reflective of the concentration in Lake Gordon at the intake level. Dissolved oxygen concentrations at the compliance site were generally high and did not reflect the concentration of dissolved oxygen in Lake Gordon or in the tailrace. With the exception of the October outage, changes in dissolved oxygen concentration at the compliance site appear to be influenced by the rate of discharge from the power station, with higher dissolved oxygen coinciding with higher discharges. It is probable that the high dissolved oxygen is due to the significant aeration that the water receives as it travels the 12 km from the tailrace to the compliance site.

4 Fluvial geomorphology

4.1 Introduction

This report summarises the Basslink fluvial geomorphology monitoring results for the period March 2010–February 2011, which represents the time between the end of the previous year's field monitoring and the end of the current year's monitoring. Geomorphology monitoring in the middle Gordon River is being completed as part of Hydro Tasmania's Basslink commitments.

4.1.1 Aims of monitoring program

The aims of geomorphology monitoring in the Gordon River are to:

- document fluvial geomorphological processes and changes in the middle Gordon River between the power station tailrace and the mouth of the Franklin River (defined as the middle Gordon River);
- relate these changes to power station operations, or other factors, wherever possible; and
- compare results collected since the introduction of Basslink with pre-Basslink results to determine whether changes in the river are within 'limits of acceptable change' (trigger values).

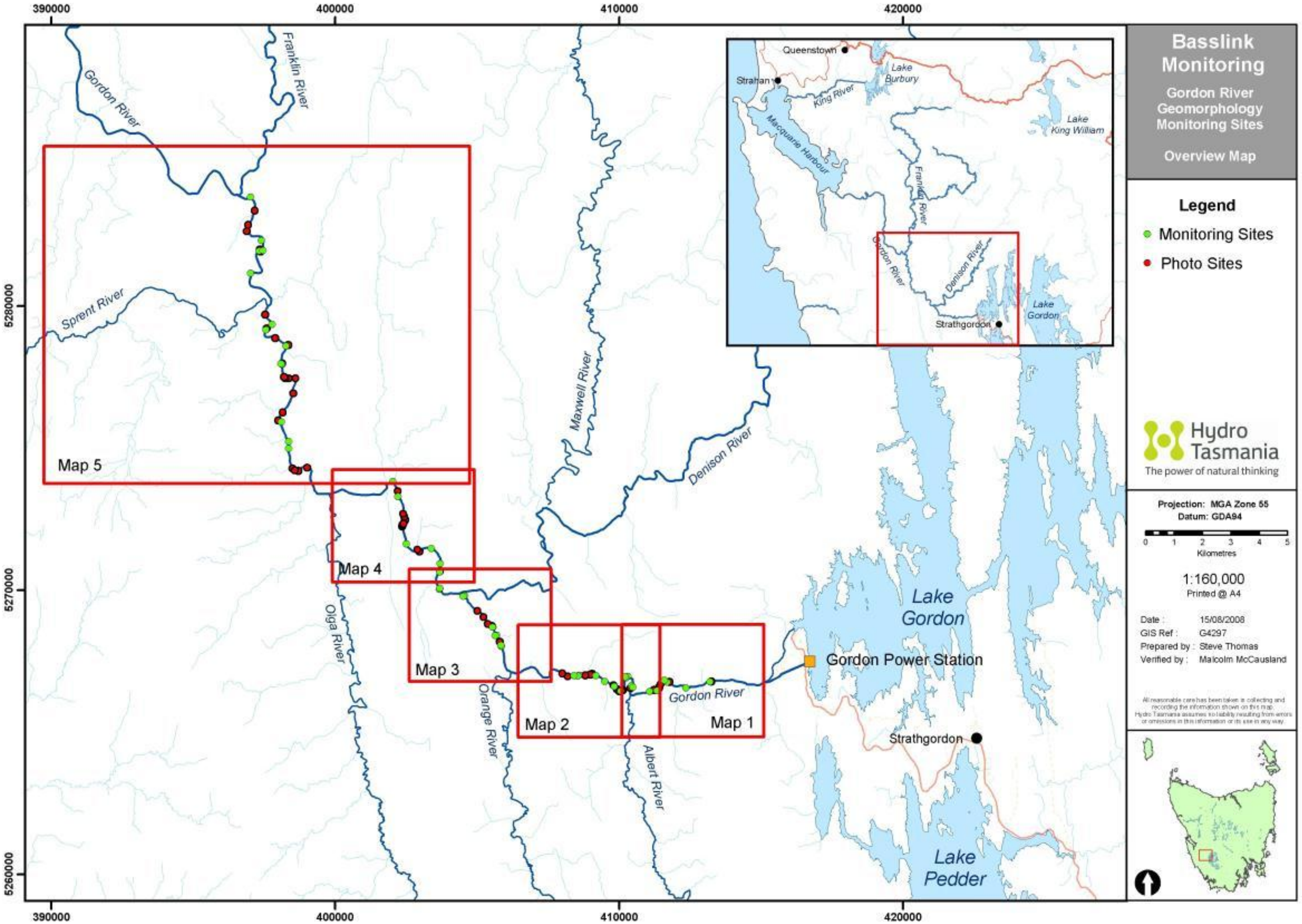
Post-Basslink limits of acceptable change were identified based on pre-Basslink erosion trends in the river, as indicated by grouping erosion pin results collected between 2001 and 2005 by zones (Figure 4-8 to Figure 4-12). Although these trends have been quantified and trigger values established, it has been recognised that over time rates are likely to change in the presence or absence of Basslink due to the non-equilibrium condition of the river, which continues to adjust to the initial damming of the river and introduction of a third turbine in 1989. These issues were discussed in the Basslink Review Report 2006–09 (Hydro Tasmania, 2010a) and a recommendation was made to reduce the reliance on 'trigger values' for detecting change in the Gordon River and instead adopt a multiple-lines-of-evidence approach which incorporates erosion pin results, photo-monitoring, bank profiling, field observations, piezometer results and a large-scale conceptual model to interpret post-Basslink changes in the river. This approach has been endorsed by the Gordon River Basslink Scientific Reference Committee, and therefore discussion involves a multiple lines of evidence approach in addition to the presentation of erosion pin results as 'trigger values'.

4.2 Methods

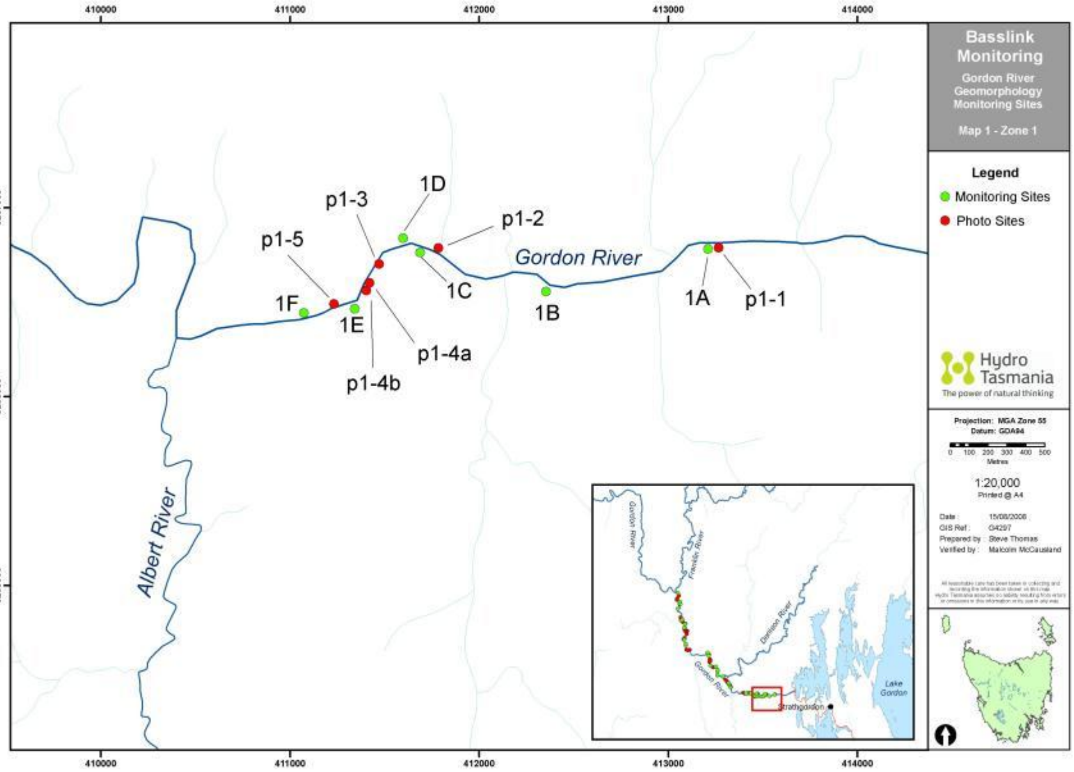
Geomorphology monitoring methods are described in detail in the first pre-Basslink fluvial geomorphology monitoring report (Koehnken and Locher, 2002) and the Basslink Baseline Report (BBR) (Hydro Tasmania, 2005a) and these documents should be consulted for a detailed description and background material pertaining to the monitoring program. Descriptions of the zones, bank types and processes operating in the middle Gordon River are contained in the initial Basslink Integrated Impact Assessment Statement (IIAS) report (Koehnken *et al.* 2001) and the BBR (Hydro Tasmania, 2005a). The following is a brief summary.

Geomorphology monitoring includes field observations and the measurement of ~250 erosion pins and 25 scour chains located at 47 monitoring sites in the middle Gordon River twice per year (usually October and March), and photo-monitoring of an additional 54 sites on an annual basis in March each year (Table 4-1 and Table 4-2). The monitoring sites are distributed over five geomorphic zones in the river, which have been identified based on hydrologic and hydraulic attributes and shown in Map 4-1. Erosion pins are located in sandy alluvial banks along the middle Gordon within the height affected by power station operation. The location of pins at each site has also been classified according to the turbine discharge required for inundation (<1-turbine indicates that the operation of one turbine is likely to inundate the pin, 1–2 turbine bank level requires the operation of two turbines for inundation and 2–3 turbine bank is inundated when all three turbines are in operation). These levels are approximate and based on field observations under low flow conditions only, as no hydraulic model is available for the river and observations during periods of variable power station discharge have not been undertaken.

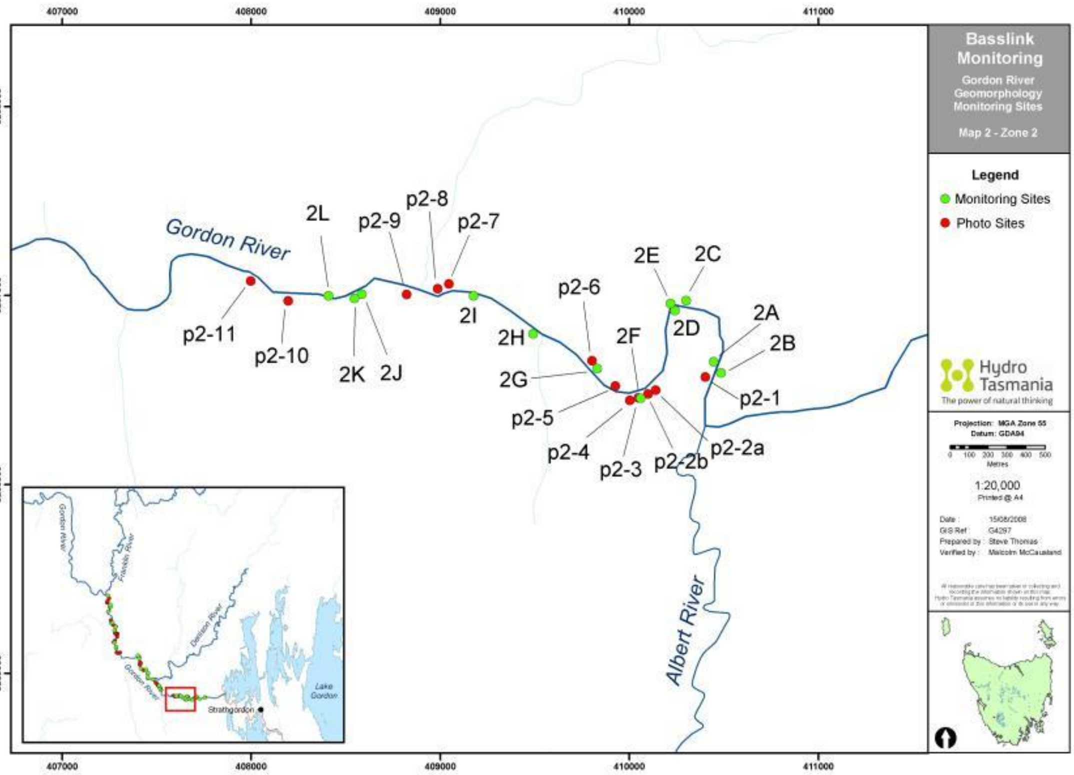
Additional field observations are collected opportunistically when access to the middle Gordon is possible.



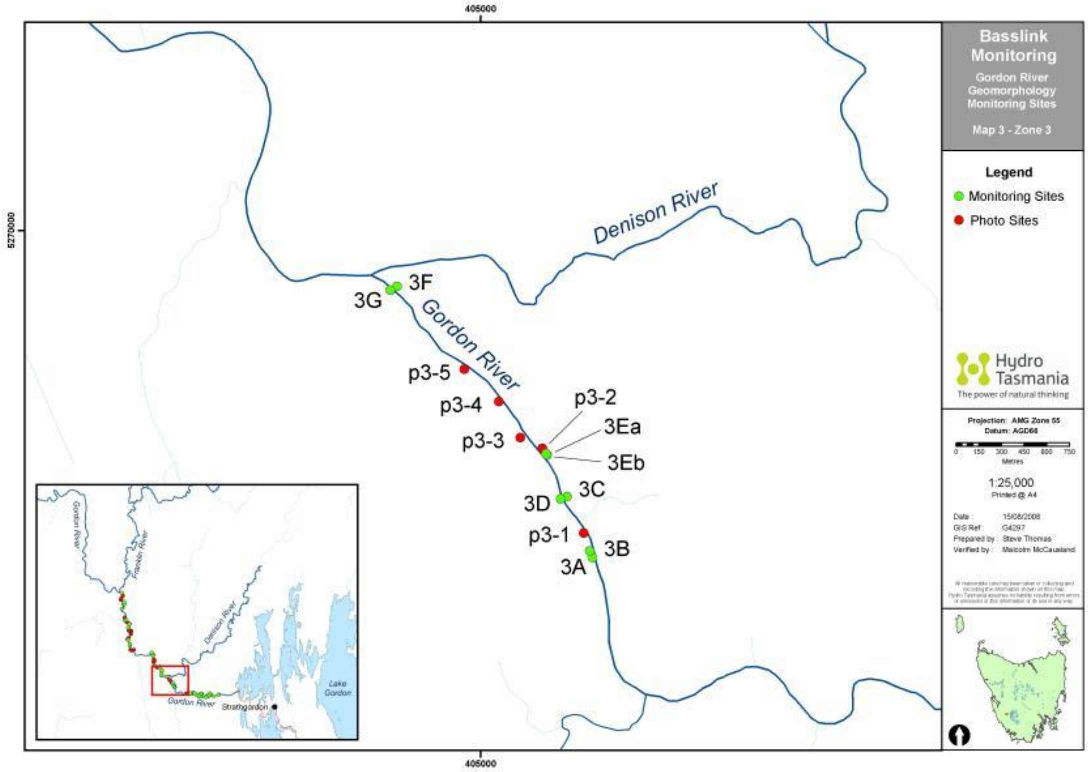
Map 4-1 Overview of Gordon River geomorphology monitoring sites



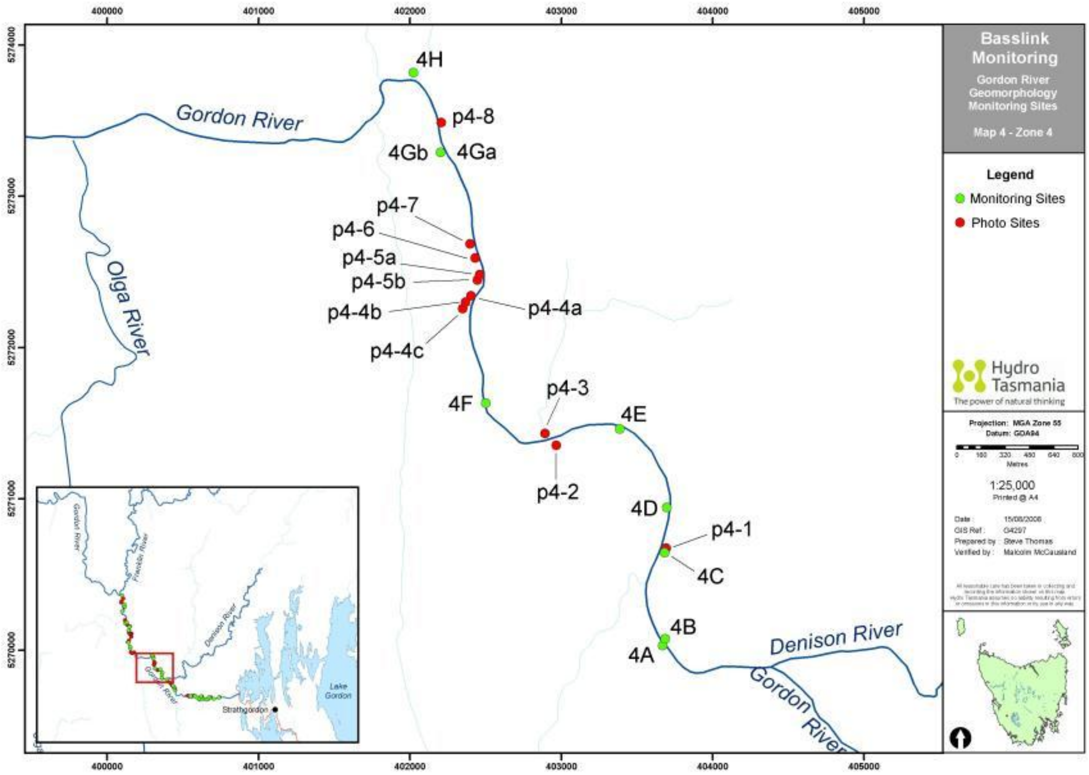
Map 4-2 Gordon River geomorphology monitoring sites, zone 1 (Serpentine River to Abel Gorge)



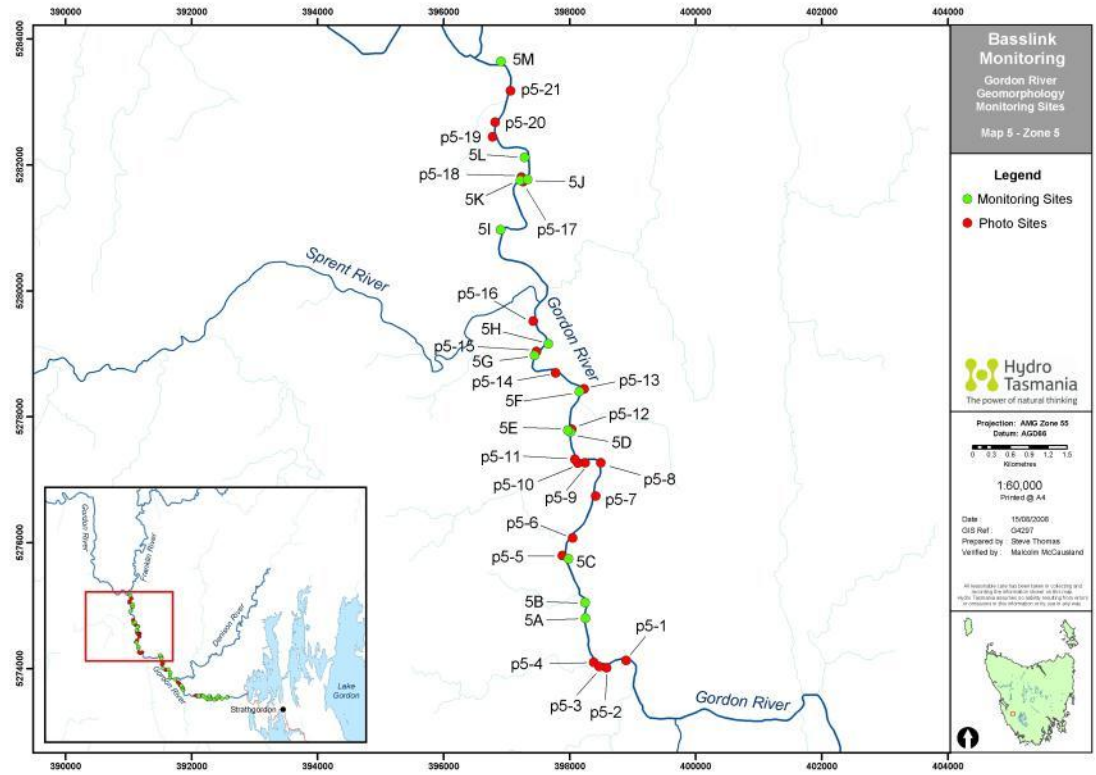
Map 4-3 Gordon River geomorphology monitoring sites, zone 2 (Albert River to The Splits)



Map 4-4 Gordon River geomorphology monitoring sites, zone 3 (The Splits to Denison River)



Map 4-5 Gordon River geomorphology monitoring sites, zone 4 (Denison River to Sunshine Gorge)



Map 4-6 Gordon River geomorphology monitoring sites, zone 5 (Sunshine Gorge to Franklin River)

Table 4-1 Summary of geomorphology monitoring activities in the middle Gordon River between 1999 and present. Derivation indicates that the data was used in the formulation of trigger values, 'test' indicates that the erosion pin results from that monitoring period have been compared with the trigger values

Monitoring Type	Triggers – Derivation/Test	Season	Dates	Monitoring completed
Pre-Basslink	Initial investigations		11 Dec 99, 18 Dec 99, 4 Mar 00, 25 Mar 00, 22 Jul 00, 2 Sep 00, 4 Aug	Investigations for IIAS, Field observations, Erosion pin measurements, Photo-monitoring, Scour chains, Painted cobbles
	Derivation	Spring 01	23 Nov 01, 9 Dec 01	Field observations, Erosion pin measurements
		Autumn 02	10 Feb 02, 9 Mar 02	Field observations, Erosion pin measurements, Photo-monitoring
		Spring 02	5 Oct 02, 16 Dec 02	Field observation, Erosion pin measurements
		Autumn 03	29 Mar 03	Field observation, Erosion pin measurement, Photo-monitoring
		Spring 03	18 Oct 03	Field observation, Erosion pin measurements
		Autumn 04	6 Mar 04	Field observations, Erosion pin measurements, photo-monitoring
		Spring 04	9 Oct 04	Field observation, Erosion pin measurement, Bank profiling
		Autumn 05	2 Apr 05	Field observation, Erosion pin measurement, Photo-monitoring
		Spring 05	15 Oct 05	Field observation, Erosion pin measurements
Transition	Test	Autumn 06	11 Mar 06	Field observation, Erosion pin measurement, Photo-monitoring
Post-Basslink	Test	Spring 06	17 Oct 06	Field observation, Erosion pin measurements
		Autumn 07	17 Mar 07	Field observation, Erosion pin measurement, Photo-monitoring
		Spring 07	20 Oct 07	Field observation, Erosion pin measurements
		Spring 07	1 Dec 07	Field observations
		Autumn 08	1 Mar 08	Field observation, Erosion pin measurement, Photo-monitoring
		Spring 08	17–19 Oct 08	Field observation, Erosion pin measurements
		Autumn 09	20–22 Mar 09	Field observation, Erosion pin measurement, Photo-monitoring
		Spring 09	17 Oct 09 (zones 3 and4) 31 Oct 09 (zones 1,2,5)	Field observation, Erosion pin measurements
		Autumn 10	12–14 Mar 10	Field observation, Erosion pin measurement, Photo-monitoring
	Test	Spring 10	19 – 20 Oct 10	Field observations, Erosion pin measurements
	Ramp-rule investigations	Summer 11	22-23 Jan 11 23-25 Feb 11 7-8 Mar 11	Observations of ramp-downs and drawdowns at varying levels of bank saturation associated with investigations to review ramp-rule.
	Test	Autumn 11	26–27 Feb 11	Field observations, Erosion pin measurements, Photo-monitoring

Table 4-2 Number of monitoring sites and erosion pins in each geomorphology zone

Zone	# Sites	# Erosion Pins
Zone 1	6	35
Zone 2	12	63
Zone 3	8	47
Zone 4	8	39
Zone 5	13	63
Total	47	247

4.2.1 Monitoring in October 2010 – February 2011

Geomorphology monitoring was completed over two days, 19–20 October 2010, using two boat-based teams. Discharge from the power station had been relatively low for several months prior to monitoring, characterised by generally short-duration discharge events of <150 $m^3 s^{-1}$. Tributary inflows to the Gordon River were high during the monitoring period due to recent rain, and many pins were partially or totally inundated. The pins which were not found in October, or affected by changes to the banks, were mostly in zone 5 and are listed in Table 4-3.

In 2011, post-Basslink geomorphology monitoring was completed over two days, 26–27 February. This monitoring occurred approximately one to two weeks earlier than usual to ensure all Gordon monitoring was completed prior to a scheduled start of an outage of the Poatina Power Station in April 2011. Monitoring was completed by two boat-based teams, and river level was low due to low tributary inputs. During the three days prior to monitoring, observations of drawdowns associated with ramp-rule seepage trial investigations had been completed, which necessitated varying degrees of bank saturation. This resulted in the Basslink monitoring being completed following a period of prolonged saturation of the 0–1 and 1–2 turbine bank levels.

The pins which were not found in February, or affected by changes to the banks, are listed in Table 4-3. In October, most 'missing' pins were due to high water levels and inundation. In February, only two pins were not found, both at site 5B. No major changes to the site were noted by the investigating team, and the reason for the pins being missing is unknown.

Table 4-3 List of erosion pins not located in October 2010 and Feb 2011

Pin	Monitoring period	Change(s) to site	Comment
4A/6	Oct 10	None	Not found Mar 10. Presumed buried
5A/2	Oct 10	None	Inundated and not found
5A/3	Oct 10	None	Inundated and not found
5B/6	Oct 10	None	Unknown why missing
5H/1	Oct 10	None	Horizontal and completely buried
5M/3	Oct 10	None	Inundated and not found
5B/1	Feb 11	None	Not found
5B/6	Feb 11	None	Not found

4.3 Flow characteristics relevant to geomorphology results

A detailed discussion of the hydrology of the Gordon River during the monitoring year is contained in chapter 2 Hydrology and water management. Hydrographs for the Gordon Power Station, the compliance site (zone 3), and the Gordon above Franklin gauging site are shown for the period relevant to the geomorphology monitoring period in Figure 4-1 to Figure 4-3. The following aspects of the hydrology are relevant to the geomorphology monitoring results:

- between April 2010 and the end of August 2010, the power station was run at low discharges, with infrequent periods of 3-turbine usage;
- from September through December, there was very low power station usage, with no discharge in excess of 180 $m^3 s^{-1}$; and
- the January through March period was characterised by frequent peaking operations, and some periods of prolonged 2-turbine discharge. The operation of the station from mid-January through the end of February was strongly influenced by the ramp-rule trial investigations which required varying degrees of bank saturation.

In spite of the 3-turbine peaking operations in summer, overall discharge from the station was low during the year (year five post-Basslink: May 2010–April 2011), with power station discharges in excess of 210 $m^3 s^{-1}$ and 150 $m^3 s^{-1}$ limited to ~7 % and 13 % of the time, respectively (Figure 2-11). Median flow for the year was slightly below 25 $m^3 s^{-1}$, which is very low, but similar to the past two monitoring years (Figure 2-11).

The peaking operations and drawdown investigations resulted in increases in the number of hours that flow reduction exceeded 30 $m^3 s^{-1}$ per year relative to the past two years, with 44 hours for the 1 April 2010 to 1 October 2010 period, and 71 hours for the 1 October to 1 April 2011 period (see Figure 2-13).

In addition to power station releases, flow in the river was affected by unregulated tributary inflows. At the Gordon above Franklin site there were two events of about 600 $m^3 s^{-1}$ during the year, and about 10 additional events in excess of 400 $m^3 s^{-1}$ (Figure 4-3). Although these are sizeable flows, they are not, relatively speaking, major floods for the catchment. In 2007 there was a flow recorded that was in excess of 1400 $m^3 s^{-1}$ at the same site.

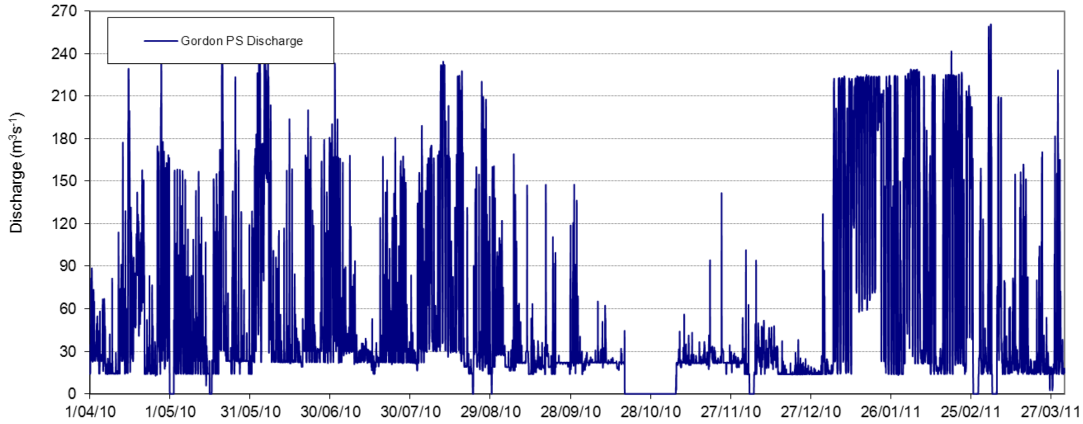


Figure 4-1 Discharge at the Gordon Power Station 1 April 2010 to 21 March 2011

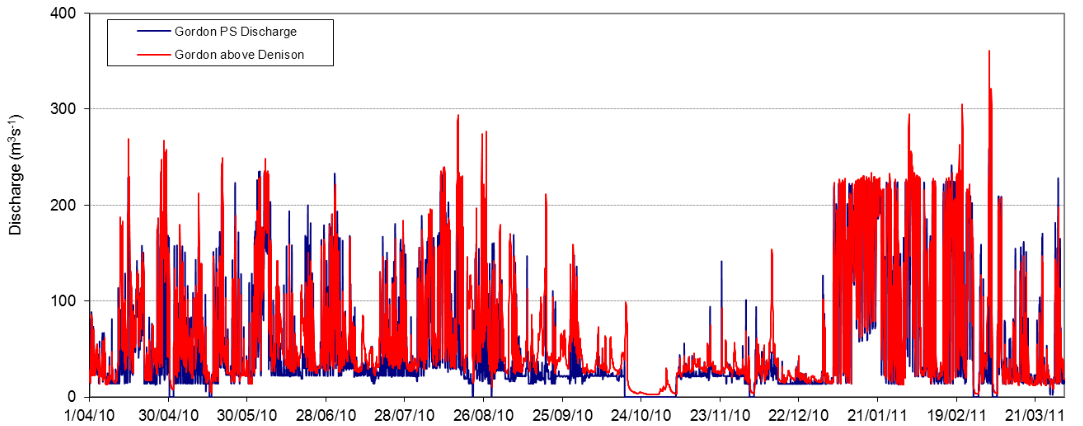


Figure 4-2 Gordon Power Station discharge and flow at the compliance site (zone 3) between 1 April 2010 and 21 March 2011

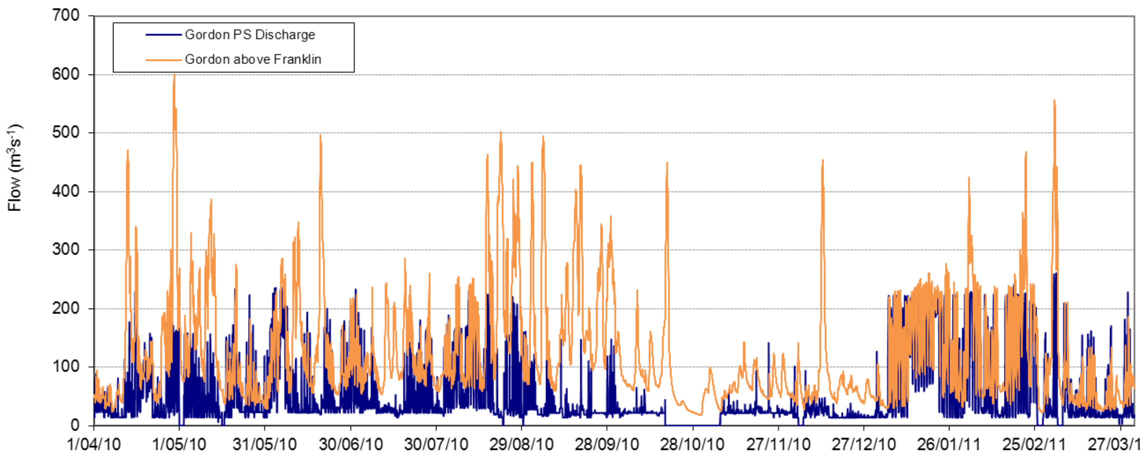


Figure 4-3 Gordon Power Station discharge and flow at the Gordon above Franklin (zone 5) gauging site

4.4 Sediment transport capacity

A theoretical sediment transport model for zone 1 in the Gordon River was developed by S. Wilkinson and I. Rutherfurd during the IIAS investigations (Koehnken *et al.* 2001). Actual results from the model are not particularly meaningful, but changes between years provide a relative indication of how the potential for scour in the river varies as a function of power station discharge. Figure 4-4 compares the model results for the 2010–11 monitoring year with previous years and the unregulated (natural) flow regime.

The results show that total sediment transport remained low during the 2010–11 monitoring year, although higher than the previous two years. The theoretical total calculated sediment capacity for the year was ~63 kg, which is about twice the value for the 2009–10 period of 32 kg. It is also evident that the majority of the transport capacity coincided with flows of between 64 and 185 m^3 s^{-1} (1–2 turbine flow), and that sediment transport associated with the highest flows (>185 m^3 s^{-1}, three turbines) has also increased relative to the past two years.

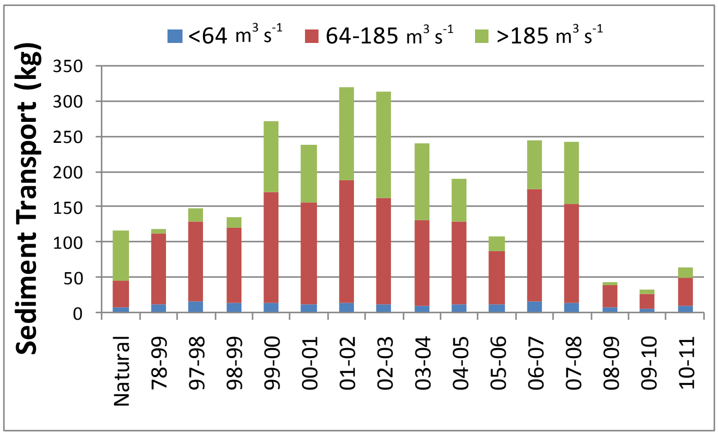


Figure 4-4 Theoretical sediment transport in zone 1 of the Gordon River. Total calculated sediment transport is divided into flow levels approximately equivalent to 1, 2 and 3-turbine power station operation. Model by Wilkinson and Rutherfurd

4.5 Monitoring results

4.5.1 Field observations – October 2010

Field observations in October 2010 were similar to those reported in October 2009 and March 2010 when the power station was run in a similar manner. Field observations include:

- deposition of locally derived organic matter in the 2–3 turbine level of the banks which is indicative of low 3-turbine power station discharge;
- abundant seedlings in the 2–3 turbine level of the banks, and some mosses and seedlings in the 1–2 turbine bank level (Photo 4-1 to Photo 4-3);
- the surface of banks were wet, but banks were not saturated, suggesting that the surface moisture was related to the rainfall days immediately prior to the observation rather than bank saturation due to inundation;
- rilling and tension cracks were present on the mid and lower banks (0–1 and 1–2 turbine levels) and bank toes, but not in the upper banks (2–3 turbine bank level);
- there was no recent evidence of seepage flows in the 2–3 turbine bank level;
- in the zones upstream of the Denison River, the development of a break in slope at approximately the 2-turbine level continued (Photo 4-4 and Photo 4-5);
- in zones 3–5, the recent fluvial deposition of sand and mud on bank toes was evident, and associated with unregulated inflows; and
- a new bank failure was observed in the lower Albert River in the cobbles along the left bank of the river (Photo 4-6).

Photo 4-1 Vegetation in backwater channel behind site 2A indicative of low levels of inundation and high light conditions

Photo 4-2 Grasses in 1–2 turbine bank level at site 2G. Note the lack of sediment flows at cavities on bank

Photo 4-3 Organic debris and mosses in 1–2 turbine bank level at site 2C

Photo 4-4 Break in slope at ~2-turbine discharge level, and seedlings in 1–2 turbine level at site 2H

Photo 4-5 Break in slope at 2-turbine discharge level in zone 2 upstream of site 2C. Toe affected by seepage processes

Photo 4-6 Bank failure on the left bank of lower Albert River

4.5.2 Field observations – February 2011

In February 2011, field observations of the alluvial banks included:

- the continued presence of vegetation in the 1–2 and 2–3 turbine bank levels. This is of particular note because the vegetation survived in spite of the increased 3-turbine power station operation over the summer months (Photo 4-7 and Photo 4-8);
- unsaturated banks in the 2–3 turbine bank levels, with no evidence of seepage induced erosion in the 2–3 turbine bank level. This observation may be linked to the ramp-rule trial investigations which had been completed in the days prior to the Basslink monitoring, and for which bank saturation levels were limited to <2.75 m (as measured at the zone 2 piezometer site);
- recent scouring of bank faces in the 1–2 turbine bank level. Scouring was not evident on bank faces which supported mosses or abundant seedlings;
- evidence of seepage-derived sediment deposits in the <1-turbine bank level on banks which continue to support root mats and tea tree. These types of sediment deposits were observed in zones 2 and 3. At site 2H, the deposits were at the base of the root mat, below the environmental flow level (Photo 4-9 and Photo 4-10). In zone 3 deposits were present where the root mat had been breached (Photo 4-11). These deposits are likely associated with the drawdowns following peaking events, with the deposited material derived from the 1–2 turbine level; and
- a new, very unusual large sediment flow consisting of poorly sorted angular clasts in a sandy matrix, was observed just downstream of site 2K, at the downstream end of zone 2, on the left bank (Photo 4-12 and Photo 4-13). Upon investigation, a recent landslip was identified, located about 10 m inland, which had a similar assemblage of angular material at the base of the collapse. It is hypothesized that the landslip occurred during a period when the bank was saturated, and the collapse forced saturated landslip derived material out under the vegetation mat. This is one of the most unusual deposits observed in the Gordon River since investigations began in 1999.

Photo 4-7 Increased vegetation in the backwater behind geo monitoring site 2A

Photo 4-8 Increased vegetation in the 1–2 turbine bank level in the downstream end of zone 2

Photo 4-9 Sediment fans deposited at base of root mat. Sediment derived from seepage process

Photo 4-10 Close-up of sediment deposit at base of root mat

Photo 4-11 Sediment flow at breach in root mat at site 3A, upstream end of zone 3

Photo 4-12 Sediment flow deposit on left bank, downstream end of zone 2 consisting of angular clast in a sandy matrix associated with a landslip

Photo 4-13 Detail of sediment deposit associated with landslip

4.5.3 Zone 2 piezometer results

The two piezometer arrays installed on the same bank in zone 2 continued to record water levels within the banks in 2010–11. The piezometers include three 'old' piezometers situated at 0 m, 6.3 m and 13.3 m from the river's edge, and five 'new' ones located at 0 m, 10 m, 20 m, 30 m, 40 m and 50 m from the river's edge. During maintenance and calibration of the 'old' piezometers, the casing of the probe located at 6.3 m inland was damaged and replaced. Unfortunately, the new casing does not have adequate drainage holes, and water levels within the casing do not decrease below the present ground level, making this probe no longer useful in the interpretation of water levels in the banks. All other probes in the 'old' and 'new' array were serviced, calibrated and were functioning well.

Between 22 January and 7 March 2011, seven field days were spent completing observations of ramp-downs and drawdowns in zone 2 of the Gordon River. This work is associated with investigations aimed at improving the environmental benefit of the ramp-down rule and is described in detail in Appendix 5. This work is relevant, however, to the interpretation of the 2010–11 piezometer results, as the power station was manipulated during January to March to provide specific levels of bank saturation for the ramp-rule investigations.

Figure 4-5 shows river level and water level at new piezometer 2 (P2), located 10 m inland from the bank toe. During the 2010–11 monitoring year, water level at piezometer 2 was low (generally <2.5 m) between 1 March 2010 and 1 January 2011. After 1 January 2011, peaking operations increased, as did more extended power station usage associated with achieving target saturation levels within the bank for the ramp-down rule field trials. This period is indicated with a red circle.

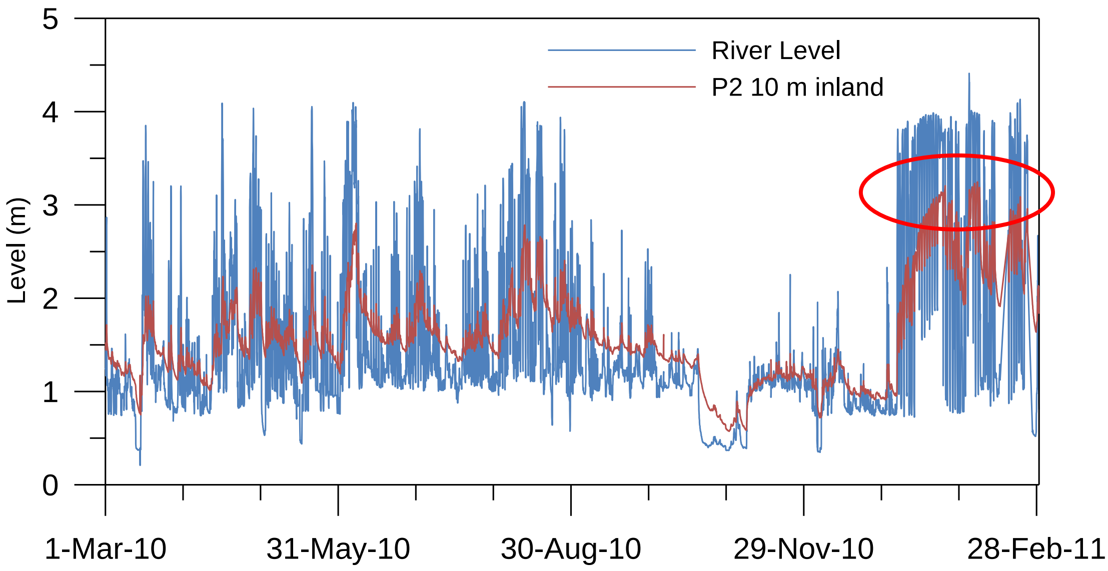


Figure 4-5 Piezometer results from new piezometer array (1 March 2010 to 28 February 2011) showing river water level and piezometer 2 water level

The risk of seepage induced erosion in the 2–3 turbine bank level can be evaluated by determining the period of time when groundwater slopes exceeded 0.1 and when water level at P2 exceeded 2.75 m. Water slopes for the monitoring year, as determined using P2 and river level (Figure 4-6), indicate that water slopes remained consistently below 0.1 until January 2011. The elevated slopes post 1 January are associated with peaking operations and ramp-rule investigations, however, none of these periods coincided with water levels in excess of 2.75 m at the river or at P2 as shown by the graph in Figure 4-7. These elevated slopes occurred when the river water level was low, and are likely associated with periods of rilling on the bank toes, and possibly the seepage flows observed in the <1-turbine bank level on the tea tree bearing banks.

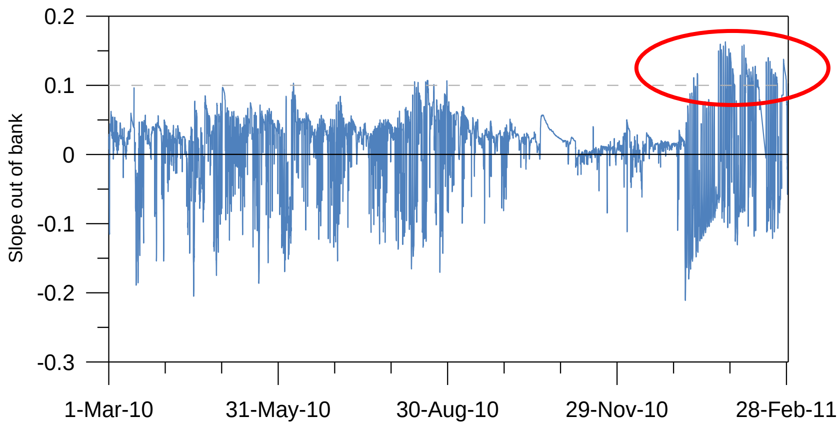


Figure 4-6 In-bank water slope in piezometer bank. Positive values are sloping towards the river. Based on difference in water level between old new probe 2 (10 m from edge of river) and river level. Note none of the periods when water slopes exceeded 0.1 were accompanied by water levels in the river or at P2 in excess of 2.75 m

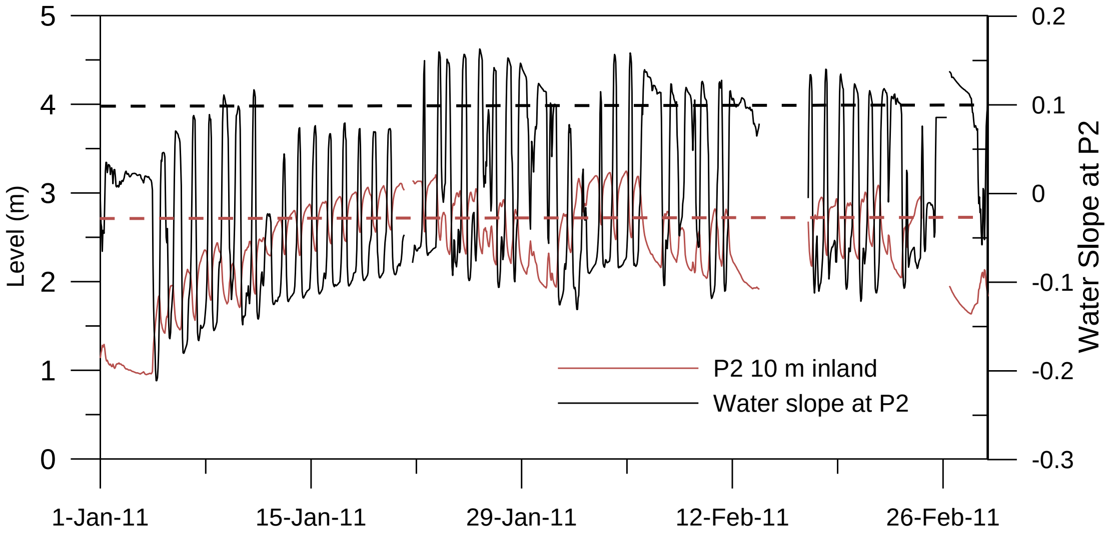


Figure 4-7 Water level at P2 (red) compared with water slope at P2 (black) showing that water levels are <2.75 when water slopes exceed 0.1

4.5.4 Erosion pin results

4.5.4.1 Results grouped by zones

Graphs showing the erosion pin results are contained in Appendix 2.

Erosion pin results grouped by zones are plotted in Figure 4-8 to Figure 4-12. This is the grouping that was used to derive trigger values, although it is now recognized that a multiple lines of evidence approach is a more appropriate indicator of change.

For each zone, several data sets are presented on the graphs. The central data set shows the average change of all pins in the grouping using spring 2001 as the baseline (value indicates net change since 2001). The difference between data points on the graphs indicates the relative difference in erosion or deposition between the two dates. The 'net erosion' data set is further divided into pre- and post-Basslink periods. The pre-Basslink results (spring 2001–spring 2005) were used to predict a trend into the future, as shown by the line in each graph. The 95th percentile confidence interval for each projected trend was also calculated and is shown on the graphs in dashed lines. This 95th percentile envelope defines the Basslink trigger values, and post-Basslink results are discussed with respect to this envelope in Chapter 10 Discussion of trigger values.

Two additional data sets on each graph show the average change for pins recording erosion (compared to spring 2001) during the monitoring period in the grouping, and the average change for pins showing deposition (compared to spring 2001) during the monitoring period. The relative changes between data points in these data sets shows whether erosion or deposition has increased or decreased between monitoring periods. The positioning of the data sets relative to the mean values provides an indication of the relative number of pins recording erosion or deposition (e.g. if the trend for all results is closer to the erosion trend, more pins are showing erosion than deposition).

A summary of the net changes for each zone relative to the previous monitoring period (rather than spring 2001) for the 2010–11 monitoring year is shown in Figure 4-13, with annualised erosion rates summarised in Figure 4-14.

In zone 1 (Figure 4-8) net erosion rates remain close to zero and within the predicted envelope for both of the 2010–11 monitoring periods. There has been a small shift from net depositional to net erosional over the October 2010 to February 2011 period. This shift is attributable to a large number of pins recording relatively small increases in erosion rather than a few pins showing high rates of change. The largest erosional change recorded in the zone was 25 mm at 1 A/7 which is located in colluvium in the 1–2 turbine bank level, with twelve pins recording erosion of between 1 and 10 mm. The larger increase in erosion in the second half of the year suggests peaking operations contributed to this trend. In spite of this increase, the net trend remains below the projected mean based on the pre-Basslink monitoring results. This zone continues to show low levels of 'net' change, although individual erosion pins shows variability.

In Figure 4-13, the erosion pin results for zone 1 are compared to the previous season, rather than spring 2001, with both periods showing increases in erosion. On an annualised basis (Figure 4-14) the 2010–11 results show erosion, which is a change for this zone which has shown low levels of deposition for the entire post-Basslink monitoring period.

The erosion pin results for zone 2 (Figure 4-9) show no net change in October 2010, and a reduction in the net erosion rate in February 2011. The February 2011 net change falls outside of the projected 'envelope' and is only about 25 % of the projected mean based on the pre-Basslink monitoring results. This decrease is attributable to a higher number of pins recording deposition, and a lower rate of erosion in the pins which recorded erosion. The present net change is equivalent to that recorded in autumn 2007, highlighting the non-linearity of geomorphic change in the catchment. Compared to the previous monitoring periods (Figure 4-13), the October 2010 results show a low rate of erosion, and the March 2011 results, a higher rate of deposition. The annualised results (Figure 4-14) show that post-Basslink, changes in zone 2 have fluctuated between +/- 8 mm of change each year.

Zone 3 (Figure 4-10) has continued to record fluctuating rates of erosion which are below the projected 'envelope' based on pre-Basslink results, with the October results showing a decrease in erosion relative to March 2010, and the March 2011 result an increase relative to October 2010 (Figure 4-13). The March 2011 increase is attributable to a decrease in deposition rather than an increase in erosion, as indicated by the stable erosion rate (blue triangles) for pins recording erosion and decreased deposition rate (orange dots). On an annualised basis (Figure 4-14), zone 3 has shown little change since the 2007–08 monitoring year when there was a sizeable increase in erosion. This lack of change may reflect the relatively low power station discharge over the past few years.

Results from zones 4 and 5 reflect the impact of large unregulated inflows in the river as well as the power station discharge. The October 2010 net results for zone 4 (Figure 4-11, Figure 4-13) show a relatively large decrease in erosion relative to March 2010, with the decrease returning results back to similar values recorded between autumn 2008 and spring 2009. The February 2011 results are almost unchanged, with a very small decrease in erosion. Both the October and February results remain outside of the projected 'envelope'. The annualised result (Figure 4-14) shows the decrease in erosion (increase in deposition) which occurred over the year is the largest change in any zone during any monitoring year.

Similar to zone 4, zone 5 also showed a decrease in erosion during the March 2010–October 2010 period, but the pins returned a small increase in the second monitoring period (Figure 4-12, Figure 4-13) resulting in the net change above the projected 'envelope'. Zone 5 continues to be the only zone where post-Basslink results are higher than predicted, however, it was the only zone where the projection was for net deposition. The annualised result (Figure 4-14) shows a decrease in erosion, similar to zones 2, 3 and 4.

The reduced erosion in zones 4 and 5 may be attributable to deposition associated with unregulated inflows. Whilst the median power station discharge for the monitoring year was only ~30 $m^3 s^{-1}$, the median flow at the Gordon above Franklin site (located in zone 5) was 80 $m^3 s^{-1}$ demonstrating the high proportion of inflows.

The net change in pins for all zones relative to spring 2001 (Figure 4-8 to Figure 4-12) shows that zone 3 has recorded the largest change followed by zones 4 and 2.

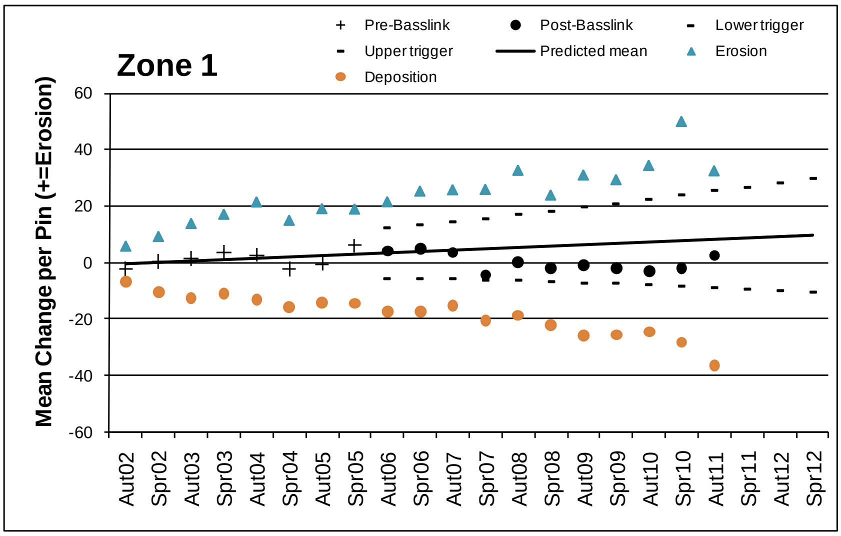


Figure 4-8 Erosion pin results grouped by zones for zone 1. Black crosses show mean change for all pins relative to spring 2001 in zone during the pre-Basslink monitoring period. Solid line shows projection of mean based on pre-Basslink monitoring results. Dashed lines show 95th percentile confidence interval for this projected mean. Black circles show mean change relative to spring 2001 for all pins in zone post-Basslink. Triangles show mean erosion rate for pins recording erosion in each monitoring period. Orange circles show mean deposition rate for pins recording deposition in each monitoring period

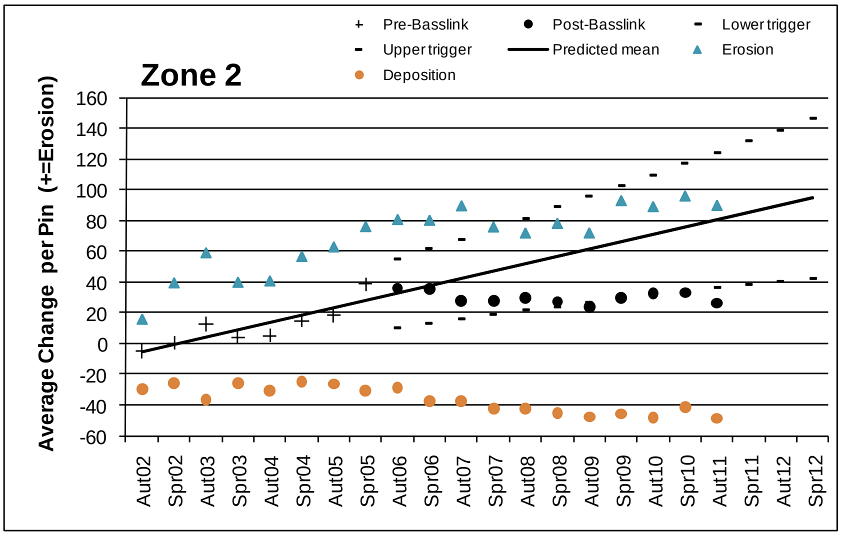


Figure 4-9 Erosion pin results grouped by zones for zone 2. Black crosses show mean change for all pins relative to spring 2001 in zone during the pre-Basslink monitoring period. Solid line shows projection of mean based on pre-Basslink monitoring results. Dashed lines show 95th percentile confidence interval for this projected mean. Black circles show mean change relative to spring 2001 for all pins in zone post-Basslink. Triangles show mean erosion rate for pins recording erosion in each monitoring period. Orange circles show mean deposition rate for pins recording deposition in each monitoring period

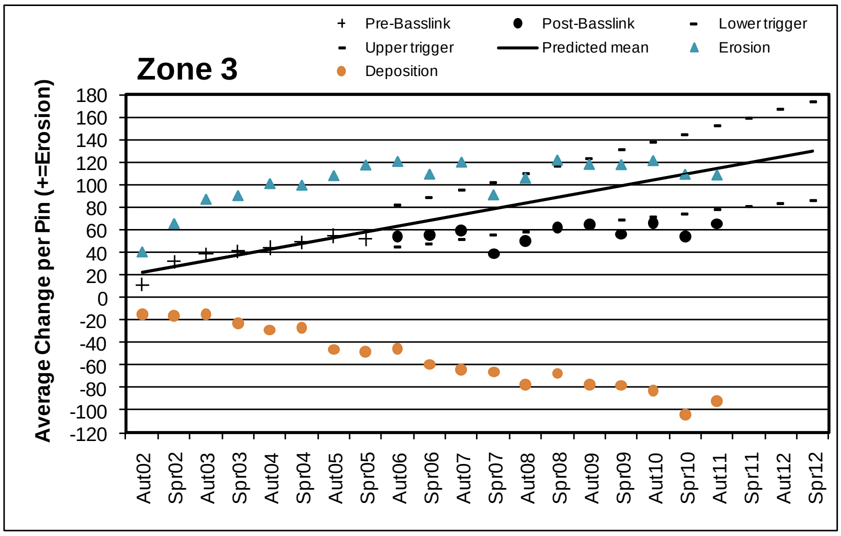


Figure 4-10 Erosion pin results grouped by zones for zone 3. Black crosses show mean change for all pins relative to spring 2001 in zone during the pre-Basslink monitoring period. Solid line shows projection of mean based on pre-Basslink monitoring results. Dashed lines show 95th percentile confidence interval for this projected mean. Black circles show mean change relative to spring 2001 for all pins in zone post-Basslink. Triangles show mean erosion rate for pins recording erosion in each monitoring period. Orange circles show mean deposition rate for pins recording deposition in each monitoring period

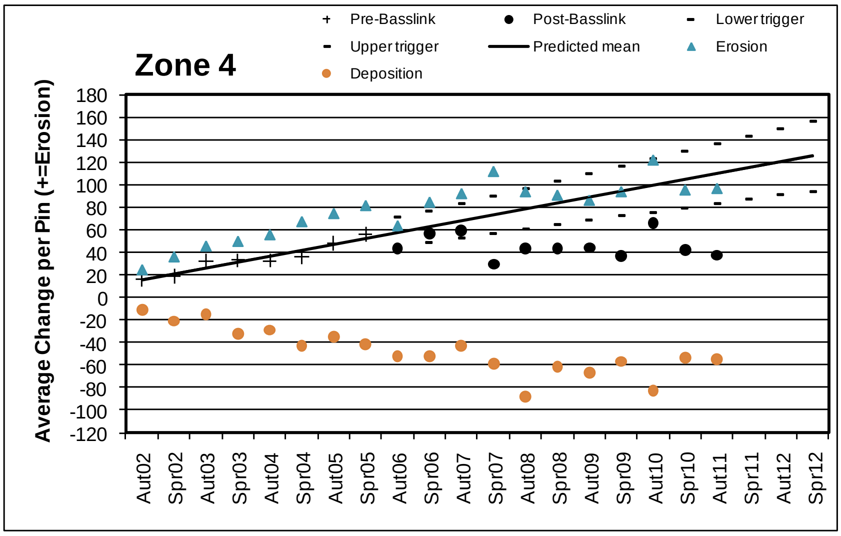


Figure 4-11 Erosion pin results grouped by zones for zone 4. Black crosses show mean change for all pins relative to spring 2001 in zone during the pre-Basslink monitoring period. Solid line shows projection of mean based on pre-Basslink monitoring results. Dashed lines show 95th percentile confidence interval for this projected mean. Black circles show mean change relative to spring 2001 for all pins in zone post-Basslink. Triangles show mean erosion rate for pins recording erosion in each monitoring period. Orange circles show mean deposition rate for pins recording deposition in each monitoring period

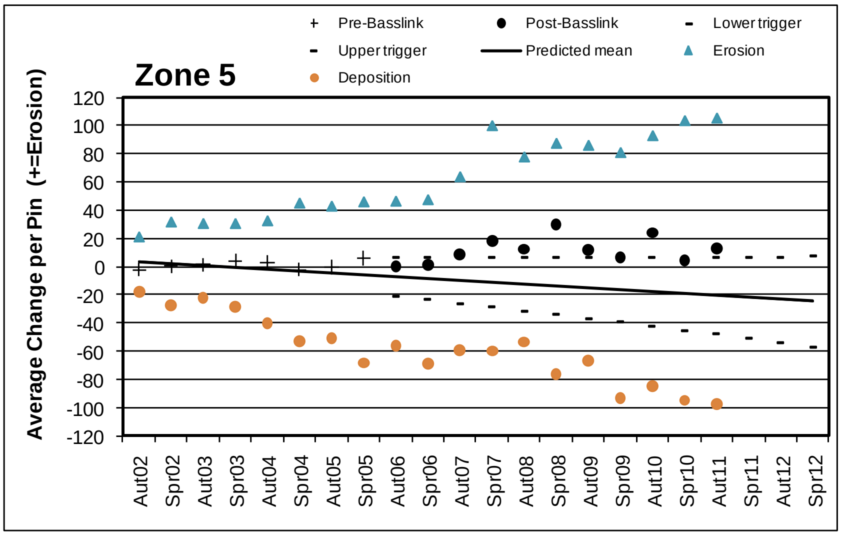
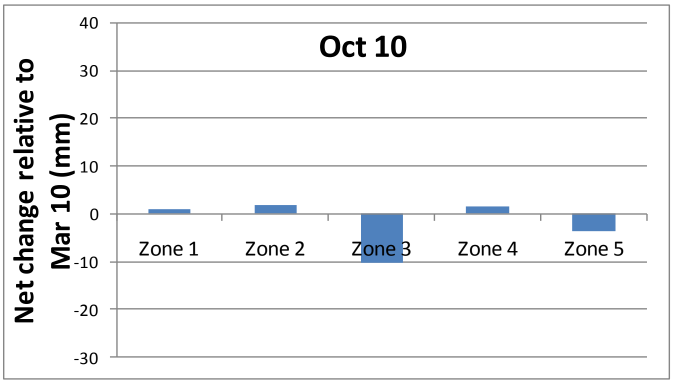


Figure 4-12 Erosion pin results grouped by zones for zone 5. Black crosses show mean change for all pins relative to spring 2001 in zone during the pre-Basslink monitoring period. Solid line shows projection of mean based on pre-Basslink monitoring results. Dashed lines show 95th percentile confidence interval for this projected mean. Black circles show mean change relative to spring 2001 for all pins in zone post-Basslink. Triangles show mean erosion rate for pins recording erosion in each monitoring period. Orange circles show mean deposition rate for pins recording deposition in each monitoring period



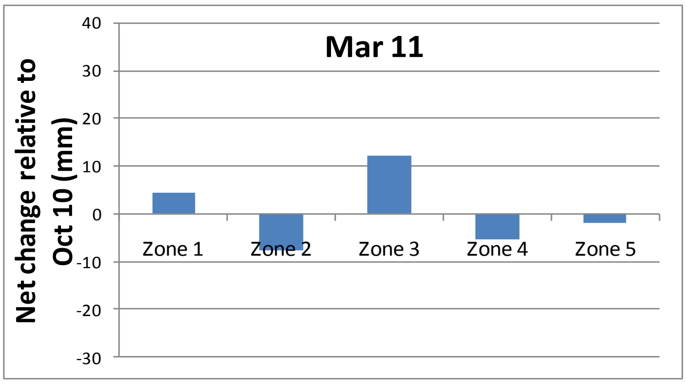


Figure 4-13 Net erosion results by zones compared to previous monitoring period. October 2010 results compared to March 2010, March 2011 monitoring results compared to October 2010

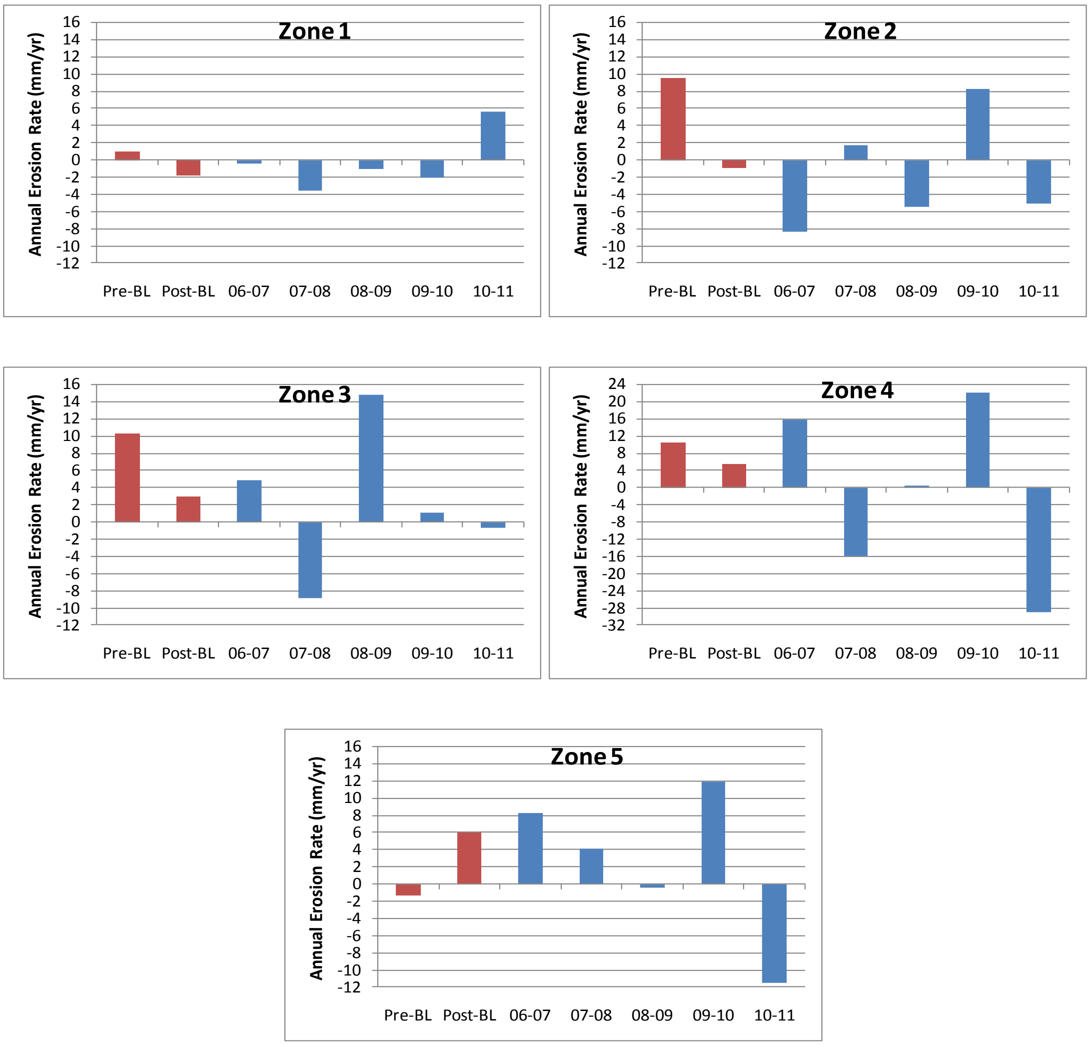


Figure 4-14 Annual erosion rates for zones. First two bars in each data set show the net erosion rate for the pre- and post-Basslink periods, respectively based on March results. The annual; ‘bars’ show the rate of change based on changes between the autumn (March) monitoring results for each year (eg. 2006–07 = change between March 2006 and March 2007). Note the scale for zone 4 differs from the other zones

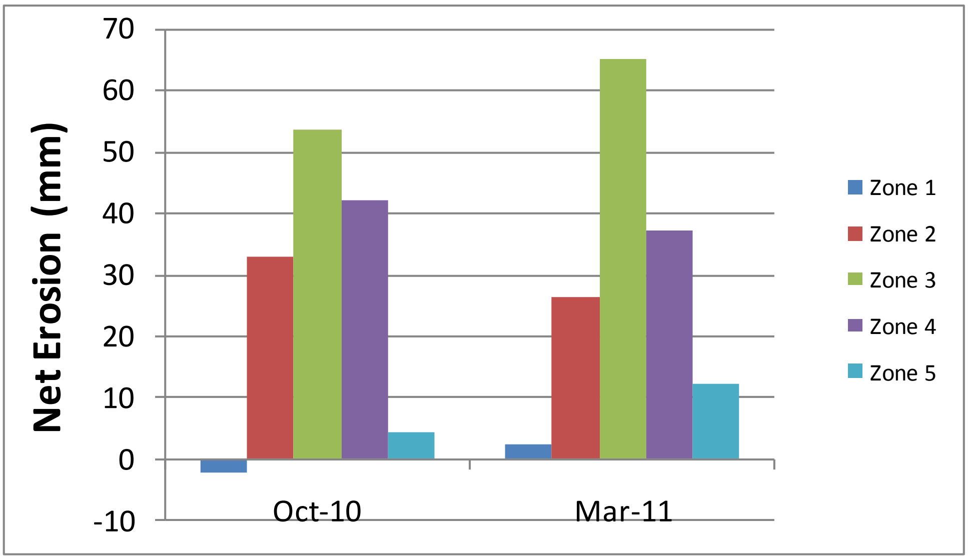


Figure 4-15 Comparison of net erosion rates for October 2010 and March 2011

4.5.4.2 Results grouped by zones and turbine levels

Figure 4-16 to Figure 4-18 contains the same erosion pin results grouped by turbine levels across the five zones, for zones 2 and 3, and for zones 4 and 5, respectively. The results show the net change for each turbine level relative to the beginning of monitoring in October 2001. Between March 2010 and October 2010, there was a decrease in erosion in the 1–2 turbine level and <1-turbine level, with no change in the 2–3 bank level. Since October 2010, the <1-turbine level has shown an increase in erosion similar in magnitude to the decrease recorded over the previous period, and there has been little change in the other bank levels.

Examining the results for zones 2 and 3 and zones 4 and 5 reveal that the downstream zones have recorded higher levels of activity, and that all data sets show a reduction in erosion between March 2010 and October 2010 with the exception of the 2–3 turbine level in zones 2 and 3. During this period the power station was not frequently used at high discharges, and these changes may be associated with deposition from catchment inflows, and/or sub-aerial processes, such as the erosion and deposition of sediment on the exposed and denuded banks through rilling.

In the second half of the monitoring year, bank toes in zones 4 and 5 recorded increased rates of erosion, with the 1–2 turbine levels showing increased rates of deposition. Collectively this suggests steepening of the bank. The higher rates of change in these zones are also consistent with the higher flow volumes associated with the unregulated tributary inputs.

The increase in erosion in the 1–2 turbine bank level in zones 2 and 3 is consistent with field observations which noted evidence of recent scour on some bank faces, and may be related to the peaking operations which occurred just prior to monitoring.

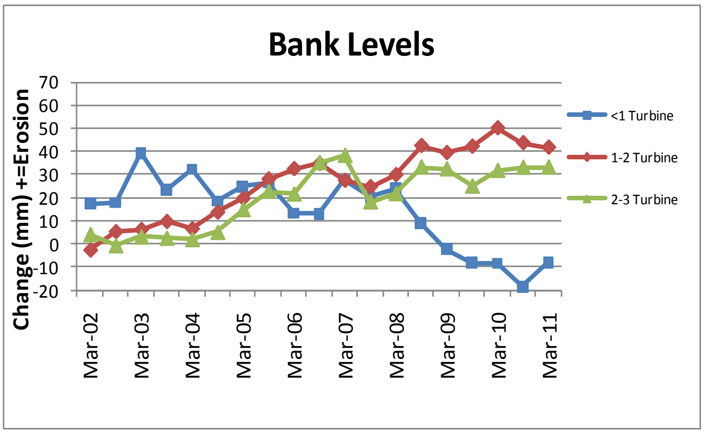


Figure 4-16 Erosion pin results grouped by turbine level. Results are relative to October 2001

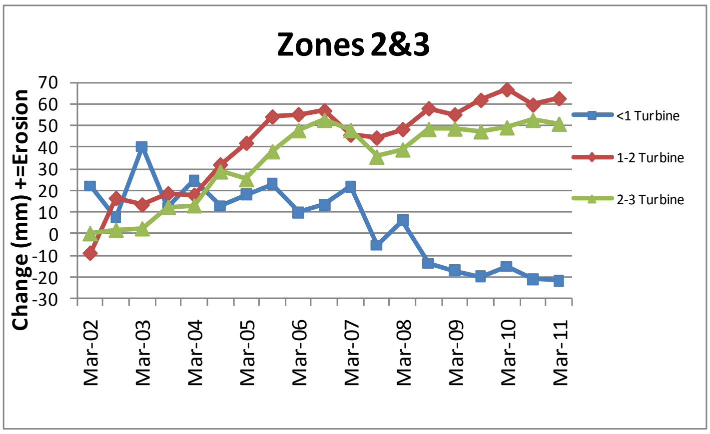


Figure 4-17 Erosion pin results grouped by turbine levels for zones 2 and 3. Results are shown relative to October 2001

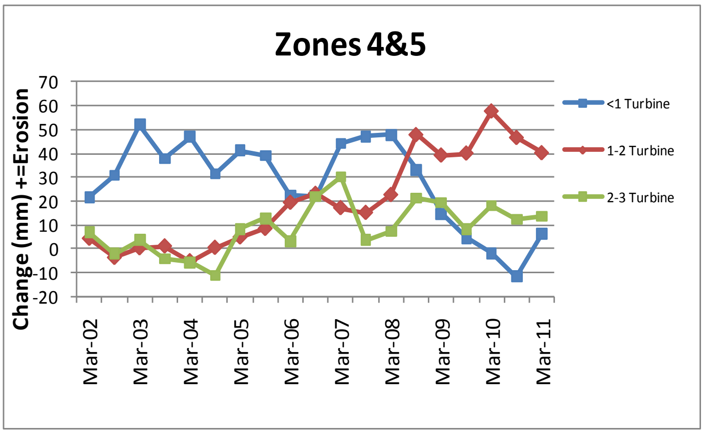


Figure 4-18 Erosion pin results grouped by turbine levels for zones 4 and 5. Results are shown relative to 2001

A comparison of net erosion since spring 2001 by turbine level for all zones, zones 2 and 3 and zones 4 and 5 is presented in Figure 4-19. This shows that zones 2 and 3 have undergone the largest changes for each bank grouping, with the 1–2 and 2–3 turbine levels recording erosion, and the <1-turbine level showing deposition. Although the results have changed little over the past year, this overall trend is consistent with the 'endpoint' contained within the conceptual model for these zones which is a low angle toe extending to a break in slope above which there is a steeper bank. The low rates of change for zones 2 and 3 relative to the previous monitoring period (Figure 4-20) this year is consistent with the low volume of water discharged from the power station over the year.

In zones 4 and 5, net erosion pin results show erosion across all bank levels, with the highest rate occurring at the 1–2 turbine level. This trend remains in spite of the overall decrease in erosion recorded in this bank level during the 2010–11 monitoring year (Figure 4-20).

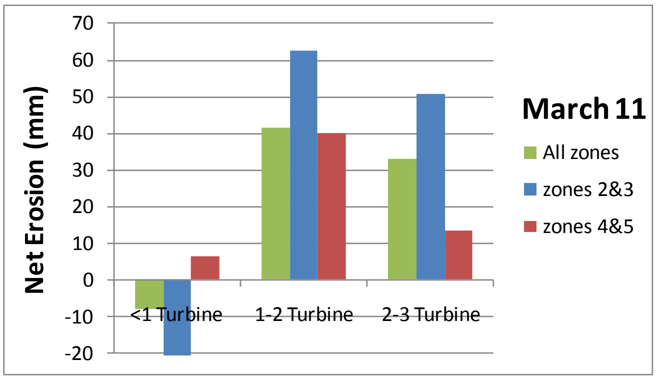
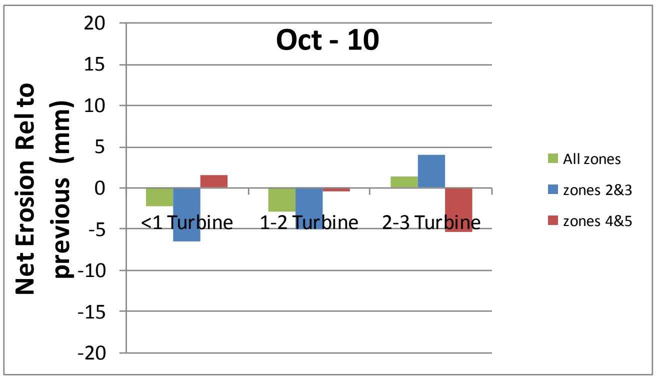


Figure 4-19 Net erosion pin results grouped by zones and turbine levels. Results are relative to spring 2001



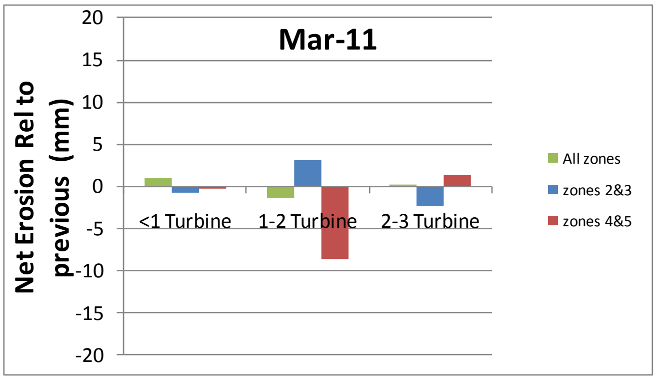


Figure 4-20 Comparison of net erosion rates relative to previous monitoring period for October 2010 and March 2011

4.5.5 Trigger values

Trigger values based on the erosion pin results grouped by zones were developed for the Basslink Baseline Report (Hydro Tasmania 2005a). The trigger values are defined by 95th percentile confidence interval of the projected net erosion rate for each of the zones based on the 2001–05 monitoring results, and are shown in Figure 4-8 through to Figure 4-12. Here, the trigger values are used as the basis for further discussion as one of the 'multiple lines of evidence' in the assessment of the Gordon River fluvial geomorphology.

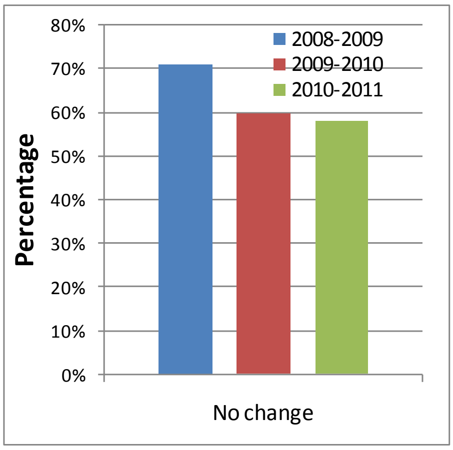
As noted in the previous discussion, the net erosion pin results for each zone falls outside of the projected 'envelope' with the exception of zone 1. Results for zones 2, 3 and 4 fall below the predicted rates of change, with the low rates of erosion in zones 3 and 4 attributable to a large decrease associated with a flood event in August 2007. The low result in zone 2 appears to be due to a lack of change over a prolonged period, and may be associated with the very low power station discharge volumes which have occurred post-Basslink. Zone 5 is the only zone in which measured erosion has been greater than the projected rate, with the February 2011 result falling slightly above the 95th percentile confidence 'envelope'. It is unknown if the reduction in erosion in the upstream zones has led to reduced deposition in zone 5, and/or the greater influence of unregulated inflows relative to the low power station discharges post-Basslink have altered the erosional regime from low rates of deposition to low rates of erosion.

4.5.6 Photo-monitoring results

Photo-monitoring at 62 sites was completed in March 2011. The photos are contained in Appendix 4, along with Table A4-1 summarizing the types of changes observed in 2011. 'Changes' are determined by comparing the March 2010 photos with photos obtained in March 2011. The results are summarized in Figure 4-21 below, which also contains results from the 2008–09 and 2009–10 monitoring years for comparison. A similar percentage of sites in 2010–11 recorded no change as during the 2009–10 monitoring year. Observed changes included additional tree fall upslope of the power station-controlled high-water level, and increased vegetation on bank faces.

In the 'other' category, the majority of changes (nine out of 12) were associated with the movement of woody debris on bank toes, similar to the results from the previous year and are indicative of high flow events and/or the ongoing degradation of woody debris. One of the 'other' changes was scour of cobbles at a site in zone 2, which also occurred in the previous year.

Four photos were not obtained either due to not being able to identify the site, or accidently progressing downstream without obtaining the photo. Many of the sites are becoming difficult to identify due to increased vegetation coverage.



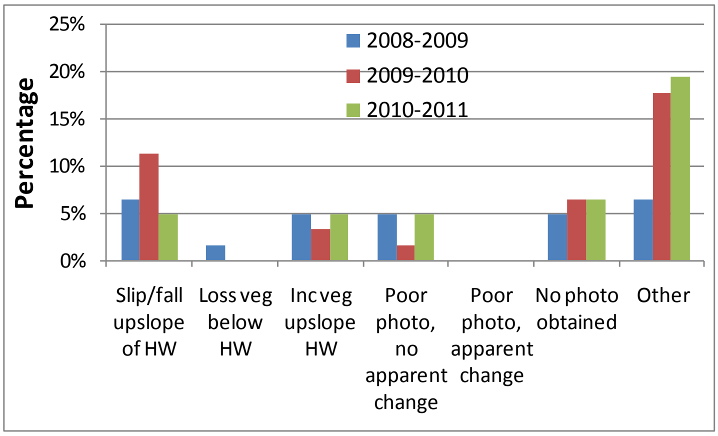


Figure 4-21 Summary of photo-monitoring results for 2010–11. Photos are compared to previous year's photos. Results from 2008–09 and 2009–10 included for comparison

4.6 Conclusions

Based on the observations, erosion pin and photo-monitoring results, there has been little change in the geomorphology of the river during the 2010–11 year as compared to other years. This is likely attributable to the relatively low power station discharges during the monitoring year, and lack of very high unregulated flood events. Perhaps also contributing to stability within the river is the continued presence of vegetation on many of the banks in the 1–2 and 2–3 turbine bank level. The continued survival of these mosses and grasses within the power station-controlled operating level is interesting given that the power station was operating in a peaking pattern for much of the summer prior to monitoring in late February 2011.

The peaking pattern of the power station immediately prior to February 2011 monitoring is suggested as being linked to field observations of scour in the 1–2 turbine bank level, and seepage-induced deposition of sands originating from the lower part of the bank on the toes of banks supporting tea tree. These localised observations were not widely reflected in the statistical analysis of the erosion pins. It is suggested that if this power station operating pattern continues for an extended period, then these types of changes may become more widespread.

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5 Karst geomorphology

5.1 Introduction

The objectives of monitoring the karst caves along the Gordon River are to:

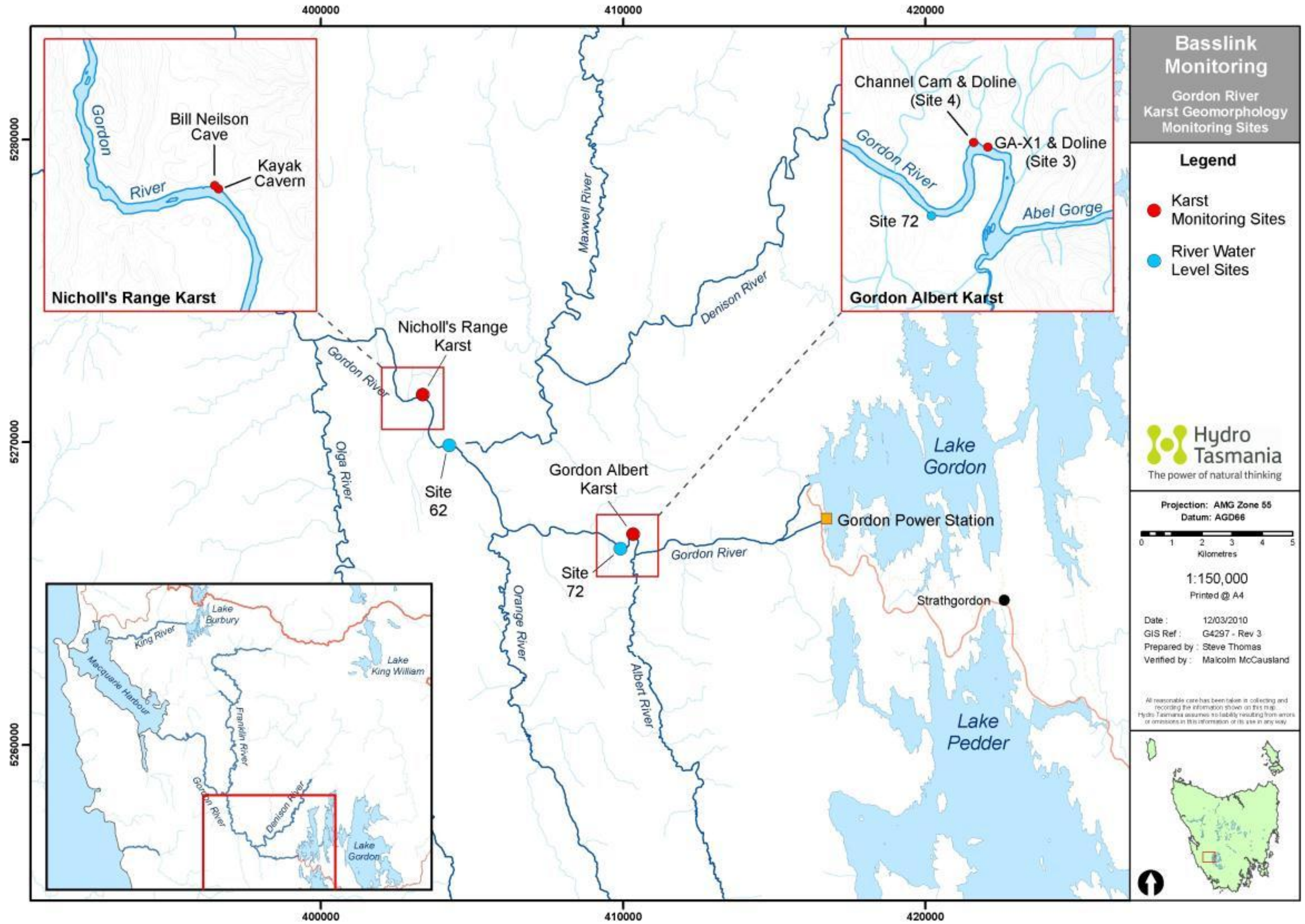
- provide an understanding of the sediment fluxes occurring in the caves, and to determine how these may relate to the hydrology of the Gordon River; and
- monitor dolines to gather evidence to determine whether they may be affected by repeated drawdown in the river channel under the predicted Basslink operation.

This report provides a summary of:

- the karst monitoring data (erosion pin and water level data from Bill Neilson Cave, Kayak Kavern, GA-X1, Channel Cam and dolines) obtained during the 20 October 2010 and 27 February 2011 field trips, including a brief discussion of the results; and
- analysis and discussion of the monitoring results in the context of the informal trigger values determined as part of the Basslink Baseline Review.

5.1.1 Karst areas

Key karst features are monitored at six sites in both the Gordon-Albert and Nicholls Range karst areas twice per year. Map 5-1 shows the location of the two karst areas investigated by the monitoring program.



Map 5-1 Map of the karst monitoring sites in the Gordon River

5.2 Site description and methods

5.2.1 Gordon-Albert karst area

There are four karst monitoring sites in the Gordon-Albert karst area. Site 1 is a backwater channel known as Channel Cam, site 2 is the GA-X1 cave with a doline at the entrance and sites 3 and 4 are dolines. Each site has a number of stainless steel erosion pins installed and a photo-monitoring site marked with a red metal peg. A water level recorder is installed in GA-X1.

The GA-X1 cave is 28 m long (including the large entrance area), 10 m deep and is located approximately 10–20 m from the Gordon River. There are two entrances to the cave – the smaller entrance is a short, near-vertical shaft leading down into the main chamber; the second entrance is much larger and is effectively the base of a second large doline. The cave has a sump at its lowest level, which is at approximately the same elevation as the Gordon River.

5.2.2 Nicholls Range karst area

There are two karst monitoring sites in the Nicholls Range karst area – site 5 in Kayak Kavern and site 6 in Bill Neilson Cave. Bill Neilson Cave contains a cave stream. Kayak Kavern has six erosion pins installed and a photo-monitoring site. Bill Neilson Cave site has three sub-sites within the cave which are designated 6A–C and comprise various arrays of erosion pins. There are also three lightweight capacitive water level probes deployed in the cave. Bill Neilson Cave and Kayak Kavern are accessed by boat.

Table 5-1 Karst area site information

Karst area	River flow gauge	Site no.	Site name	Erosion pin no.
Gordon Albert	72 G5A	1	Channel Cam backwater channel	1, 28
		2*	GA-X1 cave	2, 3, 4
			Doline at entrance of GA-X1	9, 10, 34
		3	Doline adjacent to GA-X1	5, 6, 7, 8
		4	Small doline	12, 13, 14, 31, 32
Nichols Range	62 Gordon below Denison	5	Kayak Kavern eddy slope	19
			Kayak Kavern active slope mid	29, 30, 33
			Kayak Kavern active slope high	16, 17
			Kayak Kavern top flat	18
		6*	Bill Neilson Cave 6A wet sediment bank I at entrance	20, 21, 22
			Bill Neilson Cave 6B wet sediment bank II	25, 26, 27
			Bill Neilson Cave 6C dry bank	23, 24

* water level loggers installed

5.2.3 Water level recorders

Water level recorders located in Bill Neilson Cave and GA-X1 are used together with site 62 (Gordon below Denison), site 72 (G5a), and power station discharge flow data to assist in interpreting the effects of the Gordon River flow on the cave sediment erosion and deposition. Data are presented on a March to March cycle, as this corresponds with the period preceding monitoring events.

Some of the water level data from the March 2010 to March 2011 monitoring year could not be retrieved for a variety of reasons as indicated in Table 5-2 below.

Table 5-2 Missing water level data used for cave assessments

Missing data	Period	Comment
Gordon below Denison (site 62) water level	3 December 2010 – 1 March 2011	Lightning strike disabled site
Bill Nielsen Cave - all water level recorders	17 May – 20 October 2010	Lightning strike or software failure caused logging malfunction
GA-X1 water level	17 May – 20 October 2010	Lightning strike or software failure caused logging malfunction

In the absence of these data:

- the relationships which have previously been drawn between the cave water levels and the Gordon below Denison site were relied upon;
- the Gordon above Franklin water level data, and the compliance site data were referred to where necessary during periods of no available data at the Gordon below Denison site; and
- water level data at site G5a were used as a surrogate measure of water levels in GA-X1.

The four loggers in the caves were replaced with permanent *in situ* level Troll 300s on 20 October 2010. The data for all four loggers are being reported to the same datum as the previous loggers, which accounts for the negative numbers in some cases. The logger in the mouth of Bill Neilson Cave was installed in a deeper location that is more permanently under water than previously, which is the reason for the apparent shift in the dataset. Data are presented in Figure 5-2.

5.2.4 Erosion pin data

Erosion pin measurements and photo-monitoring were undertaken on 20 October 2010 and 27 February 2011. The height of all erosion pins was measured to the nearest millimetre using a steel ruler placed to the right side of the pin, on the contour level. Data for all sites are presented in Appendix 6 and graphically in each of the monitoring site sections. The sum of the distances between the tops of the pins located in the dolines at sites 3 and 4 were also measured to determine whether any major structural change had occurred. These measurements are provided in Appendix 6 and presented graphically in section 5.3.5.

Erosion pin data are interpreted in the context of the water level recorder data or surrogate river level data. Data collected during October are considered to be indicative of winter conditions (March to October inclusive), while data collected in February are considered to be indicative of summer conditions.

5.2.5 Photo-monitoring

Photos were taken at all photo-monitoring sites as planned. The photo-monitoring does not have the aim of comparison of changes at specific sites over time, but is used to aid interpretation of data by providing a record of the sites that are difficult to see in the dark conditions in the caves.

The photo-monitoring is used for detecting any macro-scale changes that have occurred at the monitoring sites, including identification of features that are not the focus of the monitoring program (e.g. collapse of cave wall, deposited tree branches), but have potential to affect the results of the pin measurements. These photos are kept on file by Hydro Tasmania.

5.3 Results and discussion

5.3.1 Bill Neilson Cave

5.3.1.1 General observations

Fresh platypus scats with evidence of burrowing continue to be found in the sediment banks in the dark zone in the middle of the cave, reconfirming this relatively unusual extent of their habitat range.

5.3.1.2 Sediment transfer

There are three sets of erosion pin data in Bill Neilson Cave, the wet sediment bank in the entrance chamber (pins 20–22), the wet sediment bank 5–10 m further into the cave (pins 25–27), and the dry sediment bank 175 m into the cave (pins 23–24).

The October sampling data show that during the winter period there was a moderate level of erosion (3 mm) at the lower level of the first wet sediment bank close to the cave stream; with slight erosion at the mid level (1 mm) and slight deposition (2 mm) higher up (Figure 5-1a). Exactly the same pattern of change took place on the second wet sediment bank, although the changes were more subdued with 2 mm deposition at the lower level, no change at the mid level, and just 1 mm of deposition at the higher level (Figure 5-1b).

During the summer period, the trends at the higher and mid levels were generally the opposite of the winter changes (0–1 mm of erosion at the higher levels and 2 mm of deposition at the mid levels), while the changes were mixed at the lower level where there was 1 mm erosion in the first wet sediment bank, and 1 mm of deposition in the second (Figure 5-1a, b).

Over the 12-month monitoring period, there were similar trends at both the wet sediment banks. The net change at the lower level was erosion, with 4 mm occurring in the first bank, and 1 mm at the second. There was 1–2 mm of net sediment deposition at the mid and higher levels.

At the dry sediment bank at both pins, there was 1 mm of erosion recorded during the winter period, and 1 mm of deposition during the summer, resulting in zero net change over the 12 months (Figure 5-1c). However, the water level data show (Figure 5-2) that it is unlikely that the pins were inundated for more than a few hours this year and, as the recorded change is very small and within the margin of error of the measurement technique, it is not considered to be significant.

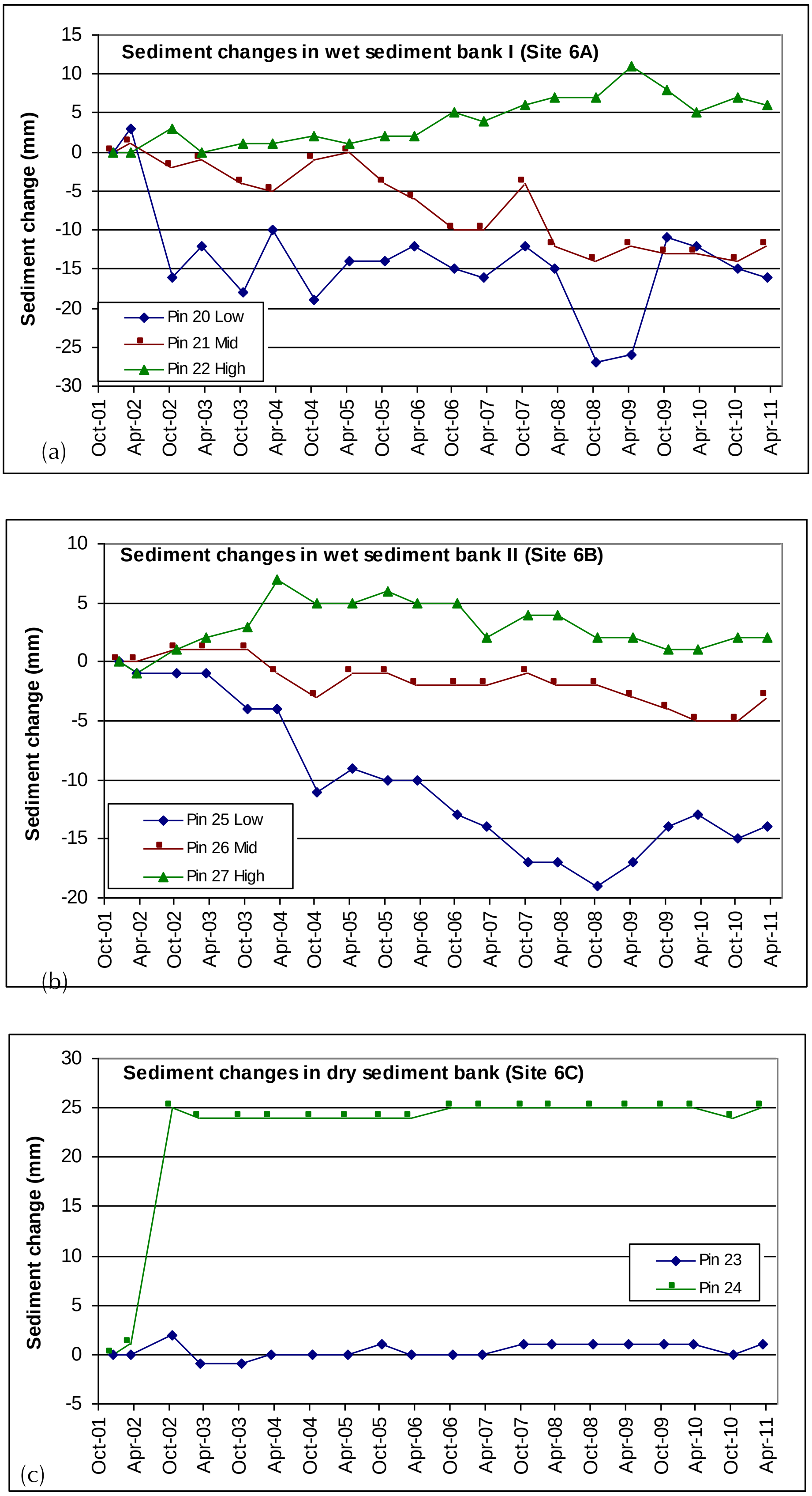


Figure 5-1 Changes in erosion pin lengths at the three sites in Bill Neilson Cave over time (a) site 6A, (b) site 6B and (c) site 6C

5.3.1.3 Water level monitoring

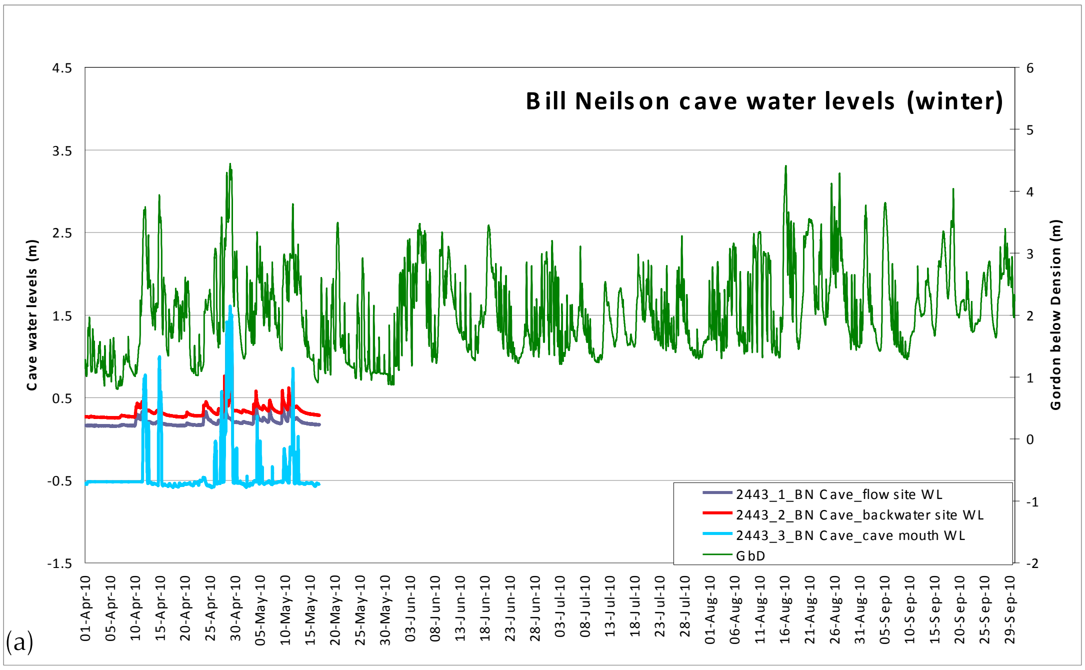
With the exception of January and February 2011, there was very little power station activity greater than 180 $m^3 s^{-1}$ this year, which has resulted in relatively little inundation (Figure 5-2), and consequently little change in the sediments. Low power station output during the winter months meant that the cave stream was the dominant flow regime during that period, which has lead to the erosion occurring at low levels within the cave. The sediment deposited at the higher levels in winter is likely to have been the result of the occasional high power station flow periods creating a backwater effect in the mouth of the cave, allowing the winter sediment load to settle out on the banks. In the few weeks leading up to the shutdown for the monitoring event, there were also a series of rainfall events which kept the river relatively consistently high despite low power station flows, which would have resulted in more stable backwater conditions favourable for deposition at the mid levels. These are the usual patterns of sediment transfer seen in the cave during the winter months.

In January and February, the influence of the large daily fluctuations in power station flows can be seen in the water levels in the mouth of the cave. The general lack of summer rainfall has meant that the fluctuating trend was dominant, resulting in very minor erosion occurring at the higher levels.

There were two significant summer rainfall events that caused increases in the flows in the cave stream, and despite these being coincident with high power station flows, the Gordon above Franklin flow record suggests it is unlikely that they were big enough to inundate the dry sediment bank. The maximum inundation level this year was just 4.4 m measured in April at the Gordon below Denison gauge, which is lower than during the majority of the other pre- and post-Basslink monitoring years.

5.3.1.4 Conclusion

Power station operations have been relatively low again this year, similar to the last two years, which has resulted in relatively little inundation, and consequently modest and generally unremarkable change in the sediments overall. The maximum level of inundation into the cave was lower than in the majority of years and is unlikely to have reached the level of the pins in the dry sediment bank for more than a few hours, if at all.



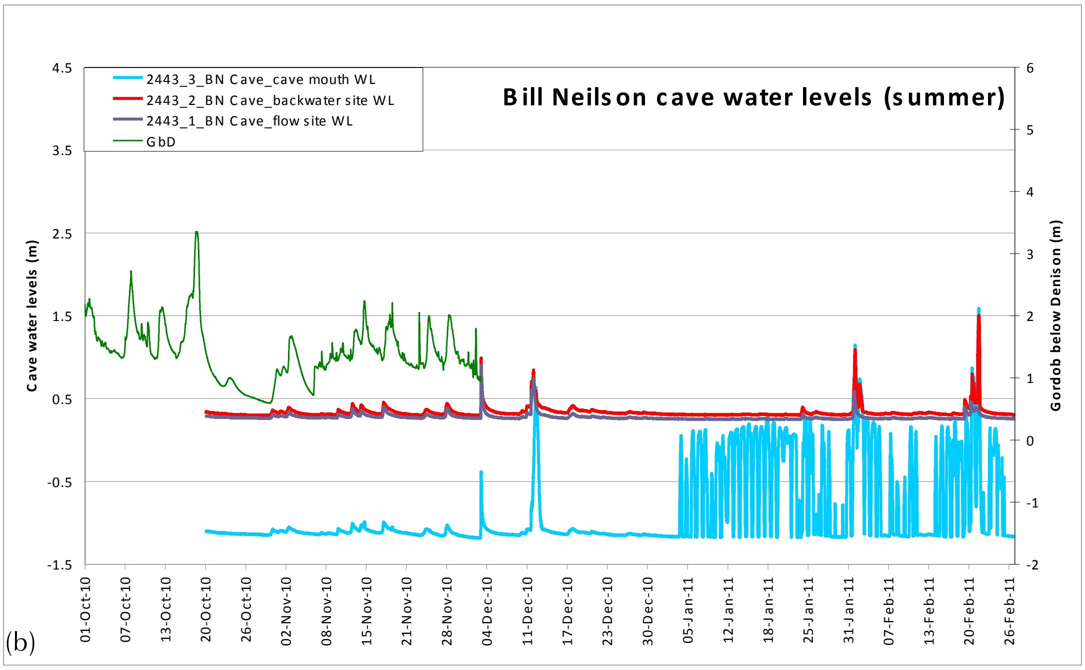


Figure 5-2 Bill Neilson cave water level recorder data together with Gordon below Denison river data in (a) winter and (b) summer

5.3.2 Kayak Kavern

5.3.2.1 General observations

Over the winter period, there was a large apparent increase in sediment at pin 30 in the mid active slope area of the sediment bank, the scale of which was not reflected in the other pins, and there is a question over whether it has been knocked by floating debris (Figure 5-3a). There was however, also a significant increase on the sediment bank recorded through the sediment bank profiling, so it is considered likely to be a true reflection of the conditions on at least part of the bank. The pin is now almost completely buried.

5.3.2.2 Sediment transfer

The majority of the active slope in Kayak Kavern is inundated when the level at the Gordon below Denison gauging station is approximately 1.9 m. This is equivalent to power station operations of approximately 140 $m^3 s^{-1}$ with little flow in the tributaries. Pin 18 on the top flat becomes submerged when the level at the Gordon below Denison gauge is approximately 2.6 m, or once the station outflow increases to 180 $m^3 s^{-1}$ when tributary flow is low.

Measurements from the October sampling (Figure 5-3) showed that over the winter period, 2–80 mm of deposition occurred at the majority of the pins, with the exception of the top flat (pin 18) and one pin on the active slope (pin 33) where erosion took place (–4 mm and –5 mm, respectively) (Figure 5-3). The winter power station flows were mostly between approximately 25 and 180 $m^3 s^{-1}$ which, in conjunction with the natural tributary inflows, inundated the active slope for much of the period resulting in relatively stable conditions conducive to deposition. This contrasts with the impacts of fluctuating flows at the higher level on the top flat which has resulted in the erosion at that level. Pin 33 on the active slope usually exhibits the opposite trend to the majority of pins, so overall the changes this period are considered to be consistent with other years.

During the summer months (Figure 5-3), almost exactly the reverse of the winter trends were seen, with erosion or no change (0 to -9 mm) occurring at the majority of pins, with the top flat and pin 33 indicating deposition (13 mm and 2 mm respectively). It is likely that these changes are related to the larger fluctuating flows with the hydropeaking in January and February, which often incorporated the full operating range from the environmental flow to three-turbine operations. Sediment may be eroded from the active slope and then deposited on the top flat. Pin 33, once again demonstrated the opposite trend to the majority.

Over the 12-month period, most of the pins (pins 17, 18, 19, 30) showed net deposition (9–80 mm), which is consistent with the overall results from the long-term sediment profiling (Figure 5-3). The two exceptions were pin 33 (–3 mm), and pin 29 (–7 mm) which also demonstrated a net loss during the previous 2009–10 monitoring season.

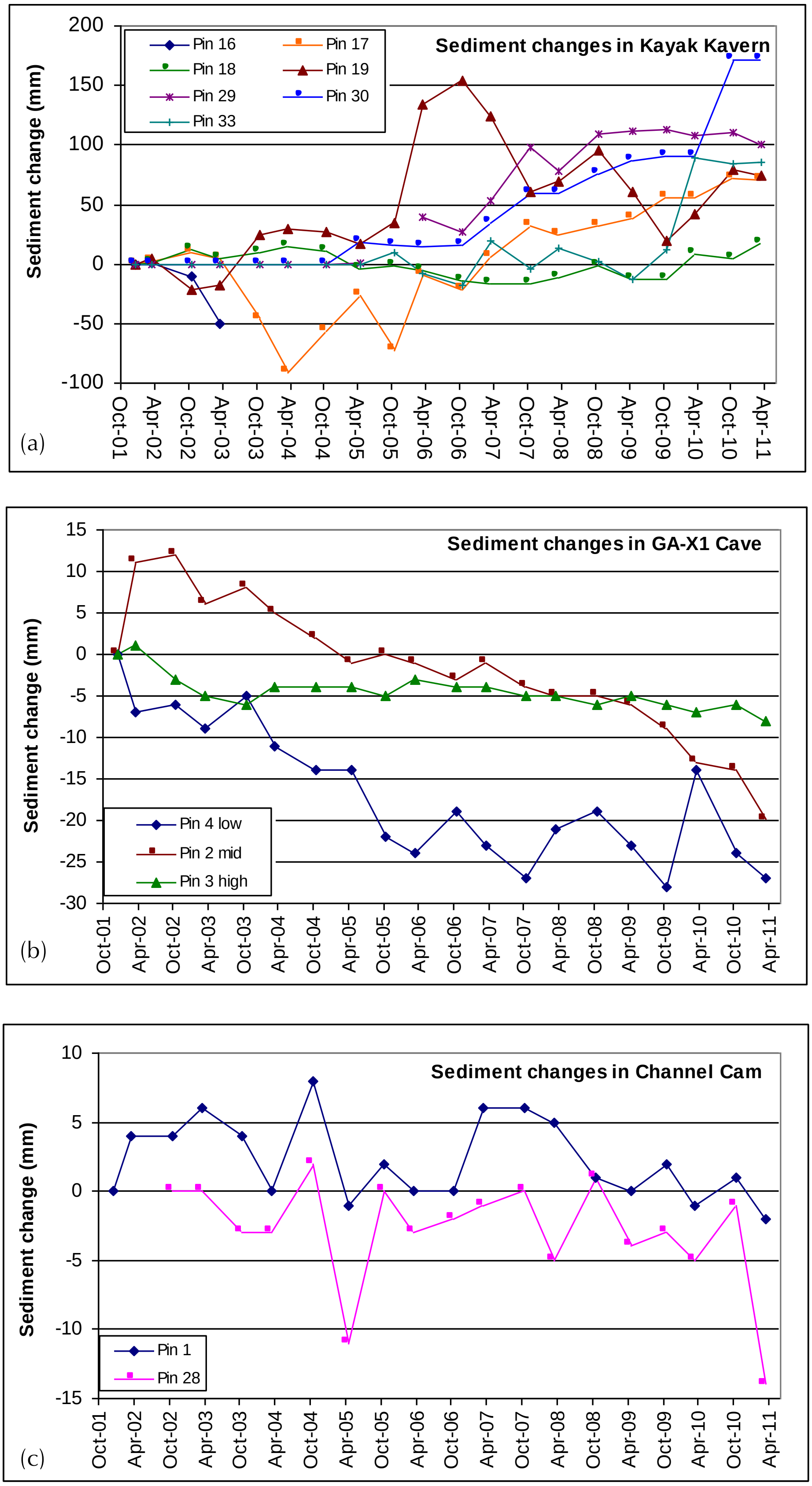


Figure 5-3 Changes in erosion pin lengths at (a) Kayak Kavern, (b) GA-X1 and (c) Channel Cam over time

5.3.2.3 Conclusion

The pins in Kayak Kavern have demonstrated that deposition has generally occurred in winter on the active slopes of the sediment bank. This is due to the relatively consistent inundation with the low to mid-range flows (up to 180 $m^3 s^{-1}$) in conjunction with the natural tributary inflows, which led to periods of stable conditions at the lower levels. Fluctuations at the mid- to high-water levels resulted in erosion on the top flat. Over the summer, the hydropeaking in January and February coincided with a combination of minor increases and decreases in sediment across all pins.

Overall, the results from Kayak Kavern are consistent with previous years and with the broad seasonal trend of winter deposition, and mixed results in the summer.

5.3.3 GA-X1

5.3.3.1 General observations

- It was noted during the October trip that a log measuring 800 mm x 100 mm had fallen into the cave and was resting against pin 4. The log was still there during the February trip; and
- There is no evidence of further collapse in the wall of the doline at the cave entrance.

5.3.3.2 Sediment transfer

Measurements from the October sampling indicated that during the winter period, significant erosion (–10 mm) took place at the lower level in the cave at pin 4, while the mid and higher level pins recorded just 1 mm of erosion and deposition, respectively (Figure 5-3b). This extent of erosion at pin 4 has not previously been seen in the cave, although there have been larger depositional events in the past.

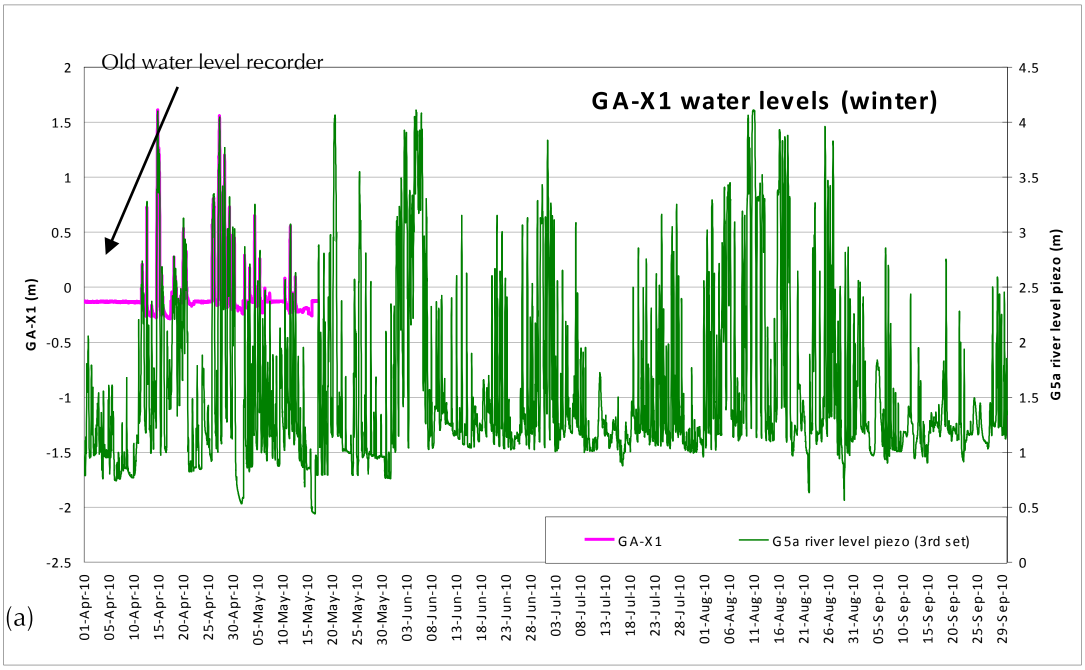
During the summer period, erosion occurred at all levels in the cave, from -3 mm at the lowest level, -6 mm at the mid level, to -2 mm at the higher level (Figure 5-3b). This is significant, as there has only been one previous summer period, in 2002–03, when erosion occurred at all three levels.

Over the 12-month period, these results have given rise to net erosion at all levels, with the extent increasing with depth into the cave. The net changes were -1 mm at the higher level, -7 mm at the mid level, and -13 mm at the lower level.

5.3.3.3 Water level monitoring

Part of the water level record for the GA-X1 record, between April and October, is missing, however the data from river level piezometer probe at G5a can be used to give an indication of what the levels would have been like within the cave (Figure 5-4).

During the winter period, the generally low levels of inundation in the cave have resulted in very little sediment changes occurring at the mid and upper levels. The erosion at the lower level reflects the fluctuations in power station output up to 180 $m^3 s^{-1}$ which occurred between May and August and would have helped to remove the sediment from the cave.



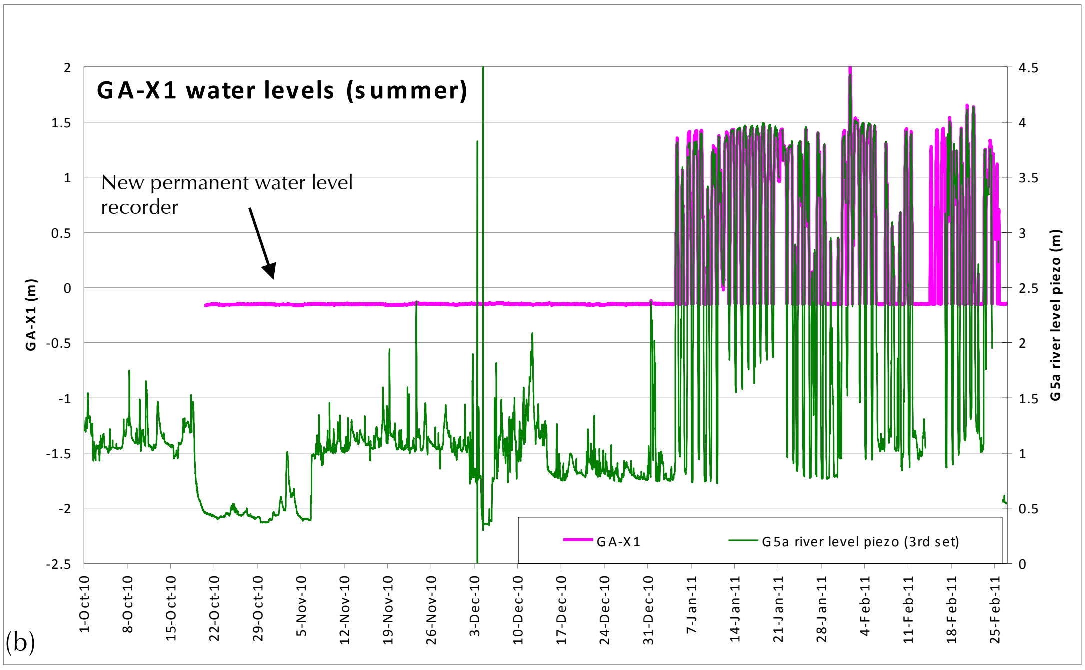


Figure 5-4 G5a piezometer, river probe data, winter and summer, together with the available GA-X1 data from the (a) old and (b) new data recorders

During the summer months, the erosion at all three levels within the cave is considered likely to be a result of the hydropeaking with three turbines that took place in January and February. The power station operations were generally otherwise restrained to low outputs this summer, and as the GA-X1 cave is upstream of the major natural tributary inflows to the river, this season has provided a useful opportunity for isolating the influence of the hydropeaking operations alone.

5.3.3.4 Conclusion

Fluctuations in the lower levels of power station output in winter resulted in erosion at the lower levels in the cave with little change higher up due to the general lack of inundation at those levels. During the summer months, hydropeaking in January and February is correlated with erosion occurring at all three levels within the cave, and indicates the potential influence of this operation on the erosion over this period.

5.3.4 Channel Cam

In Channel Cam, it was observed during both the sampling trips that there continues to be a build-up of thick mud and moss at the pins. This is a reflection of the generally lower proportion of 3-turbine operation flows within the system in comparison to the pre-Basslink years.

During the winter period, deposition took place at both pins, although there was more change evident at pin 28 (4 mm) which is closer to the small creek, than at pin 1 (2 mm) which is further away from the influence of the river (Figure 5-3c). These are typical responses for this backwater channel which is only inundated by the Gordon River when the power station is operating at the 3-turbine level. The winter deposition is likely to be a result of the small influx of sediment from the peak tributary flows in the river and/or rainfall, together with the general lack of inundation from the power station which has a tendency to remove sediment.

Following the summer months, there was 3 mm of erosion at pin 1, and a further 13 mm of erosion at pin 28, which may have been the response to the hydropeaking in January and February.

As has been the case in recent monitoring years, there was a net reduction in the sediment levels over the 12-month period.

5.3.5 Dolines

The relatively strong seasonal trends of winter increases in debris in the dolines at sites 3 and 4 has continued this winter, with four of the eight pins showing an increase of up to 24 mm and one showing no change at all. The higher increases tend to occur towards the bases of the features, although this year unusually, there was a 2 mm decrease recorded in the bottom and middle levels at site 3 (Figure 5-5). These changes are more related to the rainfall than power station operations.

During the summer months this year, four of the pins recorded a seasonal summer decrease in debris up to 9 mm, while two recorded no change. The pin at the rim of each of the dolines exhibited the opposite trend with a 1 to 2 mm increase in debris.

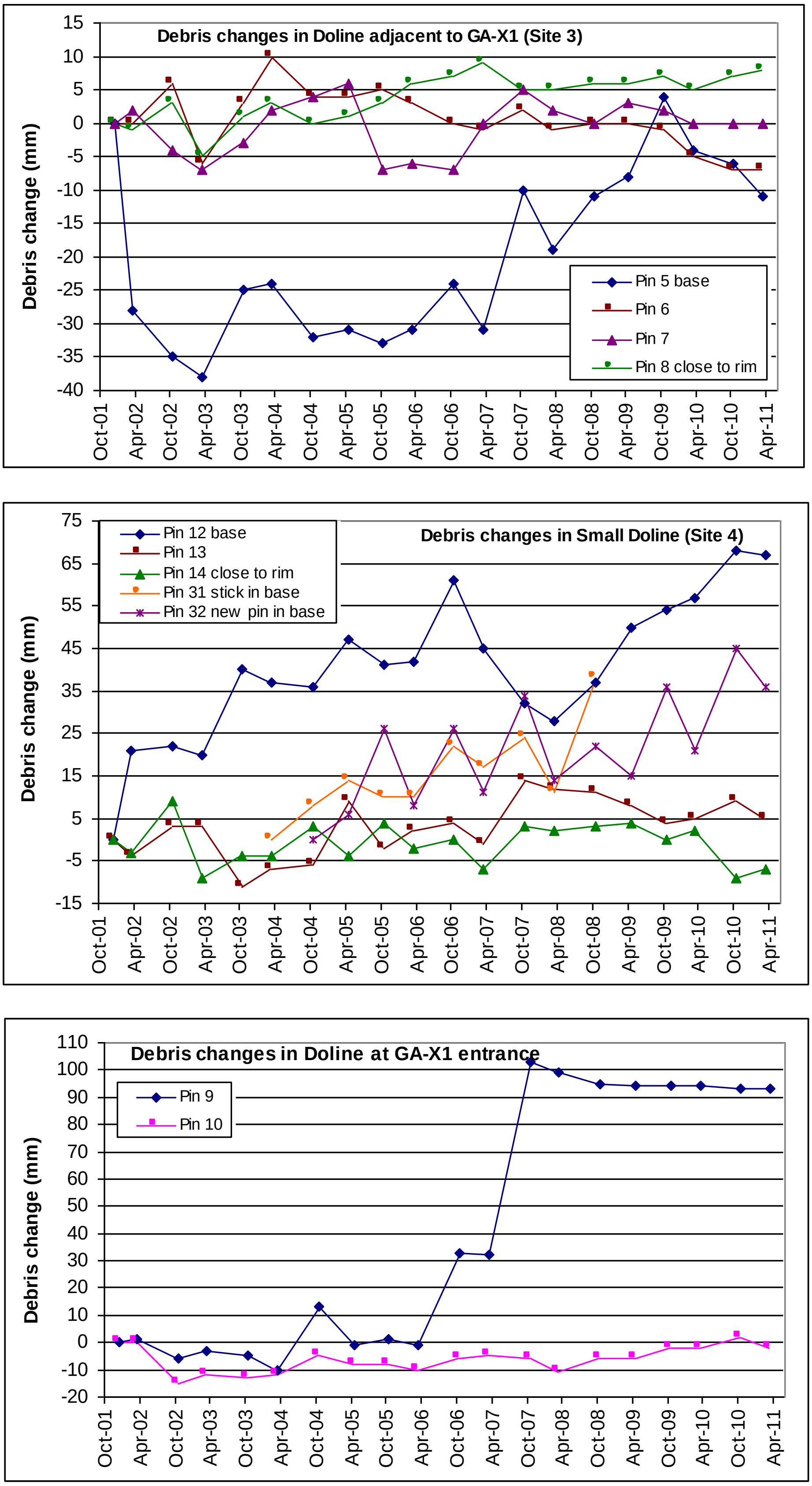


Figure 5-5 Changes in erosion pin lengths in the three dolines over time

As noted in previous reports, the changes in the lengths of the erosion pins, which only measure the changes in leaf litter in the dolines, are of less importance than changes in the distances between the tops of the pins which measure any significant structural change. Consistent with previous trips, there were no significant changes between the pins within the precision of the measuring method (Figure 5-6). This suggests that the morphology of the dolines has remained stable since the program commenced.

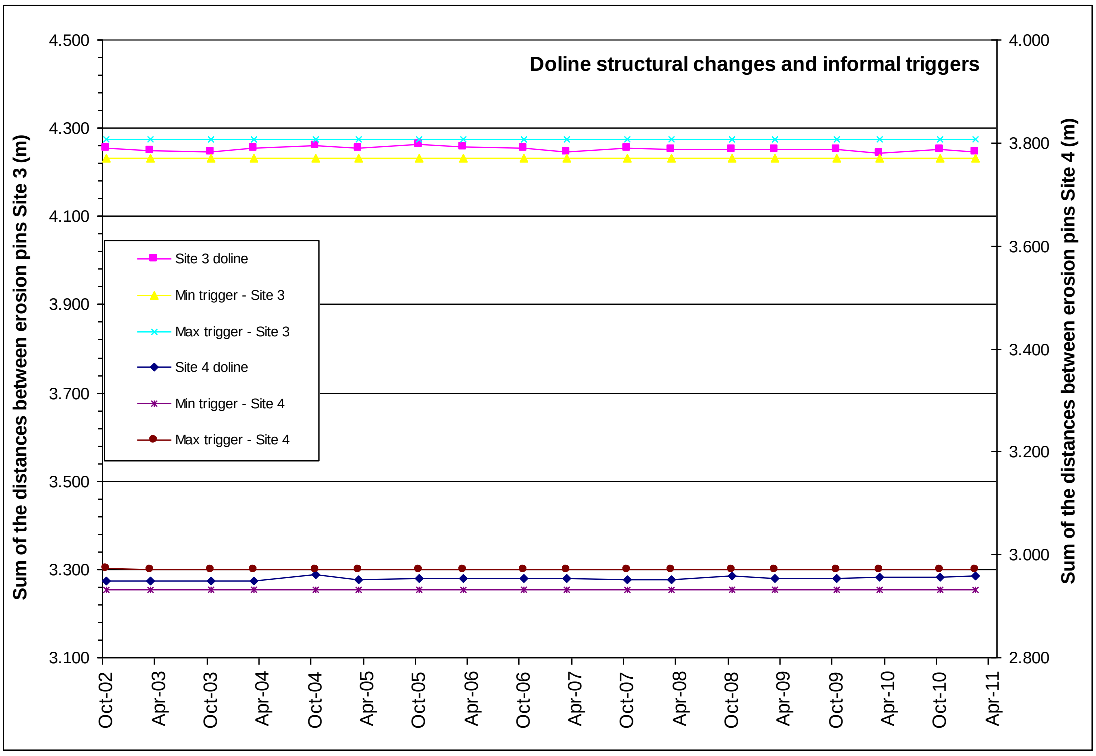


Figure 5-6 Sum of the distances between erosion pins (survey data) in the dolines at sites 3 and 4

5.4 Comparison with the informal trigger values

The primary indicator variables for assessing potential Basslink effects, as recommended in the Basslink Baseline Report (Hydro Tasmania, 2005a) and in the subsequent review of trigger values report in the 2005–06 Gordon River Basslink Annual Report (Hydro Tasmania 2006), can be divided into three main groups:

- sediment changes at erosion pins;
- inundation of the dry sediment bank in Bill Neilson Cave; and
- structural change in the dolines.

Within each group, there are three, two and one indicators, respectively, which are used to assess whether there is significant change occurring.

The Basslink Baseline Report identified that it was not feasible to determine formal trigger values for these karst indicator variables, as have been developed for the other disciplines. This is because averaging across karst sites and zones is not possible and there is no reasonable alternative consistent with the methodology being used by other disciplines. Nonetheless it was accepted that consideration of possible changes in patterns at the erosion pins should take place as an informal basis for alerting to possible changes.

A series of informal trigger values have been determined for the indicator variables which are being used to detect if potentially significant change is occurring. Should change be detected, the next step will then be to determine whether the cause of the change is Basslink related or due to one of the other potential drivers of change in the system.

5.4.1 Sediment change at erosion pins

Sediment change at erosion pins is being assessed and monitored in three ways:

- inter-seasonal and long-term maximum changes in erosion or deposition;
- inter-seasonal and long-term average changes; and
- changes in seasonal (i.e. winter and summer) or long-term trends.

Changes identified through all three methods of analysis are required for the informal trigger to be exceeded, thereby prompting the need for further investigation and/or analysis of the data.

5.4.1.1 Sediment change at erosion pins: 2010–11 season

Analysis of the erosion pin data for the 2010–11 monitoring season shows that while there were some changes compared to the pre-Basslink ranges of change at some of the pins there were, however, no changes across all of the change criteria at any of the pins, and therefore there were no exceedances of the informal triggers.

5.4.2 Inundation of the dry sediment bank in Bill Neilson Cave

The dry sediment bank, located approximately 175 m into the cave from the cave entrance, is being monitored for the extent and duration of inundation by the Gordon River. The dry bank is not typically significantly inundated unless there are three turbines operating at the power station, in conjunction with reasonably high flows in the tributaries. Under pre-Basslink conditions, the bank was inundated relatively infrequently.

The two informal triggers relating to the inundation of the dry sediment bank in Bill Neilson Cave are:

1. the percentage of time in any given season, and overall, that the pins in the dry sediment bank are inundated; and

2. the maximum height of inundation in Bill Neilson Cave, estimated based on the height of the peak flow at the Gordon below Denison gauging station, together with any available water level markers inside the cave.

The pins in the dry sediment bank in the cave are inundated when the river level at the Gordon below Denison gauge is greater than approximately 4.4 m. During the pre-Basslink period, the pins were inundated just over 1 % of the time, with the majority of peak flow events occurring during the winter months. The maximum peak flow measured during the pre-Basslink monitoring program was 6.1 m at the Gordon below Denison gauge on 12 June 2002.

5.4.2.1 *Inundation of the dry sediment bank in Bill Neilson Cave: 2010–11 season*

As part of the data record is missing from the Gordon below Denison gauge this season, an estimate as to the extent of inundation has been made using data from the Gordon above Franklin site and power station discharge.

The data suggest that this year the peak flow event reached a maximum level of 4.4 m on the Gordon below Denison water level recorder, the approximate height of the pins in the dry sediment bank. If the bank was inundated, it is probable that it would only have been for a maximum of an hour or two, and was certainly well below the 1 % of the time recorded during the pre-Basslink period. The erosion pin data indicated that there was no real impact of this event on the dry sediment bank.

It is therefore considered that there were no exceedances of the maximum inundation informal triggers this year.

5.4.3 Structural change in the dolines

Structural change in the dolines is assessed by measuring the distances between the tops of a number of erosion pins installed in a transect up the sides of the features. The average sum of the distances between the pins at site 3 was 4.25 m during the pre-Basslink sampling period and the informal trigger value was therefore determined in the Basslink Baseline Report to be 4.25 ± 0.02 m to allow for the level of accuracy inherent in the measurement technique. The pre-Basslink average sum of the distances between the pins at site 4 was 2.95 m and the informal trigger value was 2.95 ± 0.02 m. In carrying out the assessment, consideration is given to whether pins could have been interfered with by wildlife or falling debris.

5.4.3.1 *Structural change in the dolines: 2010–11 season*

During the 2010–11 monitoring period, the sum of the distances between the pins at site 3 was 4.251 m during the October sampling trip and 4.245 m during the March sampling trip. At site 4, the equivalent values were 2.957 and 2.958 m respectively. The informal trigger values were therefore not exceeded.

5.5 Conclusion

In Bill Neilson Cave, the relatively low power station discharge throughout the year resulted in little inundation of the cave, and consequently modest and generally unremarkable change in the sediments overall. The maximum level of inundation was lower than in the majority of years and is unlikely to have reached the level of the pins in the dry sediment bank for more than a couple of hours. This resulted in negligible change in the dry sediments.

The pins in Kayak Kavern have demonstrated that deposition has generally occurred in winter on the low active slopes of the sediment bank, due to the inundation by the low to mid-range flows in conjunction with the natural tributary inflows, which lead to periods of stable conditions conducive to deposition at the lower levels. Fluctuations in station operations at the upper end of the mid-range flows resulted in erosion on the top flat. Over the summer, the large fluctuating flows in January and February coincided with minor increases and decreases in sediment across the pins.

In GA-X1, fluctuations in the lower levels of power station output this winter resulted in erosion at the lower levels in the cave with little change higher up due to the general lack of inundation at those levels. During the summer months, hydropeaking in January and February appears to have resulted in erosion occurring at all three levels within the cave.

In the dolines, consistent with previous trips, there were no significant changes between the pins, suggesting that their morphology has remained stable since the program commenced.

In Channel Cam, which is only inundated when the power station is operating at three turbines, there was the typical winter deposition, with relatively large summer erosion that coincided with a previous period of hydropeaking in January and February.

None of the informal triggers were exceeded during 2010–11 monitoring period.

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6 Riparian vegetation

6.1 Introduction

Riparian vegetation monitoring is undertaken along the banks of the Gordon River to measure riparian vegetation attributes to determine if Basslink operations are resulting in changes. Specifically, the aims of the riparian vegetation monitoring program are to:

- characterise and monitor the abundance and composition of vegetation at permanent sites along the river;
- relate changes in vegetation abundance and composition to changes in the flow regime if appropriate; and
- assess these results against a set of pre-Basslink baseline condition metrics.

Vegetation and flora data have been collected for four years prior to the operation of Basslink (known as the pre-Basslink period) to determine a baseline for the system. These data have subsequently been used to develop a set of quantitative and qualitative trigger values to detect changes in the post-Basslink operational period (see Hydro Tasmania, 2005).

This chapter presents the results of the Basslink riparian vegetation monitoring program for the 2010–11 monitoring period. Summer monitoring was undertaken from 4 to 6 December 2010 in the Gordon, Franklin and Denison rivers. Autumn monitoring was undertaken from 4 to 6 March 2011. This monitoring is earlier than the normal scheduled monitoring but it was considered unlikely this would have significantly impacted on the vegetation results.

These are the fifth set of results to be compared against the trigger values based on analysis of vegetation and ground cover data, and summary variables calculated from these (species richness and evenness, similarity indices between sites and monitoring events). Some of the triggers were originally developed using the ratio of the ‘above’ quadrats compared with the ‘low’ and ‘high’ quadrats. This analysis was based on the assumption that the ‘above’ quadrats act as a ‘reference’ for the other quadrats lower on the bank and thus more directly impacted by flow changes. However, following changes to bank structure of some sites in zone 2, it was recommended (Hydro Tasmania, 2010a) that the quadrat triggers only be used for zones 3, 4 and 5 where the reference quadrats remain intact.

One site in zone 2 (2d) was particularly affected and its reference quadrat was compromised. Other sites in this zone were considered to be less affected and so it was considered to be more statistically appropriate that zone 2 (excluding site 2d) be included in all whole-of-river calculations but be excluded from the zone calculations. Consequently, the quadrat triggers have only been applied for zones 3, 4 and 5 in this report.

Implementation of the Basslink Review Report 2006–09 (Hydro Tasmania, 2010a) recommendations has retained all triggers assessing community integrity (species/taxa richness and evenness, community structure and community composition) in zones 3 to 5 and the photo-monitoring assessments in all zones. This has resulted in a total of 37 triggers being reported on, a reduction from the previous 91 triggers. To ensure that effective assessments of vegetation continue, greater emphasis has been placed on general observations and correlating observations with geomorphology, where appropriate.

Greater detail of the monitoring approach and monitoring program can be found in previous annual reports and the Basslink Baseline Report (BBR) (Hydro Tasmania, 2005). The BBR also presents material on general vegetation descriptions and vegetation responses to regulated rivers and should be consulted for further information or explanation as required.

6.2 Methods

The riparian vegetation monitoring program comprises two methods of assessment: quantitative monitoring consisting of permanent quadrat and transect sites, and photo-monitoring sites. Permanent quadrat studies involve the assessment of ground species cover, shrub and tree stem density, seedling numbers and ground conditions. These quadrat studies are undertaken annually in autumn in the Gordon River and at reference river sites. Sampling within the Gordon River is stratified by zones delineated by tributary confluences and inflows. Seedling recruitment monitoring is undertaken twice yearly, in autumn and summer, to determine seasonal recruitment patterns. Monitoring is also undertaken at sites in the Franklin and Denison Rivers. The monitoring program schedule, covering both seasons for all rivers, is presented in Table 6-1.

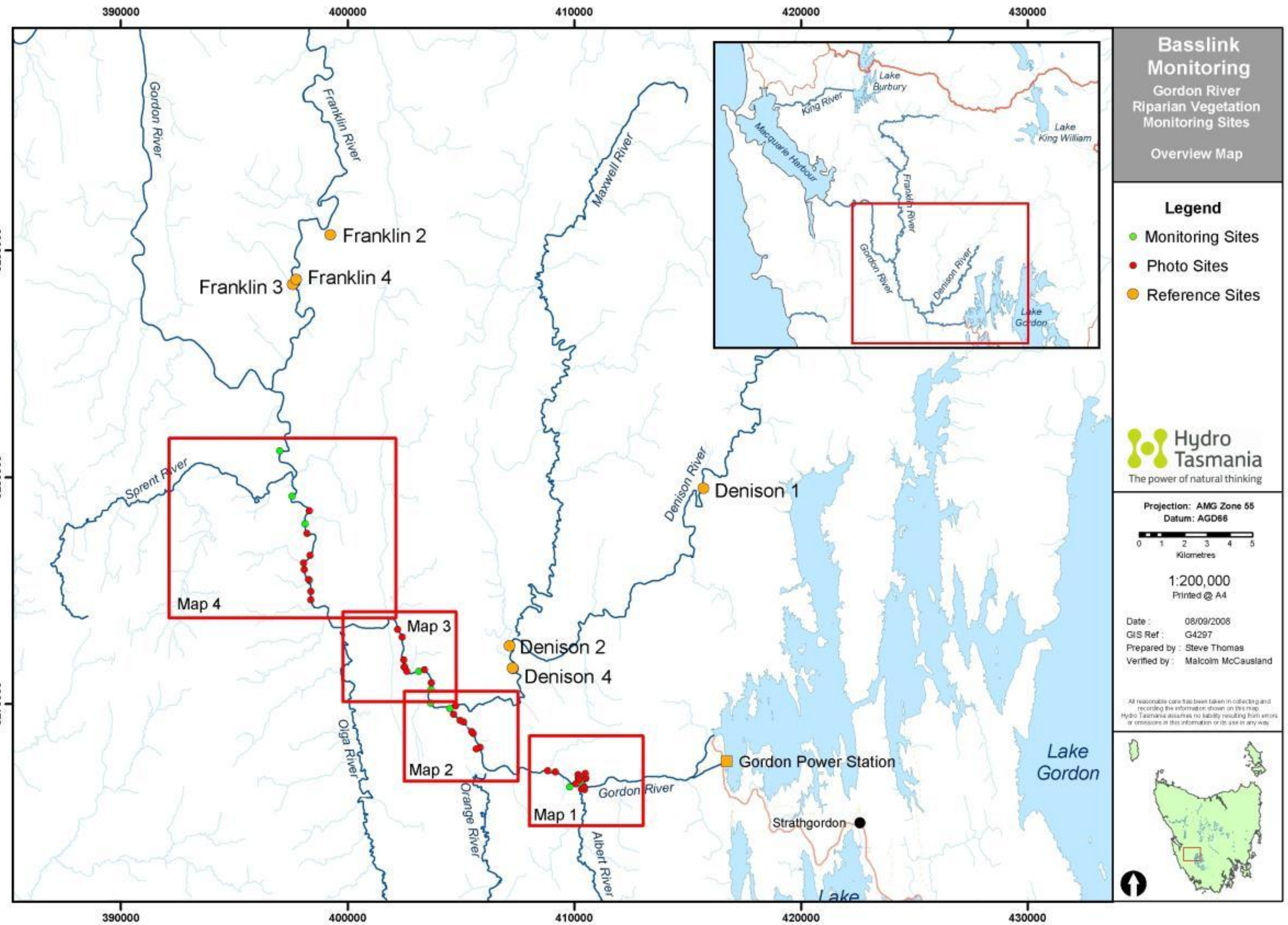
Table 6-1 Scheduled variable monitoring for riparian vegetation monitoring program specifying seasonal differences

Sites	Season	Monitored variable/method of assessment		
		Quadrat studies	Seedling recruitment	Photo-monitoring
Gordon zones 2–5	Autumn	✓	✓	
	Summer	✓*	✓	✓
Tributary sites	Autumn	✓	✓	
	Summer	✓*	✓	
* Composite vegetation cover and bare ground measures only				

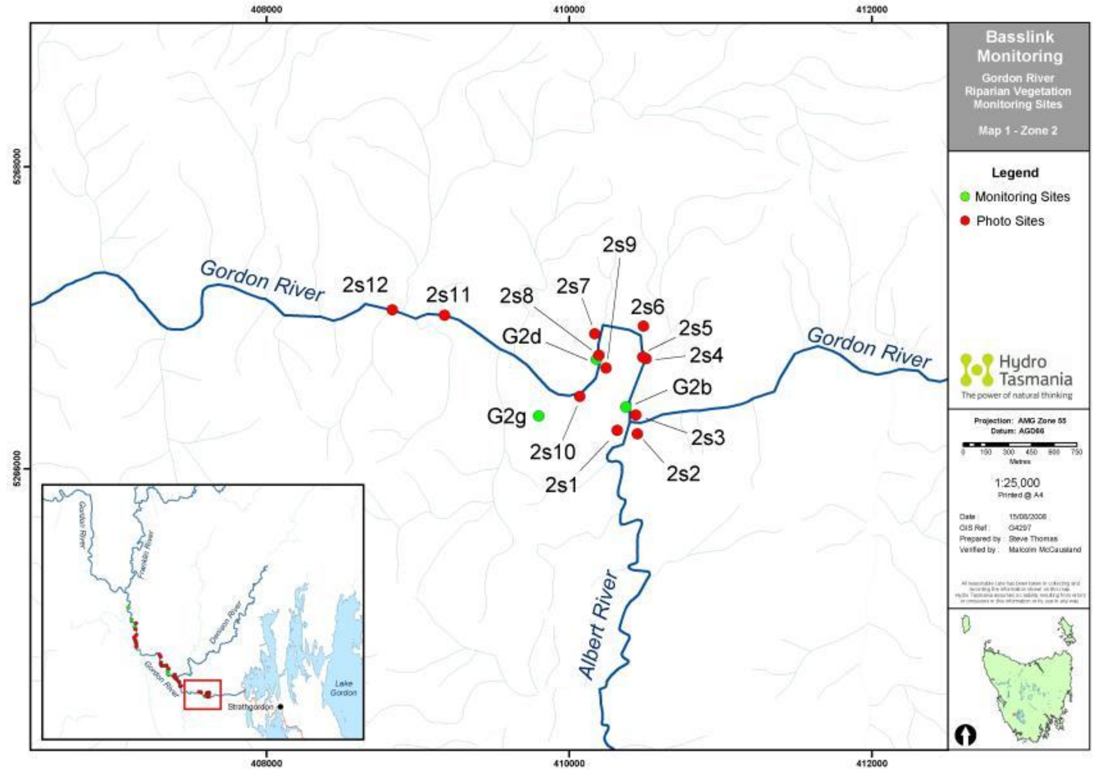
6.2.1 Photo-monitoring

Photo-monitoring sites have been established at representative sites covering all substrate types within each river reach to obtain representative data on vegetation patterns and processes within the rivers. These photo-monitoring sites enable objective measurements of canopies of shrub and tree species, presence/absence of ground layer species and assessment of vegetation health indicators.

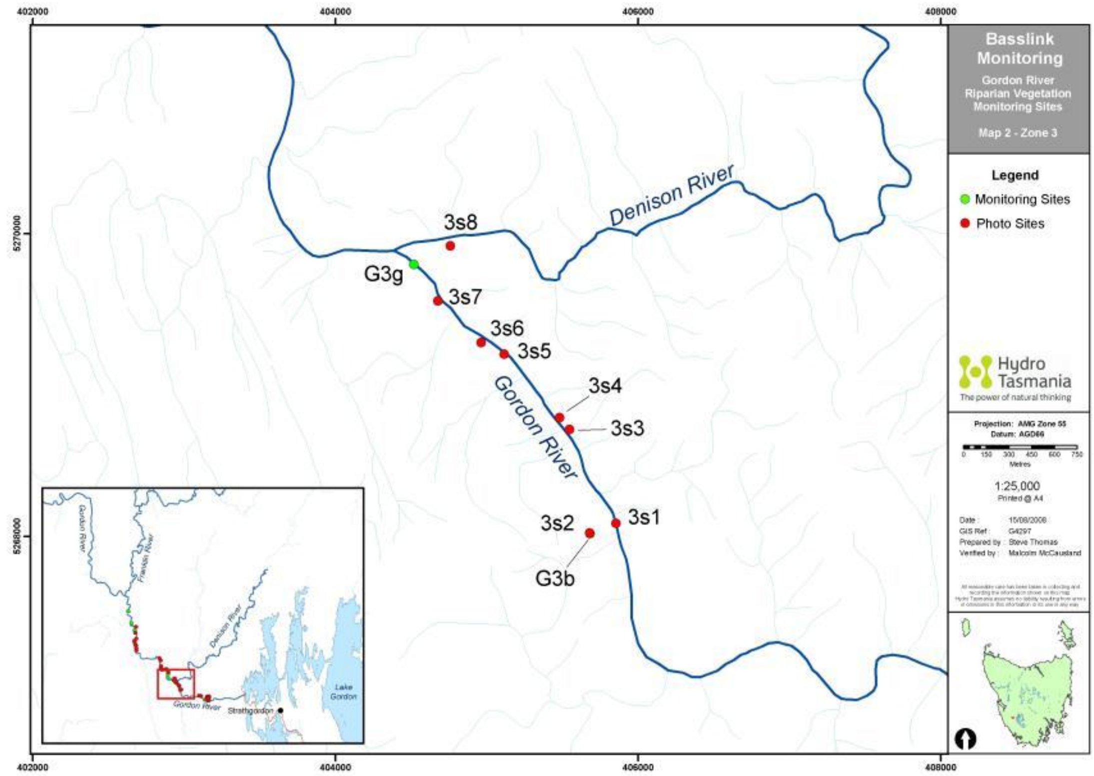
Site photographs are compared between concurrent years to identify trends between the years (e.g. the 2007 photograph is compared with 2008). The results are summarised as the proportion of photograph pairs showing: canopy expansion or contraction and/or ground cover expansion or contraction, no discernable change or no data (no photograph to compare). It should be noted that the results show the number of sites showing changes and do not detail the magnitude of changes. A change of 10 % or more in any variable is recorded for the comparison. The locations of photo-monitoring points in the Gordon River are shown in Map 6-1 (all sites), Map 6-2 (zone 2 sites), Map 6-3 (zone 3 sites), Map 6-4 (zone 4 sites) and Map 6-5 (zone 5 sites).



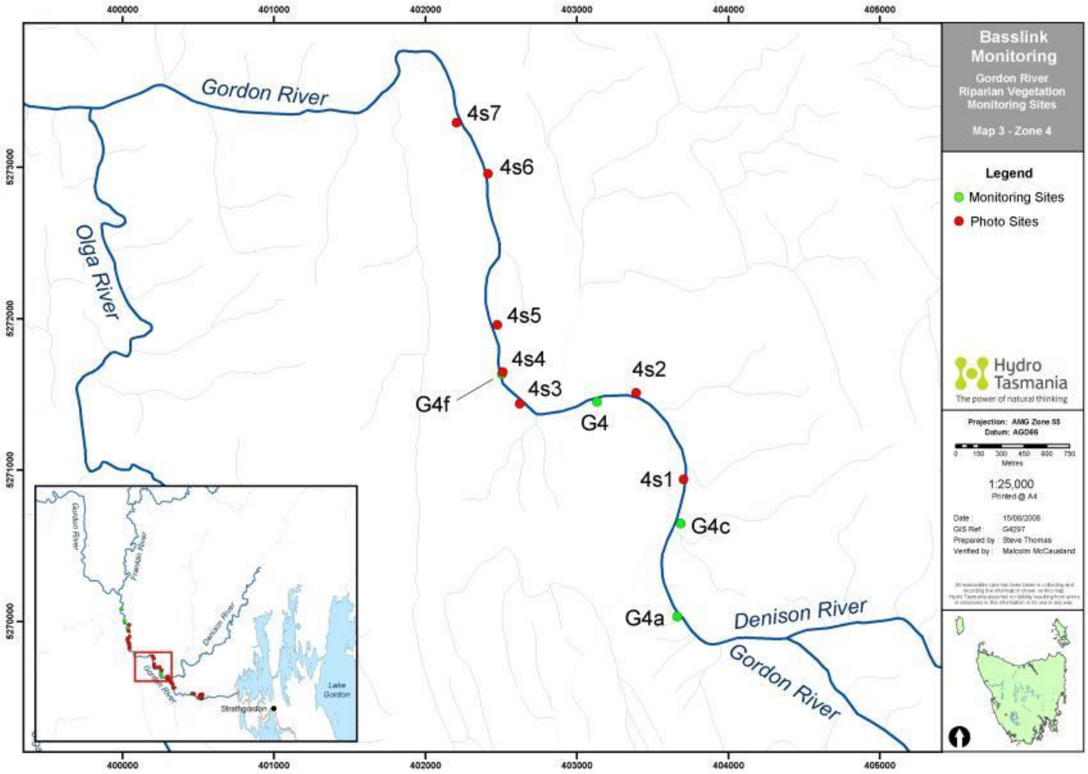
Map 6-1 Gordon River riparian vegetation photo-monitoring sites



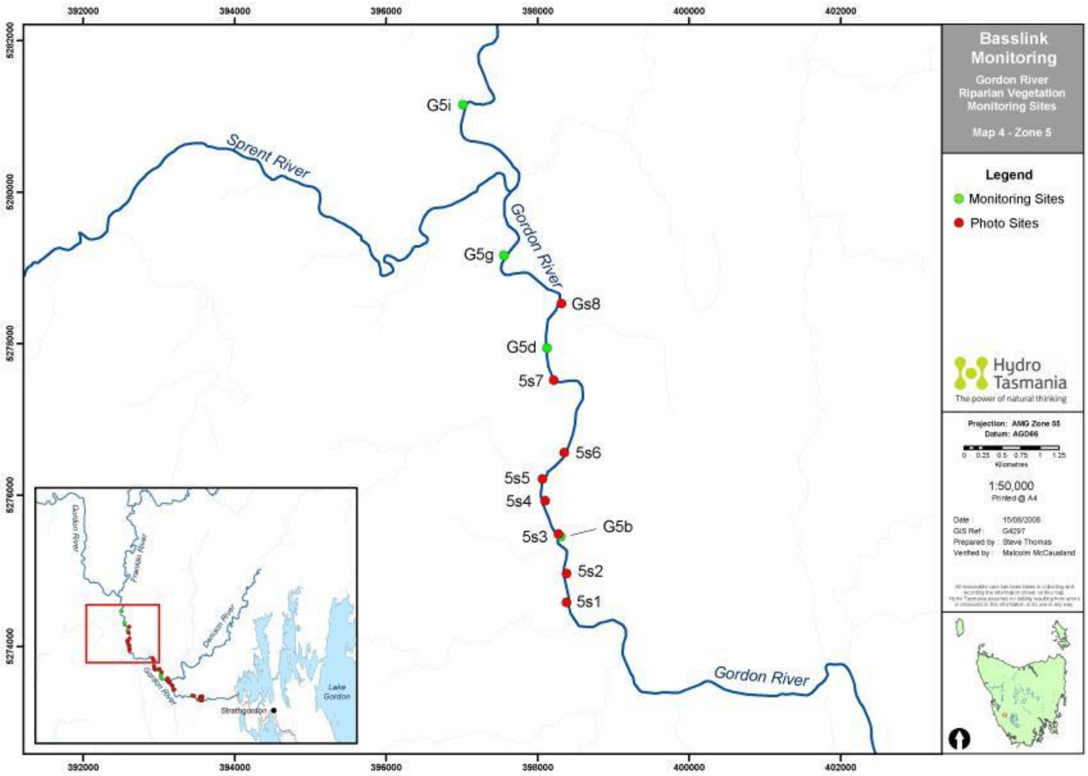
Map 6-2 Gordon River riparian vegetation photo-monitoring sites, zone 2



Map 6-3 Gordon River riparian vegetation photo-monitoring sites, zone 3



Map 6-4 Gordon River riparian vegetation photo-monitoring sites, zone 4



Map 6-5 Gordon River riparian vegetation photo-monitoring sites, zone 5

6.2.2 Quantitative vegetation monitoring

Field data collection includes assessment of seedling recruitment and vegetation cover in permanent plots in the Gordon, Denison and Franklin Rivers. Bank sampling sites were established in four of the five zones of the Gordon River. These zones correspond with those determined in initial geomorphic studies, which divided the middle Gordon River into five zones based on the presence of hydraulic controls such as gorges or the confluence of tributaries (Koehnken *et al.* 2001). No bank sites were established in zone 1, the zone closest to the power station, because it is dominated by bedrock substrate.

Vegetation monitoring in the Gordon River includes assessments of vegetation metrics at 16 permanent plots in zones 2, 3, 4 and 5 using quadrat and belt transect-based methods. At each of these permanent sites, six 1 m^2 quadrats are monitored, their positions designed to approximately correspond with river heights under the operation of two and three turbines and above the level of 3-turbine operation at the commencement of the monitoring program. The bank location has been used to label the quadrats; 'low', 'high' and 'above' respectively. Quadrats were located with reference to the high–water mark, as shown in Figure 6-1, and offset by 0.5 m from the transect line to avoid trampling impacts. Quadrat locations have been permanently marked using steel pins.

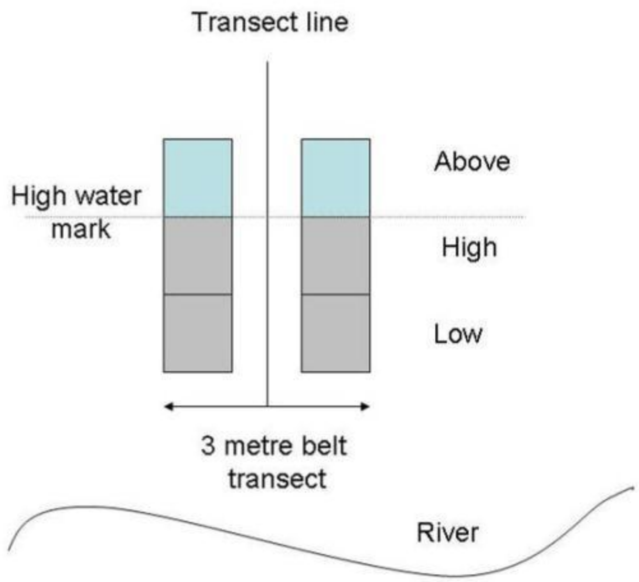


Figure 6-1 Diagrammatic representation of quadrat positions along transects in Gordon, Franklin and Denison Rivers

For each quadrat, assessments were made of ground species cover, seedling numbers, density of trees and shrubs, health of vegetation and environmental variables including substrate type, geomorphologic characteristics and aspect. Vegetation types were sorted by taxonomic class, however the class bryophytes includes some other life forms, such as algae and fungi, therefore this term should be interpreted as non-vascular plant cover. This term has not been altered in this report, to allow for consistency with previous reports.

6.2.3 Geomorphological – vegetation process monitoring

Due to the difficulty of linking the vegetation and geomorphological monitoring because of the scale of changes occurring on the river it was decided to set up some simple vegetation measurements at geomorphic monitoring sites as recommended in the Basslink Review Report 2006–09. Full vegetation monitoring occurs close to geomorphic sites but can be 15–20 metres away; however the processes occurring at the two sites can be quite different due to small-scale changes in river flow or bank formation.

At eleven geomorphological sites measuring tapes running 10–25 metres were set up perpendicular to the river bank and secured in an easy to find location such as a large tree. The tapes were positioned so as to run in line with as many existing erosion pins as possible. Additional pins were placed at changes of slope down the transect to ensure the tape followed the ground contours as closely as possible.

6.2.3.1 Bank profiles

Bank profiles were measured at each of the eleven sites using an electronic measuring device. At the start of the transect measurements were taken to the first change in slope, recording horizontal distance and vertical distance along the transect and slope angle. This was continued along the transect until the finish. Bank profiles were plotted on return from the field.

The distance from the beginning of the transect of all erosion pins were measured. The following ecological variables were also measured (distance from start) within a 2 m belt transect (one metre on either side of the tape) along the tape. A 2 m pole was run down the tape and the following variables were measured where they intersected with the pole:

- the rooted section of the following significant bank species, *Leptospermum riparium, Blechnum nudum, Blechnum wattsii* occurring closest to the river;
- the last occurrence of bryophytes (including algae lichen and moss on the ground) down the transect (i.e. the last occurrence of bryophytes closest to the river);
- the final extent of loose litter (leaves, twigs and other non fixed material on the ground). Litter was defined as more than five pieces per 20 cm x 20 cm area. This precludes having to measure single leaf falls;
- the occurrence of coarse woody debris (CWD) on the ground (exposed branches and trunks >4 cm in diameter);
- the distance from the start of the transect of the final dicot seedlings and species identification if possible;

- the distance from the start of the transect of the final monocot seedlings and species identification if possible;
- the start of the combination bare ground and root mat. This often occurred in combination and was considered important in bank stabilisation; and
- the start of bare ground.

6.3 Data analysis

6.3.1 Derivation of amended trigger values for comparisons

Following the recommendations in the Basslink Review Report 2006–09 (Hydro Tasmania, 2010a), zone 2 has been excluded from the zone trigger reporting for community composition, species/taxa richness, species richness and species/taxa evenness. However, in this report only, the one site (2d) was excluded from the 'whole-of-river' scale triggers as only this site was severely impacted and it was considered appropriate to retain the other zone 2 sites in the whole-of-river analysis. The reintroduction of sites from zone 2 means trigger values have changed slightly for whole-of-river calculations and so are generally not comparable with the previous annual report.

Whilst zone 2 data has been excluded from the trigger analysis by zone, graphs of results for these variables include the results for zone 2 for reference purposes where zone data is presented separately.

6.3.2 Community composition (Bray-Curtis similarity index)

The Bray-Curtis similarity index provides a comparison of presence-absence data for pairs of years at the zone level, providing an indication of changing community composition over time. The index was calculated for all quadrats based on presence-absence data for each monitoring period. The Bray-Curtis similarity index ranges between 0 and 100 – 100 indicating that all the same species were present and absent in both plots between time periods (completely similar), and values approaching zero indicating that no species were either present or absent in the same plots (completely dissimilar).

In the current study, plots showing a lower value between monitoring periods are less similar than those with a higher value. The trigger value range has been developed from the average similarity of pre-Basslink sites compared between the monitoring events. That is, the average similarity of the 2002–03 comparison, the 2003–04 comparison and the 2004–05 comparison. This comparison was selected, rather than a direct comparison with the pre-Basslink data, because the system is acknowledged to be changing over time. This average similarity for the pre-Basslink period is used to determine if sites are becoming more dissimilar over a period of time, and to prompt further investigations of causes.

6.3.3 Species richness

Species richness is a diversity index or measure of the total number of different species, or taxa (taxonomic units including groups of subspecies or unidentified species), found in a quadrat. The richness is calculated annually for each quadrat type and compared with pre-Basslink trigger values that incorporate the mean and a 95 % confidence interval around the mean values.

6.3.4 Species evenness

Species evenness is a diversity index or measure that numerically quantifies how equal the abundances of species are within the quadrats. The evenness of vegetation communities along the Gordon River was determined using Pielou's evenness index for quadrat abundance data. This calculation gives a value constrained between 0 and 1, with higher values showing greater evenness of taxa within the quadrat (Kent and Coker 1994). This measure is calculated with vascular species only. These values are calculated for each quadrat type annually and compared with pre-Basslink trigger values that incorporate the mean and a 95 % confidence interval around the mean values.

6.3.5 Tributary data

Data for the Denison and Franklin Rivers is presented as total vegetation cover and bare ground percentages to provide an indication of trends over time in these measures at these sites. Data is presented for sites Denison 1, Denison 2, Denison 4 and Franklin 2, Franklin 3 and Franklin 4. The sites at Denison 3 and Franklin 1 are no longer monitored as sites were severely impacted by floods in the past.

6.4 Results — photo-monitoring analysis

Photo-monitoring was completed at 30 of the 35 permanent sites in the 2010–11 monitoring period (Appendix 7). Five photos sites were missed this year due to loss of flagging tape at some sites or the inability to move back upstream once a site was passed.

6.4.1 Zone 2 photo comparisons

The pattern of vegetation establishment on the lower banks noted in December 2008 and 2009 continued in December 2010. Over 25 % of sites in zone 2 showed an expansion of the ground layer, confirming observations and anecdotal evidence of growth of mosses and liverworts and grasses on bare substrates (Figure 6-2), particularly in areas of flatter alluvial sediments. Grass and graminoid species including *Juncus* spp. continued to colonise these sites (Photo 6-1). Fifty per cent of sites showed no discernable change in the ground or canopy cover, or change less than the 10 % discernable change threshold. Contraction of canopy vegetation noted in preceding years seems to have slowed and contraction of canopy was recorded at only one site while expansion of the canopy was recorded at one site.

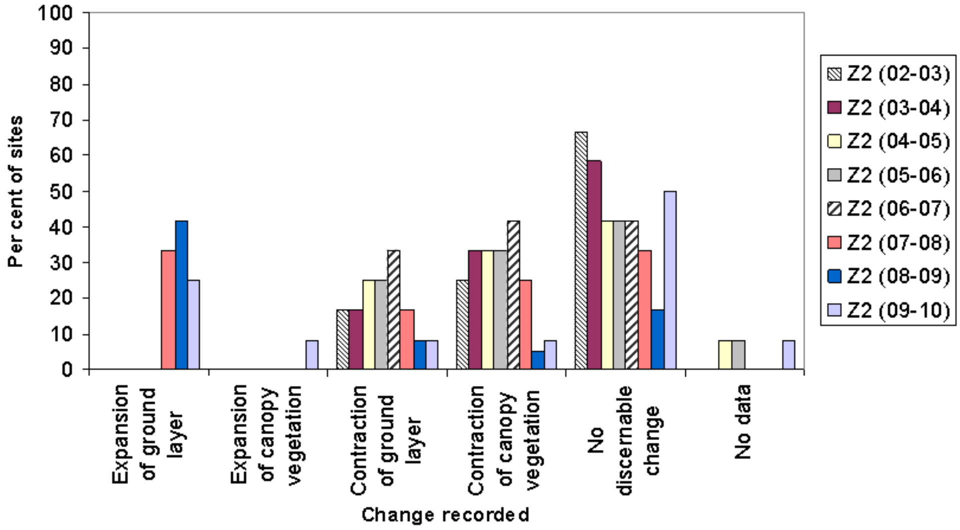


Figure 6-2 Per cent of sites showing either expansion or contraction of canopy and ground layers, no discernable change, or no data for photo-monitoring analysis results in zone 2 for the Gordon River from the inception of the program in summer 2002 to summer 2010

Photo 6-1 Expansion of graminoids (highlighted by red ovals) on a muddy bank in zone 2 in December 2009 (left) and continued colonisation of the site in December 2010 (right)

6.4.2 Zone 3 photo comparisons

Sites in zone 3 were predominantly stable, 63 % showing no discernable change greater than 10 % in either canopy or ground vegetation (Figure 6-3). Twenty five per cent of sites showed change, due to the expansion of ground layer components including the aforementioned species in zone 2, in addition to bryophytes and small herbs while 13 % of sites showed an expansion of the canopy.

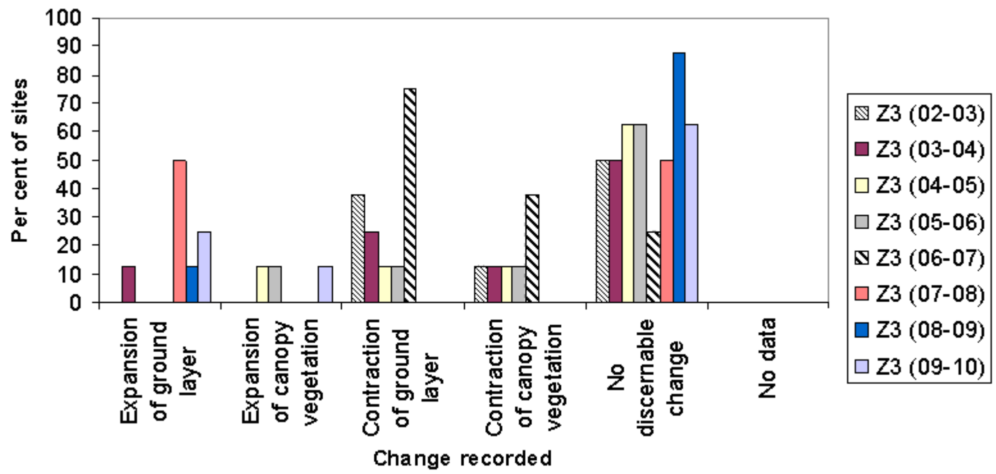


Figure 6-3 Per cent of sites showing either expansion or contraction of canopy and ground layers, no discernable change or no data for photo-monitoring analysis results in zone 3 for the Gordon River from the inception of the program in summer 2002 to summer 2010

6.4.3 Zone 4 photo comparisons

The majority of sites recorded in zone 4 (43 %) showed no discernable change (Figure 6-4) however approximately 30 % of sites exhibited an expansion of ground layer. The changes exhibited this year continued the trend identified in December 2008 with the expansion of ferns (*Blechnum nudum* and *Sticherus tener*) and herb species in alluvial deposits between cobbles. The graminoid species *Juncus* spp. was also recorded on some lower bank areas (Photo 6-2).

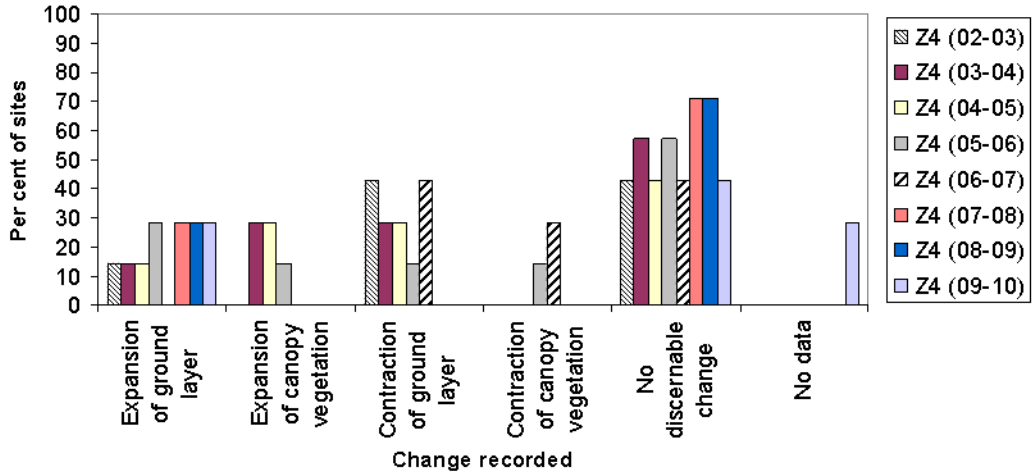


Figure 6-4 Per cent of sites showing either expansion or contraction of canopy and ground layers, no discernable change or no data for photo-monitoring analysis results in zone 4 for the Gordon River from the inception of the program in summer 2002–summer 2010

Photo 6-2 Expansion of graminoids (*Juncus* spp. – highlighted by red oval) on muddy bank in zone 4 in December 2009 (left). Continued growth and colonisation in December 2010 (right)

6.4.4 Zone 5 photo comparisons

Of the sites monitored in zone 5, most (62.5 %) had no discernable change from 2009. One site showed contraction of canopy vegetation however this was continued loss of leaves from a myrtle that had begun dying in 2007–08 (Figure 6-5).

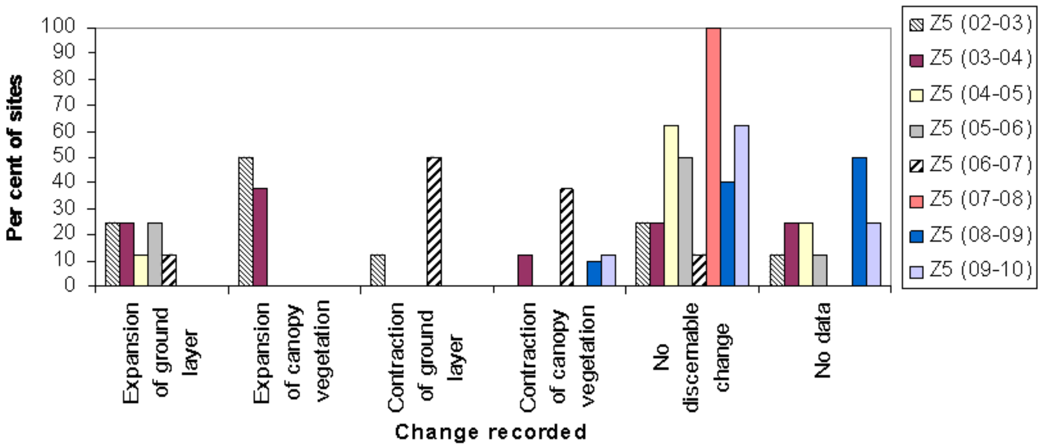


Figure 6-5 Per cent of sites showing either expansion or contraction of canopy and ground layers, no discernable change or no data for photo-monitoring analysis results in zone 5 for the Gordon River from the inception of the program in summer 2002–summer 2010

6.5 Results – geomorphological: vegetation process monitoring

Bank profiles were recorded from eleven geomorphic sites along the river. Four profiles were measured in each of zones 2 and 3 and three profiles were measured in zone 4. Profiles can be seen in Appendix 2.

In conjunction with bank profiles, the occurrence of various ground cover variables were measured from the start of the transect. These variables were recorded in October 2010, December 2010 and February 2011.

Bank profiles were measured in October 2010 and will be measure again in October 2011.

The occurrence of riparian species (*Blechnum nudum, Blechnum wattsii* and *Leptospermum riparium*) was relatively stable through the monitoring period as would be expected for rooted plants. Slight changes in the extent of occurrence of these plants along transects reflect the removal of small plants by high water flows.

Seedling and bryophyte occurrence along the transects was relatively stable but generally exhibited a trend in movement downslope over the monitoring period. This is likely to reflect the greater establishment of seedlings and new growth of moss over the summer period on the toes of banks.

Litter also exhibited a similar trend with litter generally recorded further down the toe of the bank in the December and February monitoring period than in the October period. This was despite the high discharges that occurred during January and February of 2011. It is likely that this is the result of localised leaf fall between the high flow event and the monitoring event or it is possible that some litter is transported by water and is moving the litter down the bank with the recession of the water.

The position of coarse woody debris varied only little in its position on the bank. Most sites were stable while sites 3C, 3F, 4D, 4GA had course woody debris move up the banks most likely as a result of high flow events in the first part of 2011.

The start of continuous bare ground along the transect varied only slightly. Most sites exhibited very little change in bare ground however site 2A and 3EB showed bare ground occurring higher on the bank in latter monitoring periods. This is likely to be the result of erosion either occurring immediately at that point or further upslope leading to sand being washed out of the bank and deposited over other ground cover (moss, litter etc.) lower down the slope. One site (3F) was recorded as having the first occurrence of bare ground occurring lower on the bank in the latter monitoring period. However, there was no evidence of colonisation by ground cover but a corresponding movement of the root mat downslope suggests that sand had been washed off the underlying root mat exposing it further downslope.

These results are generally consistent with erosion studies which found little geomorphological change in the river during the 2010–11 year compared to other years.

6.6 Results and trigger comparisons – quantitative vegetation monitoring

Vegetation monitoring was completed at all 12 permanent Gordon River sites in both summer and autumn for the 2010–11 monitoring period. As outlined in Section 6.1, data collected in zone 2 have been excluded from trigger analyses and zone summary graphs where triggers have been calculated at the zone level scale. The site in zone 2 which had exhibited slumping (2d) was removed from the calculation of trigger values for whole-of-river scale triggers.

Due to some past inconsistencies in plant identification, several *Coprosma* species have been recorded during the study. *Coprosma nitida* and *C. moorei* are subalpine–alpine species and are highly unlikely to occur on the Gordon River. At no point did any quadrat contain records of more than one species. It is considered that all the *Coprosma* recorded on the Gordon River are *Coprosma quadrifida*. To avoid input errors in the database and affecting species evenness and richness these species have been amalgamated. These changes impact on the way species evenness and richness are calculated and therefore trigger values have been recalculated for these variables.

6.6.1 Community composition

6.6.1.1 Community composition trigger value comparison

Community composition values were variable with six of the nine values falling outside the trigger values for the 2010–11 monitoring event (Table 6-2). Generally 'above' quadrats were remaining relatively stable while lower quadrats were becoming less similar. Changes in 'high' and 'low' quadrats were largely due to very small shifts in presence of a few species. These changes were small, often less than 1 % in total cover, involving a turnover in a few herbs and grass species. This is likely to be the result of past recruitment in lower quadrats in low flows over the past years but with the recent longer duration of high flows selectively removing various species leaving a small area of a small number of species (graminoids and herbs) able to persist on the lower banks in the high flow environment.

Table 6-2 Mean values and trigger range for Bray-Curtis similarity index for zones 3–5 based on annual similarity values calculated on presence-absence data. Figures in bold indicate a value outside the trigger range

Zone	Quadrat	Mean	Confidence interval range	2010–11 result
3	Above	53.94	51.95 – 55.17	53.10
	High	59.05	56.42 – 62.45	**53.57**
	Low	59.99	52.43 – 66.41	**27.95**
4	Above	41.37	37.86 – 45.52	**48.63**
	High	35.98	35.59 – 36.39	**39.32**
	Low	38.01	36.13 – 40.32	36.29
5	Above	59.10	53.31 – 66.35	55.08
	High	59.40	57.18 – 61.08	**50.04**
	Low	61.55	57.33 – 65.51	**21.50**

6.6.2 Species/taxa richness

Species richness is a count of the number of different flora species recorded in a quadrat. Over the pre-Basslink monitoring period, species richness fluctuated by a small degree but was considered relatively stable over time (Hydro Tasmania, 2005b). However, the differences in species richness were found between the zones and the quadrats, rather than between the monitoring periods.

There has been little change in species richness for the 2010–11 monitoring period compared to the previous years (Figure 6-6).

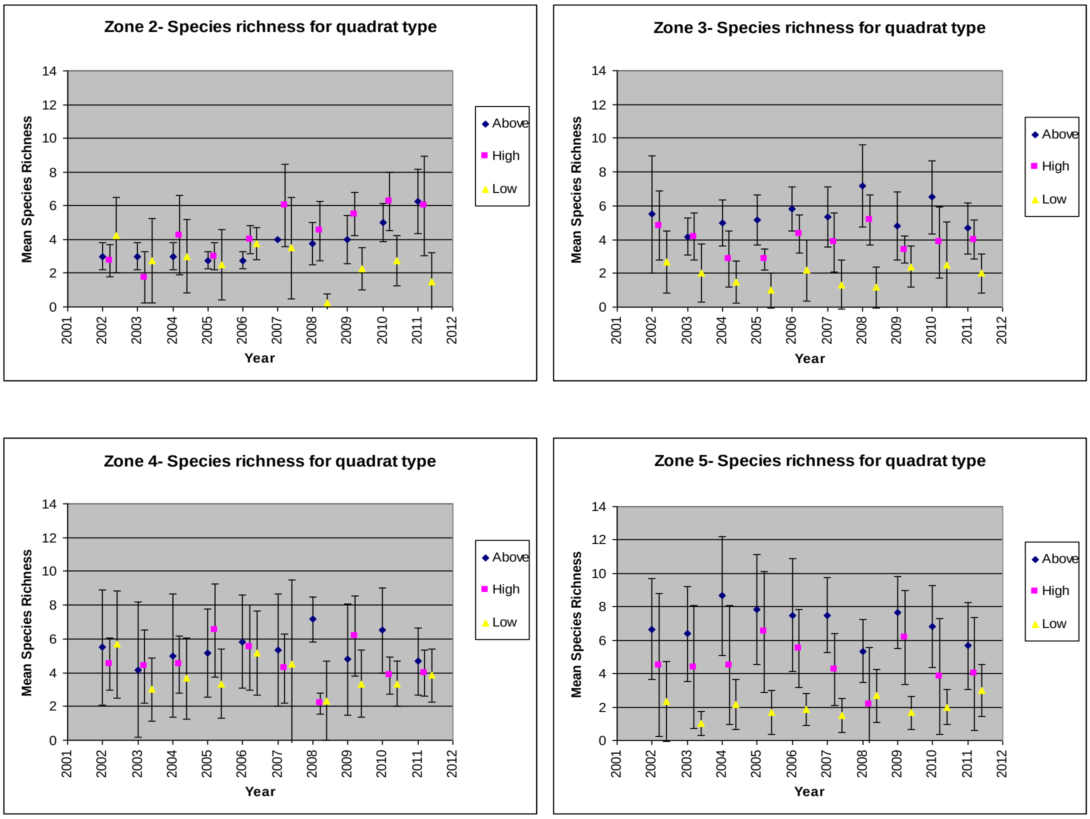


Figure 6-6 Mean species richness (± 2 SE) for the zones and quadrat types by monitoring event for 'above', 'high' and 'low' quadrats in the Gordon River

6.6.2.1 Species richness trigger value comparison

All values recorded in 2010–11 are within the trigger ranges (Table 6-3). Zone 2 continues to have relative low species richness but has increased slightly in the last few years. Species richness does not exhibit any real trends and, while quite variable, remains relatively stable.

Table 6-3 Mean values and trigger range for species richness for zones 3–5 calculated from pre-Basslink data and the results of monitoring for the fifth year (2010–11) in the post-Basslink period

Zone	Quadrat type	pre-Basslink mean	pre-Basslink trigger range	2010–11 result
3	Above	4.89	2.74 – 7.04	4.67
	High	3.94	2.18 – 5.70	4.00
	Low	2.06	0.48 – 3.63	2.00
4	Above	7.15	3.26 – 11.04	5.67
	High	4.45	2.53 – 6.37	4.00
	Low	4.00	1.40 – 6.60	3.83
5	Above	4.33	1.30 – 7.36	6.83
	High	5.78	2.14 – 9.41	5.67
	Low	1.83	0.17 – 3.50	3.00

6.6.3 Species/taxa evenness

Species or taxa evenness is a measure of the degree to which the abundance of the quadrat is equitably spread. Higher values indicate that the spread of abundance is high or more even, whilst lower values indicate that a few species or taxa may be dominating abundance and other species are just small components. The graphs presented in Figure 6-7 show species evenness values for 2010–11 with species or taxa only in the calculation.

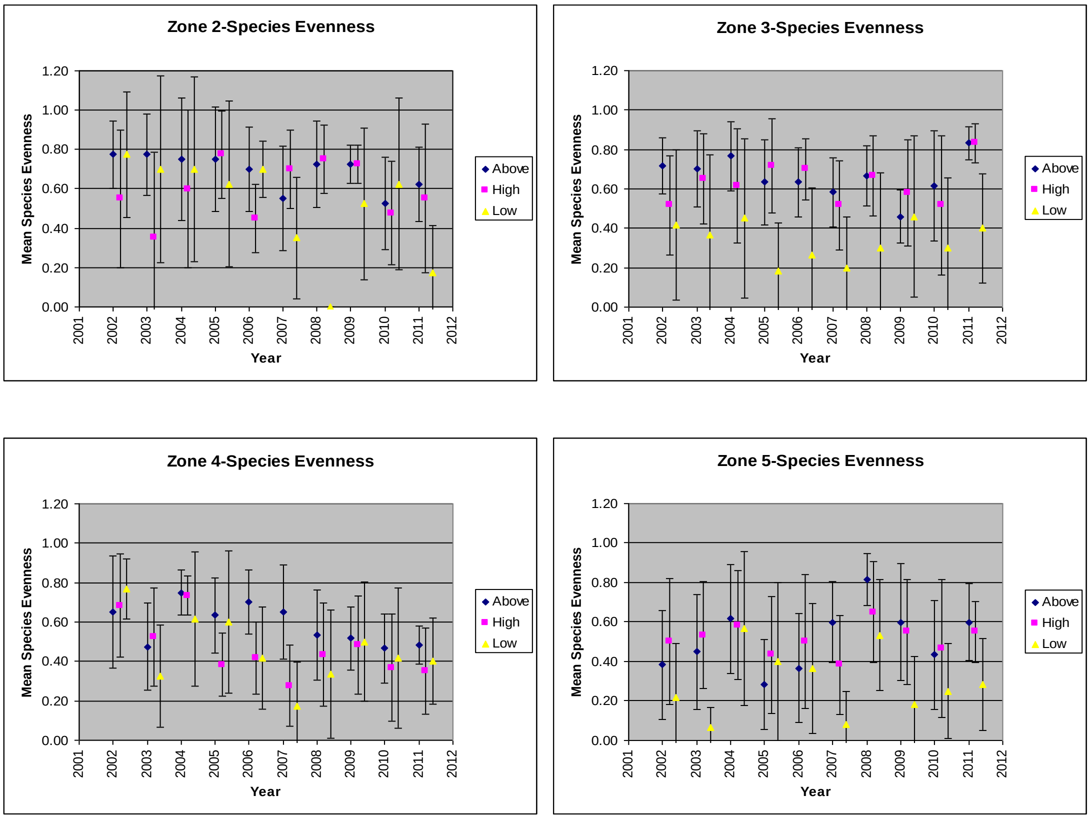


Figure 6-7 Mean species evenness (± 2 SE) for the zones and quadrat types by monitoring event for 'above', 'high' and 'low' quadrats in the Gordon River

Overall, the evenness values are moderate in the 'above' and 'high' quadrats in zones 2 and 3 that are generally characterised by low abundance of a few species. Notably at the two sites in zone 2 the species evenness of 'low' quadrats has fallen appreciably in the 2011 monitoring period. Evenness in quadrat types in zones 4 and 5 has tended to become more moderated with less difference between quadrat types and may reflect recovery of vegetation in the lower quadrats in recent years.

6.6.3.1 Trigger value comparison for species evenness

Mean species evenness was outside the trigger values for only the 'high' quadrats in zone 4 (Table 6-4). This drop in evenness in zone 4 is largely influenced by one site (4EC). A number of herbs species were recorded at this site that had not been recorded in the past monitoring event. This site has very dense vegetation dominated by a few species (*Leptospermum* and *Baura*) and is on a cobble bar in the middle of the river. It is likely that these quadrats were inundated by high water and rapid flows during the high flow event prior to monitoring. Changes in evenness are potentially the result of high water flows in January, February and March 2011 removing or moving vegetation around in the quadrats and exposing ground surface, and allowing the small herbs present to be recorded leading to a relative decrease in evenness. It is interesting that a decrease in evenness also occurred in zone 4 following the 2007 floods.

Table 6-4 Mean values and trigger range for species evenness for zones 3–5 calculated from pre-Basslink data and the results of monitoring for the fourth post-Basslink year (2010–11). Figure in bold indicates a value outside the trigger range

Zone	Quadrat type	pre-Basslink mean	pre-Basslink trigger range	2010–11 result
3	Above	0.73	0.56 – 0.89	0.83
	High	0.59	0.35 – 0.84	0.83
	Low	0.41	0.04 – 0.79	0.4
4	Above	0.61	0.37 – 0.85	0.48
	High	0.64	0.40 – 0.87	**0.35**
	Low	0.55	0.24 – 0.85	0.40
5	Above	0.48	0.21 – 0.76	0.60
	High	0.54	0.27 – 0.81	0.58
	Low	0.28	0 – 0.60	0.38

6.6.4 Bare ground cover

As shown in previous reports, for data grouped for the whole-of-river, differences were most apparent between quadrat types due to the stratification of disturbance and inundation along the river (Figure 6-8). The total area of bare ground was higher in the lower, more frequently inundated quadrats, compared to those higher on the bank.

Following a slight trend of reducing bare ground, following the flood events of 2007 in the 'above' quadrats there has been an increase in the extent of bare ground in all quadrat types. This is likely to be the result of high flow events in the January, February and March 2011.

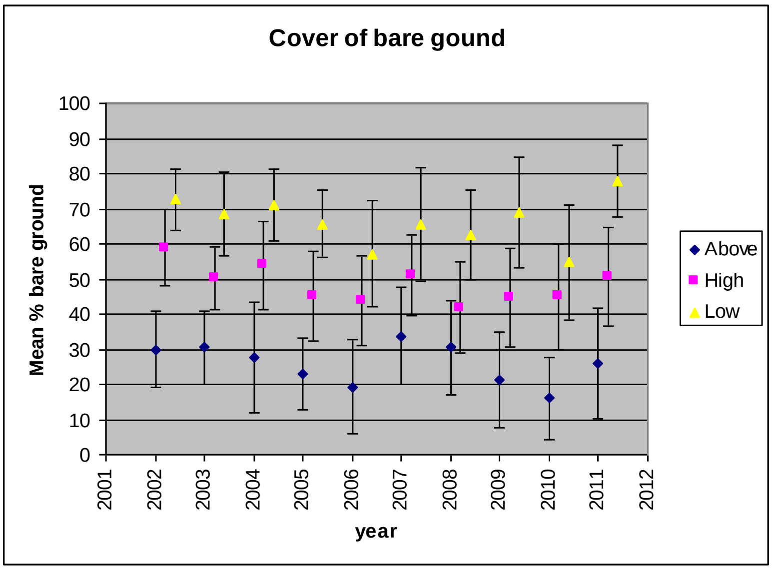


Figure 6-8 Mean per cent cover (±2 SE) of bare ground cover in zones 2–5 for 'above', 'high' and 'low' quadrats in the Gordon River for autumn monitoring events

6.6.4.1 Trigger value comparison for bare ground

The bare ground cover trigger is calculated from the ratio of bare ground cover between the 'above' quadrats and the 'high' quadrats, and between the 'above' quadrats and the 'low' quadrats at the whole-of-river scale. These data show the relative changes in the extent of bare ground in the quadrats using the 'above' quadrat as a reference for the lower sites.

The comparisons for the 2010–11 period show the ratios between 'above' and 'high' quadrats to be within the trigger ranges while the ratios between 'above' and 'low' quadrats are just on the lower boundary of trigger ranges. This is likely to be the result of the relative increase of bare ground in 'low' quadrats.

Table 6-5 The trigger value range for per cent bare ground within which 95 % of mean values are expected for zones 2 to 5. Results for one-year (2010–11) and five-year (2006–11) assessments are compared against the one-year and five-year trigger ranges. Figures in bold indicate a value outside the trigger range

Variable	Comparison	Pre-Basslink trigger One-year mean range		2010–11 One-year result	Pre-Basslink trigger Five-year mean range		2006–11 Five-year result
		Lower	Upper		Lower	Upper	
Per cent bare ground	Ratio (% above+1) to (% high+1)	0.32	0.78	0.47	0.45	0.60	0.57
	Ratio (% above+1) to (% low+1)	0.44	0.65	**0.31**	0.40	0.48	**0.39**

At the zone level, the data show that the patterns between the zones are varied (Figure 6-9). There has been an increase in the amount of bare ground in 'low' and 'high' quadrat types in all zones since the last monitoring period and this is most likely the result of high flow events in early 2011. A trend of increasing bare ground is apparent in 'low' quadrats in zone 2 as might be expected in the most impacted zone. No other trends are evident.

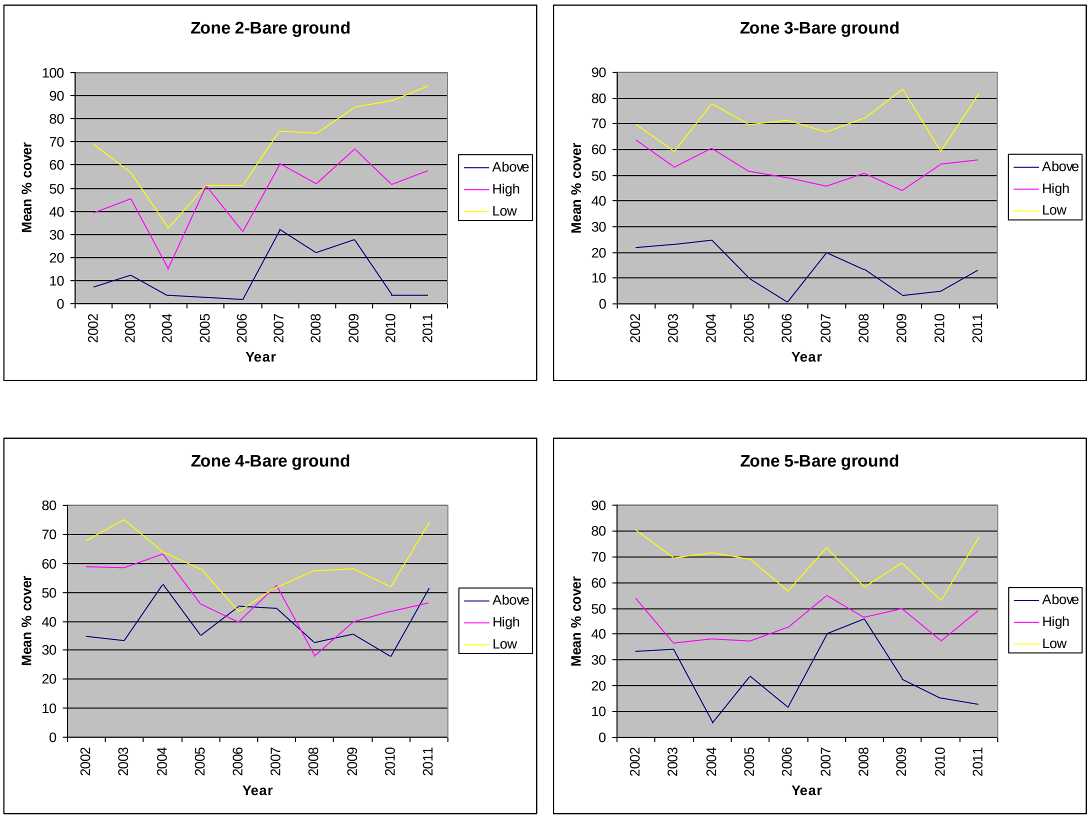


Figure 6-9 Mean per cent cover of bare ground cover for zones by monitoring event for 'above', 'high' and 'low' quadrats in the Gordon River from April 2002 to March 2011

6.6.5 Total vegetation cover

Total vegetation cover is the sum of all vascular vegetation cover within the quadrats. This measure is used at the zone and whole-of-river scale to develop and report against trigger values (Figure 6-10, Table 6-6).

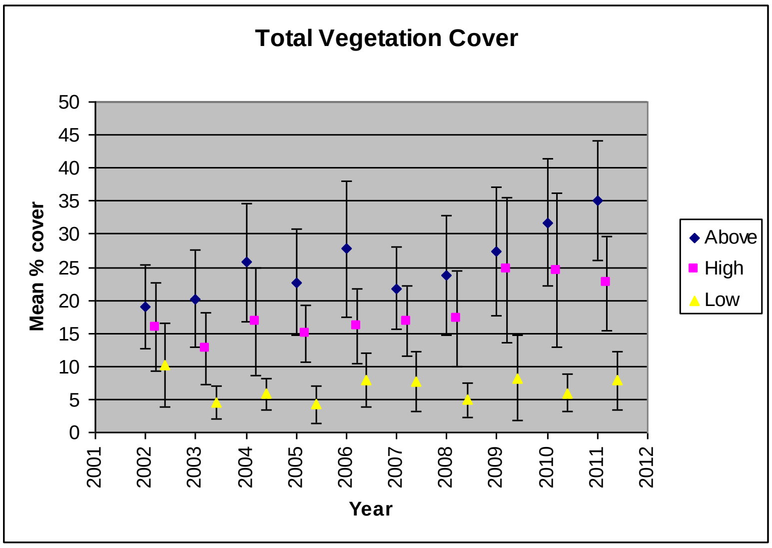


Figure 6-10 Mean per cent total vegetation cover (±2 SE) in zones 3–5 by monitoring event for 'above', 'high' and 'low' quadrats in the Gordon River

The mean per cent total vegetation cover for the whole-of-river showed no significant changes in the data for 2010–11 (Figure 6-10). Although there may be a slight trend of increasing vegetation cover in the 'above' quadrats over the past five years, the variation around the mean is high, indicating that there is a high degree of variability in the data both between and within the zones.

6.6.5.1 Trigger value comparison for total vegetation cover

The relative difference in the proportions of vegetation cover between the quadrat types is used to test for differences in the total vegetation cover and to calculate a ratio of differences for comparison with trigger values. The results for both the 'above'/'low' ratio and the 'above'/'high' ratio variables show slight changes in the relative amounts of total vegetation cover in the 2010–11 period compared with the pre-Basslink period (Table 6-6). Trigger values were marginally outside the range for the one-year and five-year cumulative ratio comparisons for the 'low' quadrats and outside the five-year cumulative ratio for the 'high' quadrats. This again may reflect the recovery of the 'above' quadrats in comparison to the relative abundance of total vegetation cover found in the 'high' and 'low' quadrats (Figure 6-10 and Figure 6-11). The exceedance of the 'above'/'low' ratios was highly influenced again by the very low cover of vegetation in 'low' quadrats in zone 2 particularly site 2b.

Table 6-6 The trigger value range within which 95 % of values are likely to lie for one-year (2010–11) and five-year (2006–11) mean values of ratios of total vegetation cover based upon pre-Basslink monitoring and values recorded for variable in the 2010–11 period. Figures in bold indicate a value outside the trigger range

Variable	Comparison	Pre-Basslink trigger one-year mean range		2010–11 one-year result	Pre-Basslink trigger five-year mean range		2006–11 five-year result
		Lower	Upper		Lower	Upper	
Per cent total vegetation	Ratio (% above+1) to (% high+1)	1.11	2.13	2.02	1.41	1.72	**1.85**
	Ratio (% above+1) to (% low+1)	5.00	7.92	**9.38**	4.39	5.60	**6.72**

Total vegetation cover in zone 2 continued to increase in higher quadrats and was relatively stable in low quadrats. This increase in zone 2 was largely related to increases in the ferns *Blechnum nudum* and *B. wattsii* and, to a lesser extent, the understorey shrub *Anopterus glandulosus*. A possible trend of increasing vegetation cover continued in 'above' quadrats in zone 3 while cover in 'high' and 'low' quadrats in this zone remained relatively stable. No other trends were readily apparent.

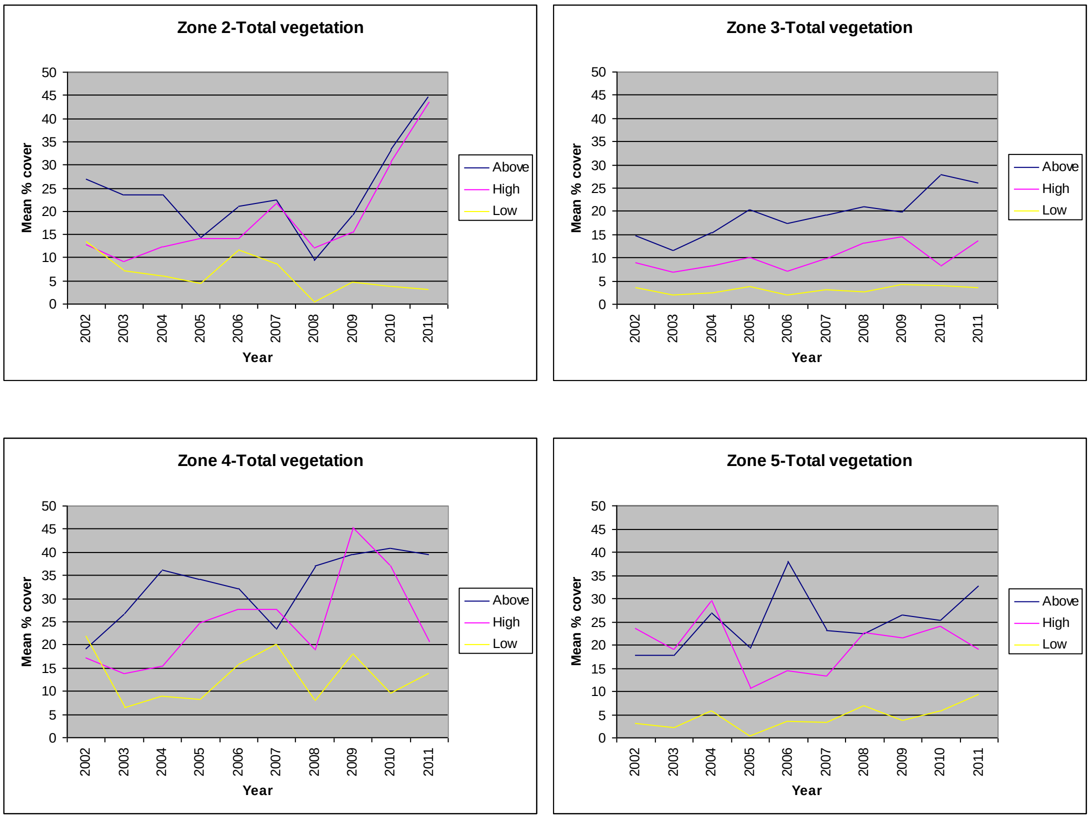


Figure 6-11 Per cent cover of total vegetation for each quadrat type by zone for each monitoring event

6.6.6 Plant abundance by life form

6.6.6.1 Non-vascular plants

Non-vascular plants (termed bryophytes, but including mosses, algae and liverworts) continued to have the highest cover in the 'above' quadrats in the region above the 3-turbine level (Figure 6-12) in the 2010–11 monitoring period (whole-of-river data).

Mean per cent cover of the bryophytes at the whole-of-river scale showed no consistent trends in the data in 2010–11 (Figure 6-12). While bryophyte cover declined in all quadrat types in 2011 the amount of variation around the mean over the monitoring period is high, indicating a high degree of variability in the data between and within the zones.

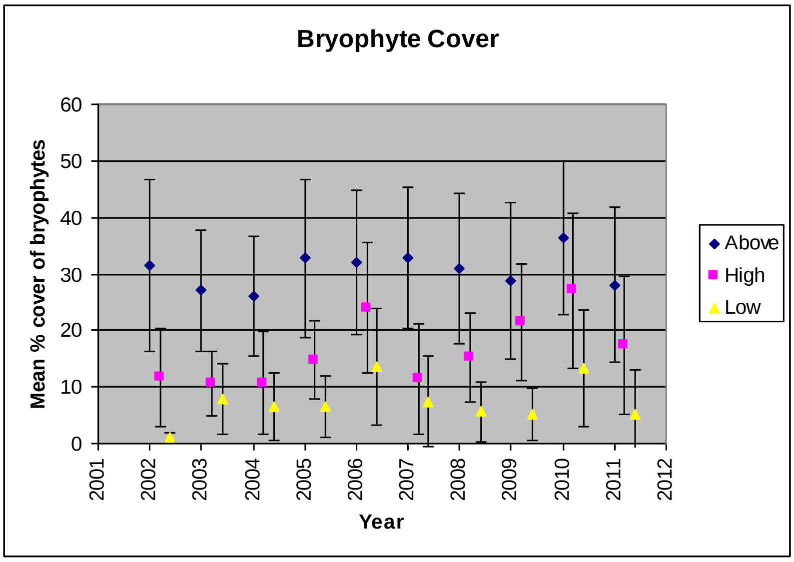


Figure 6-12 Mean per cent cover (± 2 SE) of bryophytes (including all non-vascular plants) in zones 2–5 by monitoring event for 'above', 'high' and 'low' quadrats in the Gordon River

Trigger value comparison for non-vascular plants

The results for both the 'above'/'low' ratio and the 'above'/'high' ratio variables show little change in the relative amounts of total bryophyte cover in the 2010–11 period compared with the pre-Basslink period (Table 6-7). There were no values outside the trigger range for the one-year ratio comparisons, however, values marginally exceed the trigger values for the five-year cumulative ratio comparisons for the 'above'/'low' quadrats for the whole-of-river data.

Table 6-7 The trigger value range within which 95 % of values are likely to lie for the one-year (2010–11) and four-year (2006–11) mean values of ratios of bryophyte cover based on pre-Basslink monitoring and values recorded for variable in the 2010–11 period. Figure in bold indicates a value outside the trigger range

Variable	Comparison	Pre-Basslink trigger one-year mean range		2010–11 one-year result	Pre-Basslink trigger five-year mean range		2006–11 five-year result
		Lower	Upper		Lower	Upper	
Per cent bryophytes	Ratio (% above+1) to (% high+1)	1.60	7.19	5.40	3.24	4.97	4.27
	Ratio (% above+1) to (% low+1)	12.54	21.23	18.50	10.75	14.33	**14.40**

The *relative* patterns of bryophyte abundance in zones 3 to 5 are generally consistent with those recorded in the both the pre- and previous post-Basslink results (Figure 6-13).

The trend of increasing bryophyte abundance in all quadrat types in zone 4 noticed in 2010 has declined in the 2011 quite uniformly.

The increase in the cover of bryophytes noted in the 'above' quadrats in zone 2 in the 2010 period has also stabilised.

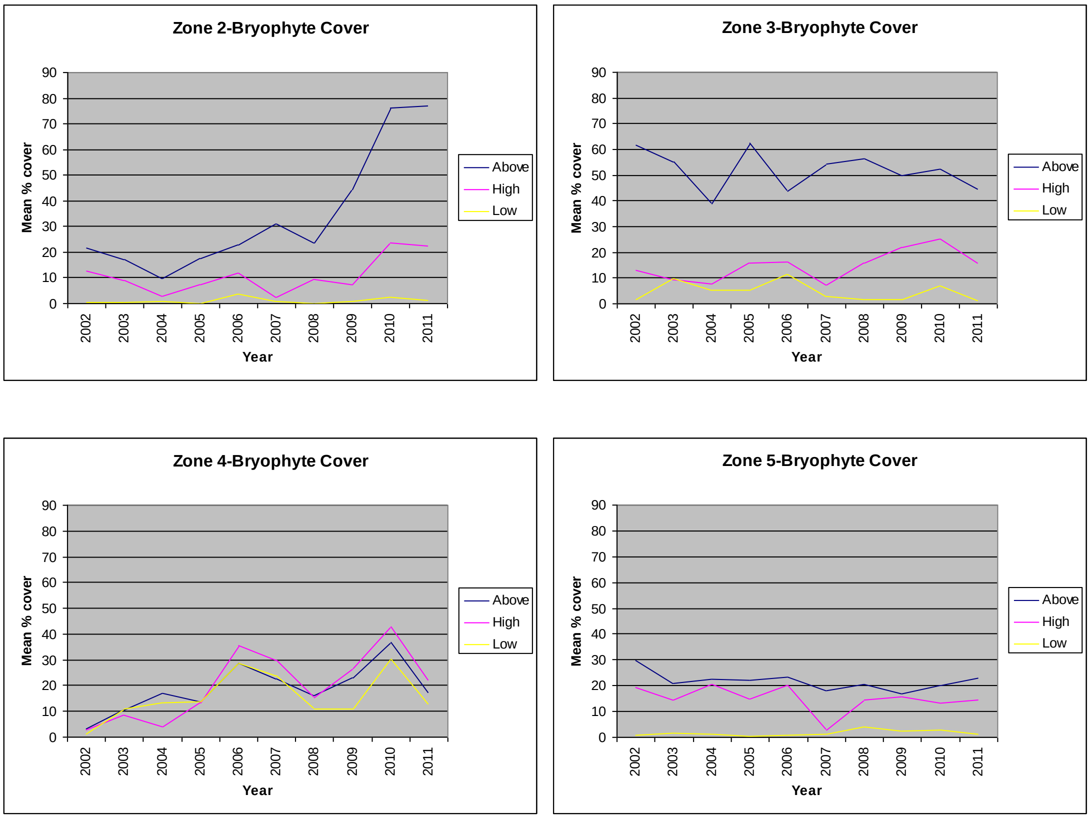


Figure 6-13 Per cent cover of bryophytes (including non-vascular species) for each quadrat type by zone for each monitoring event

6.6.6.2 Ferns

Mean per cent cover of ferns at the whole-of-river scale showed no discernable trends in the data over the monitoring period (Figure 6-14). A slight increase in cover of ferns occurs in the 2011 event for 'above' and 'high' quadrats however variability is high. 'Low' quadrats continue to have a low cover of ferns as would be expected. Both the whole-of-river and zone scale (Figure 6-15) fern data indicate the low total percentage cover that ferns comprise in zones 3–5, compared to zone 2.

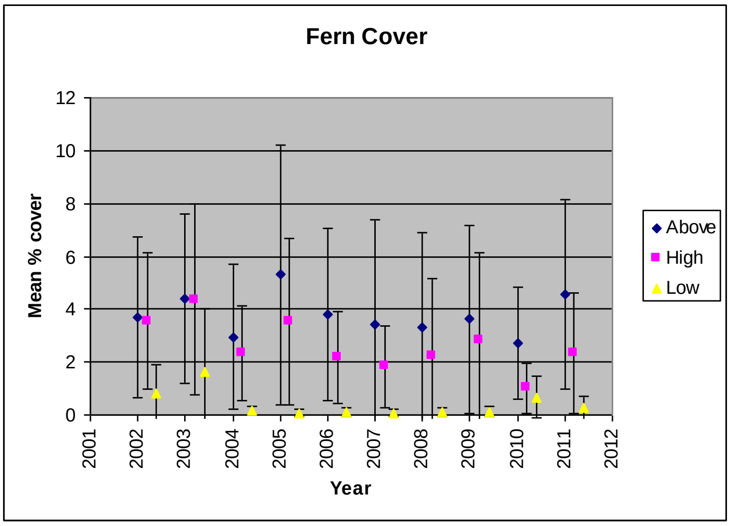


Figure 6-14 Mean per cent cover (±2 SE) of fern cover in zones 2–5 by monitoring event for 'above', 'high' and 'low' quadrats in the Gordon River

Trigger value comparison for ferns

The results for both the 'above'/'low' ratio and the 'above'/'high' ratio variables show some changes in the relative amounts of fern cover in the 2010–11 period compared with the pre-Basslink period (Table 6-8). The five-year 'above'/'low' ratio was not calculated for 'low' quadrats in zones 3–5 due to the very low abundance of ferns in low quadrats. Even in zone 2, which generally has a higher proportion of ferns, 'low' quadrats had very little cover and four of the six quadrats had no ferns recorded. Values were outside the trigger range for the one-year and five-year cumulative ratio comparisons for both the 'above' or 'low' quadrats for the whole-of-river data.

Trigger values have been exceeded and is likely to be the result of a relative increase in ferns in the 'above' quadrats and a decline or continuance of very low cover of ferns in 'low' quadrats in all zones (Figure 6-15). The exceedance of trigger values in the 'above'/'low' is highly influenced by high values for ratios in zone 2.

Table 6-8 The trigger value range within which 95 % of values are likely to lie for one-year (2010–11) and five-year (2006–11) mean values of ratios of fern cover based on pre-Basslink monitoring and values recorded for variable in the 2010–11 period. Figures in bold indicate a value outside the trigger range

Variable	Comparison	Pre-Basslink trigger one-year mean range		2010–11 one-year result	Pre-Basslink trigger five-year mean range		2006–11 five-year result
		Lower	Upper		Lower	Upper	
Per cent ferns	Ratio (% above+1) to (% high+1)	0.80	1.96	**3.40**	1.15	1.50	**2.36**
	Ratio (% above+1) to (% low+1)	3.13	5.12	**6.77**	2.73	3.54	N/A

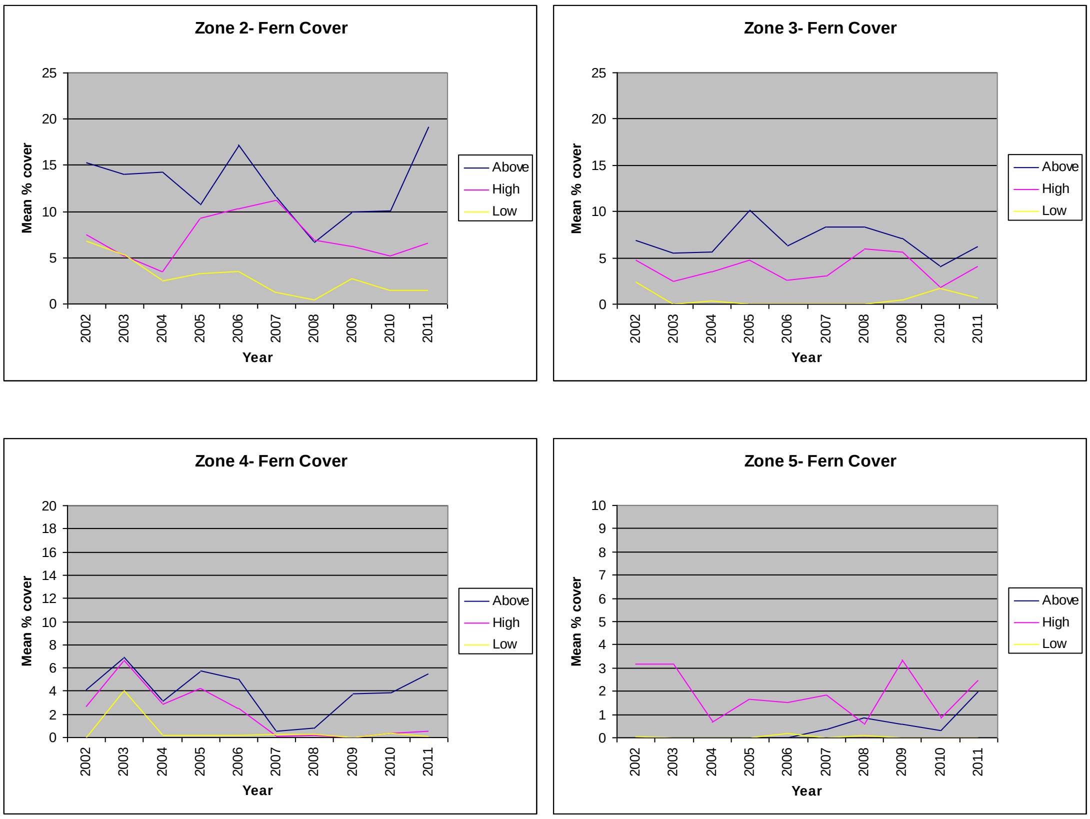


Figure 6-15 Per cent cover of ferns for each quadrat type by zone for each monitoring event

6.6.6.3 Shrubs

Mean per cent cover of shrubs at the whole-of-river scale showed no major trends over the monitoring period (Figure 6-16). Shrub cover continued to demonstrate differences between quadrat types and showed a slightly elevated shrub cover in 'above' and 'high' quadrats in the past four monitoring events; however, the data is highly variable. Zone 4 continued to show the greatest cover of shrubs (Figure 6-17). The decrease in shrub cover noted in zone 4 is largely attributable to a decline in *Bauera* in both 'above' and 'high' quadrats. While increases in zone 5 in 'above' and 'high' quadrats is largely due to an increase in *Anopterus, Acradenia and Bauera*, it should be noted that the changes in per cent cover in zones 2, 3 and 5 are very minor and are likely to be close to the ability of the recorders to identify discernable change. This is reflected in the relative high variability in this measure.

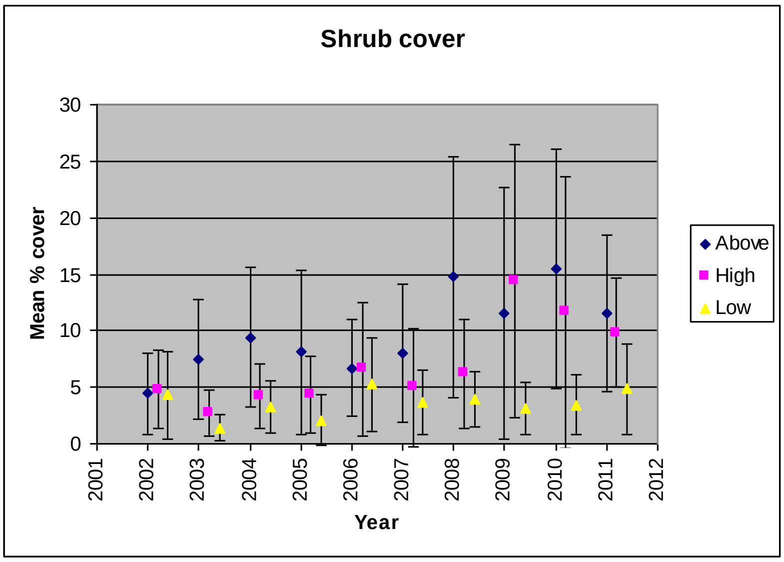


Figure 6-16 Mean per cent cover (±2 SE) of shrub cover in zones 3–5 by monitoring event for 'above', 'high' and 'low' quadrats in the Gordon River

Trigger value comparison for shrubs

The results for both the 'above'/'low' ratio and the 'above'/'high' ratio variables show some changes in the relative amounts of shrub cover in the 2010–11 period compared with the pre-Basslink period (Table 6-9). Some values were outside the trigger range for both the one-year and five-year cumulative ratio comparisons for both the 'above' or 'low' quadrats for the whole-of-river data (Table 6-9). Changes in the ratio of 'high'/'low is highly influenced by the loss of vegetation from a few 'low' quadrats resulting in very high ratio scores (sites 3g and 5d).

Table 6-9 The trigger value range within which 95 % of values are likely to lie for one-year (2010–11) and five-year (2006–11) mean values of ratios of shrub cover based on pre-Basslink monitoring and values recorded for the 2010–11 period. Figures in bold indicate a value outside the trigger range

Variable	Comparison	pre-Basslink trigger one-year mean range		2010–11 one-year result	pre-Basslink trigger five-year mean range		2006–11 five-year result
		Lower	Upper		Lower	Upper	
Per cent shrubs	Ratio (% above+1) to (% high+1)	0.95	2.29	1.80	1.34	1.76	**2.26**
	Ratio (% above+1) to (% low+1)	2.60	4.20	**6.52**	2.27	2.93	**3.98**

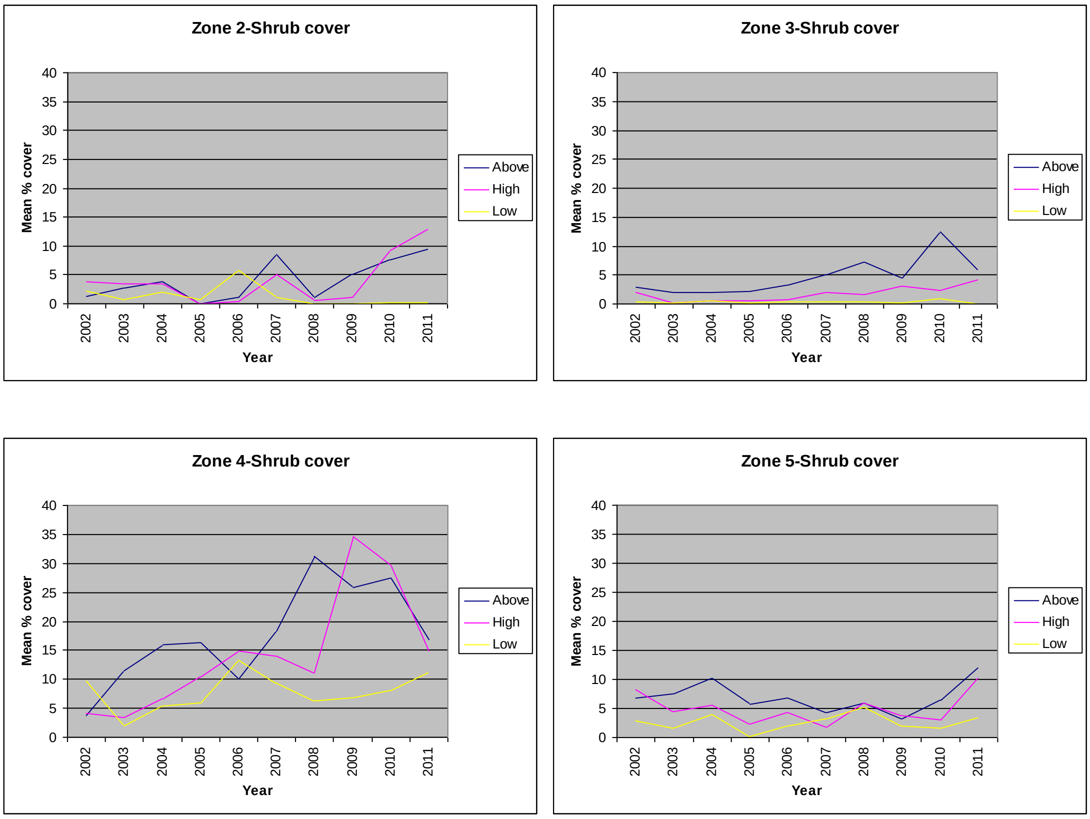


Figure 6-17 Per cent cover of shrubs for each quadrat type by zone for each monitoring event

6.7 Results – Denison and Franklin Rivers

Vegetation community dynamics are a reflection of the natural disturbance regimes and the responses of species to these disturbances. Tributary monitoring was included in the program to provide a 'reference' for seasonal, regional-scale variables such as drought or climatic changes. The intention was to use these data once changes were detected in the Gordon River, to provide evidence or otherwise of a Basslink effect.

The tributary sites should not be viewed as a 'control' for post- Basslink comparisons due to the very different nature of the rivers, substantially different processes affecting the vegetation and significantly different hydrology. As such, vegetation communities in these rivers are typical of riparian vegetation in undisturbed rivers in south-western Tasmania (Hydro Tasmania, 2005a). A broad band of riparian vegetation persists from the boundary of low summer flows to the limits of the recent flood events. A complete description of the vegetation of these rivers and the differences with the vegetation of the Gordon River is presented in the IIAS study undertaken by Davidson and Gibbons (2001).

The following discussion refers to the quadrats in the studies as 'above', 'high' and 'low'. Whilst these quadrats relate to different positions up the banks in the reference rivers, they do not reflect the distinct bank stratification that they do in the Gordon River, where they are responding to different regulated flow levels. The nomenclature used here is consistent with the Gordon River to enable easier comparisons of patterns at different bank levels. Data from 2002 to 2011 are included in this report to provide an indication of patterns of vegetation cover in the Franklin and Denison Rivers.

6.7.1 Total vegetation cover

Mean total vegetation cover (a composite of all vegetation data) can be spatially variable within locations but overall appears to have changed little at the Denison and Franklin river sites since 2002 until the last monitoring event (Figure 6-18). An apparent influence of the August 2007 flood can be seen by decreases in vegetation cover in April 2008 in the Franklin and Denison quadrats. An increase in total vegetation cover is evident in both the Franklin and Denison Rivers in the 2011 monitoring event. This is likely to be the result of growth of successional vegetation following the flood event in 2007. The increase in cover is largely the result of increased cover of the fern *Blechnum nudum* and, to a lesser extent, ground covers such as *Acaena novae-zeelandiae* (in above plots on the Franklin) as well as the increase in cover of *Pomaderris apetala* and *Eucryphia lucida*.

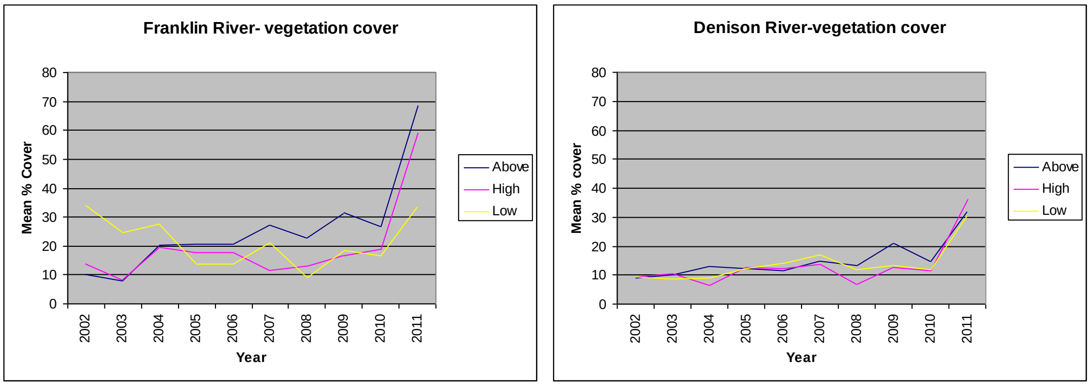


Figure 6-18 Mean percentage cover of vegetation at Denison River sites and Franklin River sites by quadrat location ('above', 'high' and 'low') from 2002 to 2011

6.7.2 Bare ground

Total bare substrate (a composite of root exposure and bare ground) was highly variable both temporally and spatially in both rivers (Figure 6-19). A decline in total bare cover for 2003–05 was reported in the Basslink Baseline Report (Hydro Tasmania 2005a). Since then, bare ground cover has fluctuated significantly from year to year. Sharp increases in bare ground for the Franklin 'above' and 'high' locations recorded in April 2008 indicate a loss of groundcover and litter which were the result of the flood in August 2007. This flood event also substantially altered the character of some sites, as large slips have appeared adjacent to Franklin River. Bare ground has reduced in 'above' quadrats on the Franklin, noticeably since 2009, and this coincides with an increase in ground cover herbs.

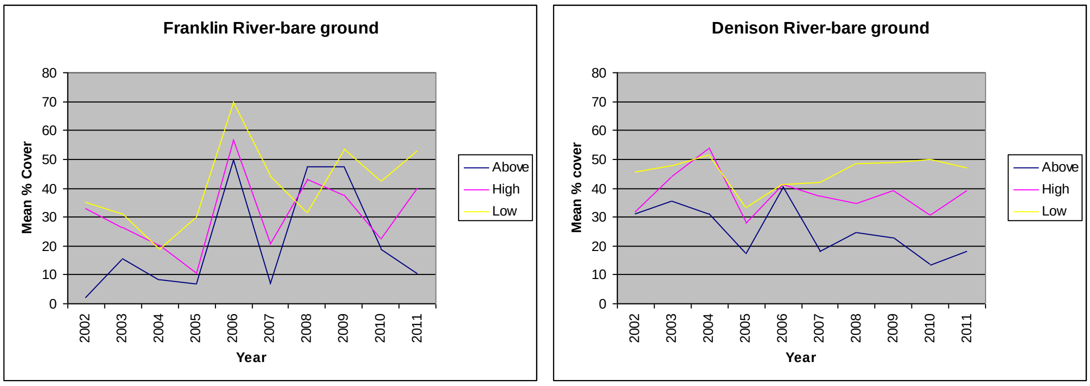


Figure 6-19 Mean percentage of total bare ground cover at Franklin River sites (left) and Denison River sites (right) by quadrat location ('above', 'high' and 'low') from 2002 to 2011

6.7.3 Identification of *Phytophthora cinnamomi* on the Gordon River

There has been substantial dieback of *Richea pandanifolia* (pandani) in past years in many areas along the middle Gordon River from Abel Gorge down to the Franklin confluence. This species is highly susceptible to the pathogen, *Phytophthora cinnamomi*. Commonly known as dieback, *Phytophthora cinnamomi* is a soil-borne pathogen of the kingdom Chromista, which affects the roots of susceptible plants starving them of nutrients and water. Long-distance spread of *Phytophthora* is principally by the transfer of infected soil or plant material by vehicles, people or animals. Dispersal of spores over short distances may occur via water movement in the soil or along water courses.

Conclusive identification of a *Phytophthora* infection requires laboratory analysis of soil or root samples. All vegetation sites were assessed for symptoms of dieback (yellowing of leaves and necrosis) in susceptible species however symptoms were only evident at one site (site 3EB). Soil samples were taken at this site and at another location across the river from site 3EB also showing symptoms of dieback of *R. pandanifolia*. The results of these analyses showed that the disease was present at these two sites and may be the most likely cause of dieback of *R. pandanifolia* at these locations. Previous testing in 2004 has confirmed *Phytophthora* from many of the sites in all zones of the river. Some areas of dieback of *R. pandanifolia* have in the past tested negative to *Phytophthora* and localised scour and physical disturbance associated with flow impacts are also a likely caused of this dieback in some situations. Soil samples will be collected over the next monitoring period if additional sites show signs of dieback.

6.8 Discussion

Conditions in the Gordon River over the 2010–11 monitoring period were generally more favourable for plant growth particularly up until the January 2011 period, continuing the pattern noted in 2008–09. These conditions were the result of reduced inundation and water logging due to lower frequency and duration of high flows (see chapter 2 Hydrology and water management). Evidence of vegetation establishment and recovery on the lower banks was noted in field observations for all zones and reflected in photo-monitoring undertaken in December 2010 where the lower banks were visible.

The establishment of herbs and graminoids in particular, recorded on both alluvial and cobble substrates in 2010, was seen to persist in flat areas, however, this was often below 'low' quadrats and not always captured in the quadrat data. Increased impact of water flows on steeper banks generally resulted in loss of vegetation cover and increased scouring in 'low' and 'high' quadrats compared to 'above'.

High flow peaking events occurring in January, February and March 2011, preceding the vegetation monitoring, have likely resulted in impacts particularly in the 'low' and to a lesser degree the 'high' quadrats in all zones. This level of impact is to be expected when periods of high flow follow an extended period of low flows. A similar range of trigger values was exceeded in 2008 following the high flows in the previous year.

Data collected in 2010–11 showed 15 of the 37 vegetation triggers to have values outside the trigger range (Table 6-10).

Table 6-10 Summary of trigger types, the variable measured, number of triggers and the number of triggers exceeded in 2010–11

Trigger type	Variable measured	Number of triggers	Number of deviances
Community composition (zones 3–5 comparisons)	Similarity index	9	6
	Species/taxa richness	9	0
	Species evenness	9	1
Community structure (whole-of-river comparisons)	Abundance of life forms	6	5
	Abundance of bare substrate	4	3

Generally these deviations were small and related to changes in the species similarity. Higher quadrats ('above' and 'high') tended to remain more stable, while 'low' quadrats became less similar. All quadrats either maintained or increased in species richness and were generally stable in species evenness. This change in similarity in 'low' quadrats is likely to be the result of past recruitment in low quadrats in the low flows over the past four years but with recent high flows selectively removing various species.

Much of the vegetation in upper quadrats is dominated by relatively stable rainforest vegetation which has a sparse, species poor understorey. Species diversity at these sites is low and changes in composition (in the absence of broadscale disturbance) are often from bird dispersed species such as *Coprosma quadrifida, Drymophila cyanocarpa* and *Pimelea drupacea* establishing and persisting for a few years before dying out. 'Above' quadrats in the absence of disturbance would be expected to be relatively stable.

Changes in the trigger values for comparison of ‘above’/’high’ and ‘above’/’low’ variables (bare ground, total vegetation, bryophytes, ferns and shrubs) can be explained by the impact of high flows of longer duration immediately prior to the monitoring event. These high flows impacted more on ‘low’ and ‘high’ quadrats than ‘above’ quadrats, resulting in increased ratios of ‘above’/’high’ and ‘above’/’low’ for the variables of total vegetation, bryophytes, ferns and shrubs and decreased ratios for bare ground. Often these ratios were influenced by the loss of vegetation in a few quadrats resulting in very high values in a few sites. Ratios of ‘above’/’low’ for ferns, mosses and total vegetation was influenced by sites in zone 2 which had very high values. It is possible that the exceedance of ratios for ferns and total vegetation is in part due to increase in cover of ferns (and so total vegetation) in ‘above’ quadrats. This could be due to the earlier sampling this year occurring during a more active growth phase of ferns than normally occurs or simply better growing condition this year.

It is interesting to note the recovery of the banks noted in 2010 by colonising species, such as the herbs *Gnaphalium* spp. and *Acaena novae-zelandiae,* the fern *Blechnum nudum* and shrub *Pomaderris apetala,* is consistent with the expansion of vegetation on the Denison and Franklin Rivers noted this year. The Gordon, Franklin and Denison rivers all exhibited a notable increase in total vegetation cover and much of this was attributable to an increase in the fern cover. It is possible that this was in part influenced by monitoring occurring earlier than normal in the active growing phase of ferns. The graminoids recorded as colonising the Gordon River last year are largely absent from the tributary rivers. This may because the vegetation on the tributaries is at a later successional stage compared to the more modified Gordon River.

6.9 Conclusions

Photo-monitoring in December 2010 continued to show recovery of vegetation on the lower banks with the continued establishment and growth of graminoids and herbaceous species. The combined geomorphological/vegetation monitoring showed minor changes in the position of ground cover variables (litter, riparian species, CWD, seedlings, bare ground and root mat) on the banks and was consistent with the results of the fluvial geomorphological studies which showed little change in the geomorphology of the river during the 2010–11 year as compared to other years.

The geomorphological field observations noted scour in the 1–2 turbine bank level, and seepage-induced deposition of sands in some areas. These localised observations, however, were not widely reflected in the statistical analysis of the erosion pins. It is suggested that if this power station operating pattern continues for an extended period, then these types of changes may become more widespread and may begin to be reflected in the combined geomorphological/vegetation monitoring.

Field observations in the March 2011 monitoring event noted the survival of mosses, graminoids and grasses in localised areas of the lower banks but these observations were not well reflected in the statistical analysis of the vegetation quadrat data.

Analysis of quadrat data monitored in March 2011 noted that the recovery of vegetation recorded in the previous four monitoring events has been impacted by the longer duration of high flow events that occurred immediately prior to the monitoring event in March 2011. While sites are showing an apparent resultant increase in bare ground and potentially a decrease in bryophyte cover, the total vegetation cover in response to these high flow events has been variable. Total vegetation cover in 'above' quadrats has largely been unaffected while 'high' and 'low' quadrats have tended to have a reduced total vegetation cover.

A number of values were recorded outside the triggers for species and ground cover abundance and this has largely been due to small changes in the similarity indices which is attributable to the change in the presence and absence of a few species.

Diverging similarity in the lower quadrats has occurred largely due to high flows removing species that had become established over the last four to five years in a low flow environment. Species evenness was generally stable.

Proportional changes in life form variables (e.g. shrubs, moss, bryophytes) and ground cover between 'above' and 'high' and 'above' and 'low' quadrats has resulted in the metric exceeding trigger values. This can be explained by proportionally greater impacts of high water flows in the early part of 2011 on 'low' and 'high' quadrats compared with the 'above' quadrats. The exceedence of trigger values for ferns, moss and total vegetation cover were influenced by very high values in zone 2 for these metrics.

It should be noted that the variation in the measured attributes is high because of the:

- variability in the hydrologic regime in the Gordon River system;
- difficulty in discerning and accurately measuring small changes in the attributes; and
- small sample size (three replicates in each zone).

This means that detecting small changes in the system is difficult. However the metrics used are sensitive and impacts have generally been to the low quadrats. The impacts shown in the data analysis are likely to be caused by the high flow events immediately prior to the monitoring done in March 2011.

These changes are due to the alternating establishment and loss of vegetation on the lower banks in response to the pattern of power station usage and are consistent with the adjustment of the river to the third turbine and the present understanding of the river.

7 Macroinvertebrates

7.1 Introduction

Macroinvertebrate sampling was conducted in spring (19, 20 and 26 October) 2010 and autumn (25–27 February) 2011 in accordance with the requirements of the Basslink Monitoring Program for the Gordon River. Both quantitative (surber) and rapid bioassessment (RBA) sampling was conducted at nine 'monitoring' sites in the Gordon River between the power station and the Franklin confluence. This sampling was also conducted at the six 'reference' sites located in rivers within the Gordon catchment.

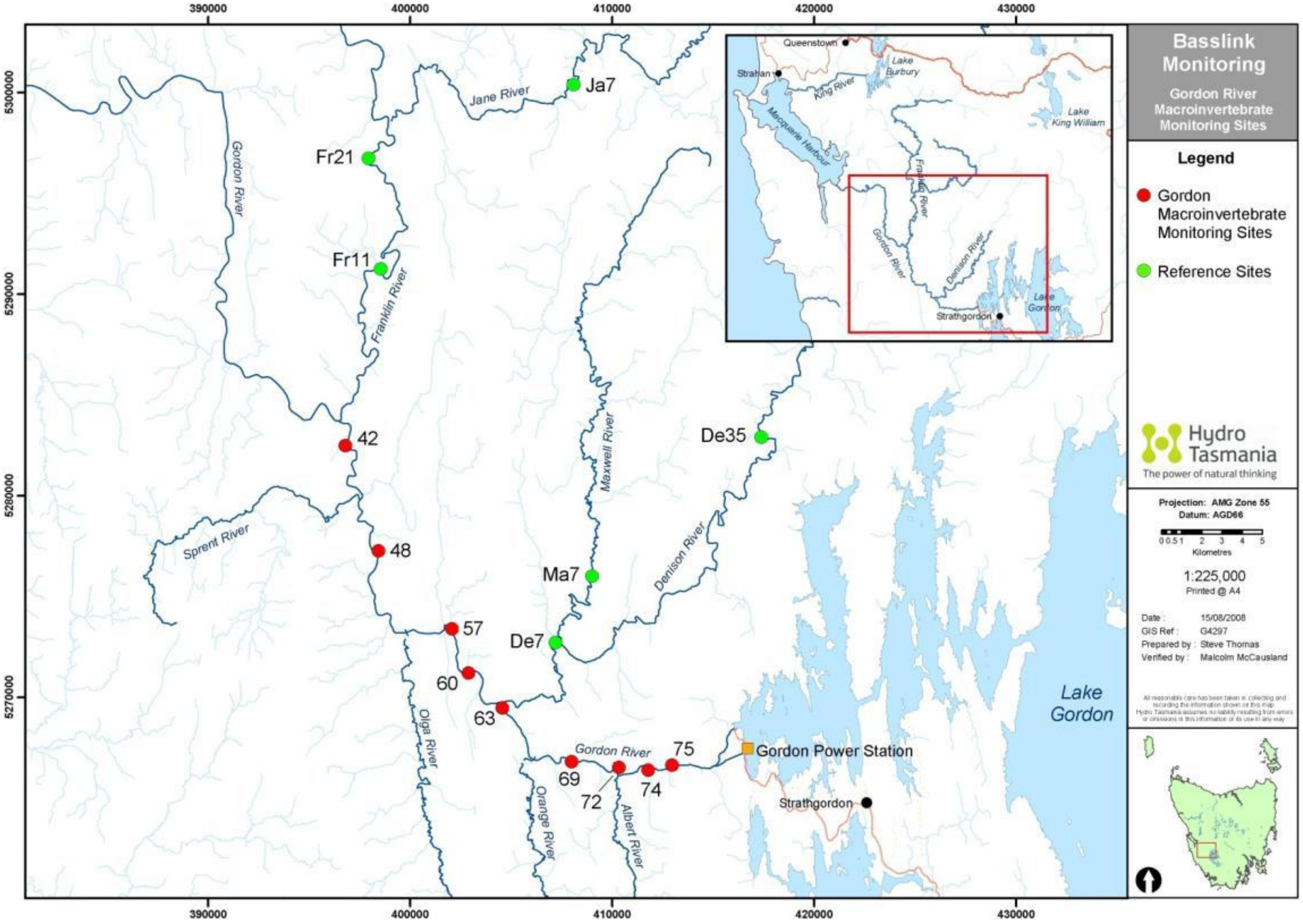
This sampling completes year ten of the Basslink macroinvertebrate monitoring being conducted in the Gordon River catchment.

This section reports on the results of field sampling for macroinvertebrates in spring and autumn 2010–11, provides a comparison of these results with those for the pre-Basslink period and describes trends over the entire monitoring program to date. Results were also compared with triggers derived from pre-Basslink period data, as detailed in the Basslink Baseline Report (Hydro Tasmania 2005a).

7.2 Methods

7.2.1 Sample sites

The locations of the monitoring and reference sites are shown in Map 7-1. All sites sampled in 2010–11 are listed in Table 7-1.



Map 7-1 Map of the locations of macroinvertebrate monitoring sites in the Gordon, Denison and Franklin Rivers

Table 7-1 Sites sampled in 2010–11 for macroinvertebrates

River	Site Name	Site code	Distance from power station (km)	Easting	Northing
Gordon	Gordon R d/s Albert Gorge (G4)	75	2	412980	5266630
	Gordon R d/s Piguenit R (G4A)	74	3	412311	5266383
	Gordon R in Albert Gorge (G5)	72	5	410355	5266524
	Gordon R u/s Second Split (G6)	69	8	408005	5266815
	Gordon R u/s Denison R (G7)	63	14	404584	5269469
	Gordon R d/s Denison R (G9)	60	17	402896	5271211
	Gordon R u/s Smith R (G10)	57	20	402083	5273405
	Gordon R d/s Olga R (G11A)	48	29	398178	5278476
	Gordon R @ Devil's Teapot (G15)	42	35	396804	5282486
Franklin	Franklin R d/s Blackman's bend (G19)	Fr11	-	398562	5291239
	Franklin R @ Flat Is (G20)	Fr21	-	397939	5296733
Denison	Denison d/s Maxwell R (G21)	De7	-	407206	5272718
	Denison R u/s Truchanas Reserve (D1)	De35	-	417400	5282900
Jane	Jane R (J1)	Ja7	-	408100	5300400
Maxwell	Maxwell R (M1)	Ma7	-	409011	5276009

7.2.2 Macroinvertebrate sampling

Quantitative sampling (surber sampling) and rapid bio-assessment kick-sampling (RBA) methods were conducted at all sites. Thus, at each site at low flows, riffle habitat was selected and sampled by:

- collecting 10 surber samples (30 x 30 cm area, 500 micron mesh) by disturbing the substrate within the quadrat by hand to a depth of 10 cm whereby attached macroinvertebrates are swept into the net; and
- disturbing substrate by foot and hand immediately upstream of a standard 250 micron kick net over a distance of 10 m (RBA).

All surber samples from a site were pooled and preserved (10 % formalin) prior to lab processing. Samples were elutriated with a saturated calcium chloride solution and then sub-sampled to 20 % using a Marchant box subsampler and random cell selection. The subsamples were then hand-picked and all fauna identified to 'family level' with the exception of oligochaetes, Turbellaria, Hydrozoa, Hirudinea, Hydracarina, Copepoda and Tardigrada. Chironomids were identified to sub-family. Identification to genus and species level was conducted for the aquatic insect orders Ephemeroptera, Plecoptera, Trichoptera – the 'EPT' group fauna – using the most current taxonomic keys.

All analyses were conducted using the 20 % (0.18 m^2) sub-sample data.

Two RBA samples were collected at each site. All RBA samples were live-picked on-site for 30 minutes, with pickers attempting to maximise the number of taxa recovered. All taxa were identified to the family taxonomic level as described above.

7.2.3 Habitat variables

A set of standard habitat variables were recorded at each site and a number of variables were recorded from 1:250000 maps. The habitat variables recorded are:

- per cent cover of substrate types (boulder, cobble, pebble, gravel, sand, silt and clay);
- per cent of site area covered by algae, moss, silt and detritus;
- site depth, temperature, conductivity, wetted width, bank-full width, flow and water clarity;
- extent of aquatic, overhanging, trailing and riparian vegetation; and
- per cent of site in habitat categories (riffle, run, pool and snag habitats).

7.2.3.1 Analysis

No detailed analysis has been conducted for this report, other than to derive O/E scores and plot summary trends. All RBA data was analysed using the autumn season Hydro RIVPACS models developed by Davies *et al.* (1999), with O/Epa and O/Erk values derived using the RBA macroinvertebrate data in combination with key 'predictor' habitat variables. O/Epa is derived using presence/absence data and models derived from presence/absence reference site data. O/Erk is derived using rank abundance category data and models derived from rank abundance category reference data.

Trigger values were those derived for the Basslink program as detailed in the Basslink Baseline Report (Hydro Tasmania, 2005a) and the 2005–06 Annual Report (Hydro Tasmania, 2006).

O/Epa and O/Erk scores range between 0, representing the condition where no expected taxa are found in the sample, to 1, where all expected taxa are found. This range is divided into *impairment bands* for reporting purposes:

- D – extremely impaired;
- C – severely impaired;
- B – significantly impaired;
- A – unimpaired, or equivalent to reference; and
- X – more diverse than reference.

7.3 Results

7.3.1 Spring 2010

7.3.1.1 Quantitative data

Data from spring 2010 season surber samples are shown for family level identification and for EPT species in Table 7-2 and Table 7-3.

Diversity and total abundance at both family and species level, as well as the number and abundance of EPT species, fell generally within or close to the range observed in previous years (Figure 7-1 and Figure 7-2).

The relative (proportional) abundance of EPT species was higher than the pre-Basslink means for all zone 1 sites (Figure 7-3), with values greatly exceeding pre-Basslink ranges for zone 1 sites 69 to 74. These sites all had high abundances of *Asmicridea* caddisfly larvae (family Hydropsychidae). Sites in the vicinity and drawdown of the Denison confluence (except site 48) had more variable *Asmicridea* caddisfly larval densities, falling around the pre-Basslink means except for site 48 where densities were higher than the pre-Basslink range.

The community compositional similarity of Gordon River sites relative to the reference sites was consistently greater than the pre-Basslink means, when measured by the mean Bray Curtis Similarity measure, based on either abundance or presence/absence data (Figure 7-4).

7.3.1.2 RBA data

Spring season RBA data is shown in Table 7-4. O/Epa and O/Erk values and their impairment bands are shown in Table 7-5.

O/Epa values in spring 2010 fell within or close to pre-Basslink values in the Gordon River, though with a higher value at site 69 (Figure 7-5). Reference site O/Epa values were not statistically significantly different from pre-Basslink means (by paired t-test of spring pre-Basslink means with 2010 values, $p > 0.05$), though were, on average, lower.

O/Erk values in spring 2010 fell within or close to pre-Basslink values in the Gordon River, though with a lower values at site 75 (Figure 7-5). Reference site O/Epa values were again not statistically significantly different from pre-Basslink means (by paired t-test of spring pre-Basslink means with 2010 values, $p > 0.2$).

7.3.1.3 Conclusions

Total abundance and diversity generally fell within the upper ranges of pre-Basslink values for zone 1 sites, while the proportional abundance of EPT species was elevated for those sites compared to pre-Basslink observations. Though O/E values have fallen since 2009–10 closer to pre-Basslink values, the overall post-Basslink changes has led to a community compositional similarity closer to those of reference site macroinvertebrate communities.

Magnitudes of all variables generally fell within historical pre-Basslink ranges for reference sites.

7.3.2 Autumn 2011

7.3.2.1 Quantitative data

Data from autumn 2011 season surber samples are shown at family level and for EPT species in Table 7-6 and Table 7-7.

Total abundance at both family and species level for the Gordon River sites generally within or higher than pre-Basslink ranges (Figure 7-6 and Figure 7-7), with total abundance falling below pre-Basslink means at six of the nine sites (Figure 7-6). Site 74 had a notably high total macroinvertebrate abundance. Abundance fell close to pre-Basslink means for five of the six reference sites (Figure 7-6).

The abundance of EPT species was variable among Gordon River sites, with three sites being lower than the pre-Basslink means but not outside historical ranges, though greatly exceeding the pre-Basslink range at site 74 (Figure 7-7). Five reference sites had abundances of EPT species below the pre-Basslink mean (Figure 7-7). The number of EPT species fell close to pre-Basslink means for all Gordon River sites except sites 48 and 76 which fell below the pre-Basslink range (Figure 7-7). Reference sites were consistently below pre-Basslink ranges.

The proportional abundance of EPT species was generally lower in the Gordon River in zone 2 than pre-Basslink means, but substantially exceeded pre-Basslink means and ranges in zone 1 (Figure 7-8). Reference site values generally fell close to, though below, their pre-Basslink means.

The community compositional similarity of the Gordon River sites relative to reference sites was greater than pre-Basslink means for six sites. Sites 74 and 75 fell below the pre-Basslink Bray Curtis Similarity measure, based on both abundance or presence/absence data (Figure 7-9). Reference sites in autumn 2011 had inter-site compositional similarities that fell close to pre-Basslink means.

7.3.2.2 RBA data

Autumn season RBA data is shown in Table 7-8. O/Epa and O/Erk values and their impairment bands are shown in Table 7-5, and are plotted with pre-Basslink values in Figure 7-10.

O/Epa values in autumn 2011 were higher than pre-Basslink means for seven of the nine Gordon River sites (Figure 7-10), but none of the six reference sites. These differences were statistically significant (by paired t-test of pre-Basslink means with 2010 values, both $p < 0.05$) for Gordon

River but not reference sites. Gordon River sites 48, 69, 72 and 75 all fell above, below, or at the upper margins of the observed pre-Basslink ranges.

O/Erk values were higher than pre-Basslink means for five of the nine Gordon River sites (Figure 7-10) but were lower than pre-Basslink means for four of the six reference sites. These differences were not statistically significant overall (by paired t-test of pre-Basslink means with 2011 values, both $p > 0.1$) for Gordon River sites. Gordon River sites 48 and 69 fell above, or at the upper margins of, the observed pre-Basslink ranges (Figure 7-10).

7.3.2.3 Conclusions

Diversity (at family and species level), and the proportion of abundance as EPT species, was greater in most Gordon River sites (especially zone 1) than pre-Basslink values. This was accompanied by a general increase in overall community compositional similarity. This can be attributed to post-Basslink within-Gordon effects, most likely driven by the presence of minimum environmental flows (Hydro Tasmania 2010), as there was no corresponding increase observed at reference sites.

Table 7-2 Quantitative macroinvertebrate 'family level' data (abundances as n per 0.18 m^2) for Gordon River and reference sites sampled in spring (October) 2010

		River	**Gordon**									**Franklin**		**Denison**		**Maxwell**	**Jane**
		Site code	**75**	**74**	**72**	**69**	**63**	**60**	**57**	**48**	**42**	**Fr11**	**Fr21**	**De7**	**De35**	**Ma7**	**Ja7**
		Old site code	**G4**	**G4a**	**G5**	**G6**	**G7**	**G9**	**G10**	**G11B**	**G15**	**G19**	**G20**	**G21**	**D1**	**M1**	**J1**
Class	**Order**	**Family**															
Platyhelminthes	Turbellaria		1			1	1	4			3	3		1		4	1
Nematoda											2						
Mollusca	Gastropoda	Hydrobiidae					1	5		12	6	14			1		
		Glacidorbidae		1													
Annelida	Oligochaeta		1	20	10	8	31	41	12	26	53	32	42	31	22	80	122
Arachnida	Acarina											1				1	
Crustacea	Amphipoda	Paramelitidae								3		1		1			
		Neoniphargidae		1			1										
	Isopoda	Janiridae	2	1			4	1			1	1					
		Phreatoicidea				1											
Insecta	Plecoptera	Eustheniidae				1	1	1			1	3	1		5	2	
		Austroperlidae						1									
		Gripopterygidae	1	5	15	8	9	6	3	7	7	9		1	17	20	4
	Ephemeroptera	Leptophlebiidae	1		4	2	16	17	13	16	13	14	12	25	19	46	35
		Baetidae						1		1	2	3			19	21	11
	Diptera	Chironomidae: *sub-fam Chironominae*				2	3	2		5	24	3			8	1	1
		Sub-fam Orthocladiinae	1	3	3	7	5		1		3				3	7	

Table 7-2 continued next page

		River	**Gordon**									**Franklin**		**Denison**		**Maxwell**	**Jane**
		Site code	**75**	**74**	**72**	**69**	**63**	**60**	**57**	**48**	**42**	**Fr11**	**Fr21**	**De7**	**De35**	**Ma7**	**Ja7**
		Old site code	**G4**	**G4a**	**G5**	**G6**	**G7**	**G9**	**G10**	**G11B**	**G15**	**G19**	**G20**	**G21**	**D1**	**M1**	**J1**
Class	**Order**	**Family**															
Insecta (cont)	Diptera (cont)	*Sub-fam Podonominae*						4	3	3	3	8		1	1	8	
		Sub-fam Diamesinae	1							1					1		
		Sub-fam Simuliidae						98	7	54	19	272	205	68	92	36	72
		Tipulidae			1		1						1				1
		Athericidae						1									
		Blephariceridae	1					5	1		4	11	59	1		1	9
		Empididae									1				1		
		Dip. Unid. Pup.	1	3	2		4	1	4	3	8	20	3			1	1
	Trichoptera	Calocidae															3
		Conoesucidae			18	2	16	5	6	7	3	2				3	
		Glossosomatidae						1				9				3	
		Helicopsychidae			1												
		Hydrobiosidae			1	1	4	7		5	2	3	1	1	6	7	3
		Hydropsychidae		25	28	5	3	3		9	3	1					
		Leptoceridae		1				1			1			3	2	3	
		Philorheithridae				1				3		3		1	1	1	1
	Trichoptera	Trich. Unid. Pup.		1	2			1		4	4						
	Coleoptera	ElmidaeA				1	1	5	1	3	3	17	1	10	8	22	14
		ElmidaeL			1		3	12		1	2	19	1	27	8	65	125
		ScirtidaeL			1								2		3		
		PsepheniidaeL										5	1	1		3	
		Total abundance	**10**	**61**	**87**	**40**	**104**	**223**	**51**	**163**	**168**	**454**	**329**	**172**	**217**	**335**	**403**
		N Taxa (families)	**9**	**10**	**13**	**13**	**17**	**23**	**10**	**18**	**23**	**23**	**12**	**14**	**18**	**21**	**15**

Table 7-3 Quantiative 'species level' data for EPT taxa (Ephemeroptera, Plecoptera and Trichoptera) for Gordon River and reference sites sampled in spring (October) 2010 (abundances as n per 0.18 m^2)

		River	Gordon									Franklin		Denison		Maxwell	Jane
		Site code	**75**	**74**	**72**	**69**	**63**	**60**	**57**	**48**	**42**	**Fr11**	**Fr21 ***	**De7**	**De35**	**Ma7**	**Ja7**
		Old site code	**G4**	**G4a**	**G5**	**G6**	**G7**	**G9**	**G10**	**G11B**	**G15**	**G19**	**G20**	**G21**	**D1**	**M1**	**J1**
Order	**Family**	**Genus/Species**															
Ephemeroptera	Baetidae	Baetid Genus 2 MV sp. 3						1		1	2	3			19	21	11
	Leptophlebiidae	*Nousia* sp. AV5/6			3		7	16	11	12	7	10		24	9	45	31
		Nousia sp. AV7	1		1	1	5		1	2	4			1	5		4
		Nousia sp. AV9								1							
		Tillyardophlebia sp AV2				1	4	1	1	1	2	4			5	1	
Plecoptera	Eustheniidae	*Eusthenia costalis*										1			3		
		Eusthenia spectabilis				1	1	1			1	2			2	2	
	Austroperlidae	*Tasmanoperla thalia*						1									
	Gripopterygidae	*Cardioperla incerta*			10	1	2		1	3	4	5		1	1	3	1
		Cardioperla media/lobata		1	3	2	7			1		1			3	9	1
		Dinotoperla serricauda							1		1	1				1	
		Leptoperla varia		1	2	5					1						
		Trinotoperla tasmanica													2		
		Trinotoperla zwicki	1	3				6	1	3	1	2			11	7	2
	Notonemouridae	*Austrocercoides* sp															
		Kimminsoperla albomacula															
		Tasmanocerca bifasciata															

Table 7-3 continued next page

		River	Gordon									Franklin		Denison		Maxwell	Jane
		Site code	**75**	**74**	**72**	**69**	**63**	**60**	**57**	**48**	**42**	**Fr11**	**Fr21 ***	**De7**	**De35**	**Ma7**	**Ja7**
		Old site code	**G4**	**G4a**	**G5**	**G6**	**G7**	**G9**	**G10**	**G11B**	**G15**	**G19**	**G20**	**G21**	**D1**	**M1**	**J1**
Order	**Family**	**Genus/Species**															
Trichoptera	Calocidae	*Tamasia variegata*															3
	Conoesucidae	*Conoesucus digitiferus*			8												
		Conoesucus nepotulus							1								
		Conoesucus norelus			10	2	12	5	4	7	3					3	
		Conoesucus sp. AV6					4		1								
		Matasia satana										2					
	Glossosomatidae	*Agapetus* sp. AV1						1				9				3	
	Helicopsychidae	*Helicopsyche murrumba*			1												
	Hydrobiosidae Includes all#	*Moruya opora*					2	3		4	2	3			3	1	
		#Taschorema apobamum					2	3								3	
		#Taschorema asmanum			1			1							2	2	3
		#Taschorema ferulum				1				1				1		1	
		Taschorema ferulum grp													1		
	Hydropsychidae	*Asmicridea* sp. AV1		25	28	5	3	3		8	3	1					
		Smicrophylax sp. AV3								1							
	Leptoceridae	*Notalina* sp.AV1									1						
		Notalina sp.		1				1						3	2	3	
	Philorheithridae	*Tasmanthrus angustipennis*										3					
		Tasmanthrus sp.				1				3				1	1	1	1
		Abundance EPT	**2**	**31**	**67**	**20**	**49**	**43**	**22**	**48**	**32**	**47**		**31**	**69**	**106**	**57**
		N EPT Taxa	**2**	**5**	**10**	**10**	**11**	**13**	**9**	**14**	**13**	**14**		**6**	**15**	**16**	**9**

* data for site FR21 rejected due to inadequate sample quality

Table 7-3 continued

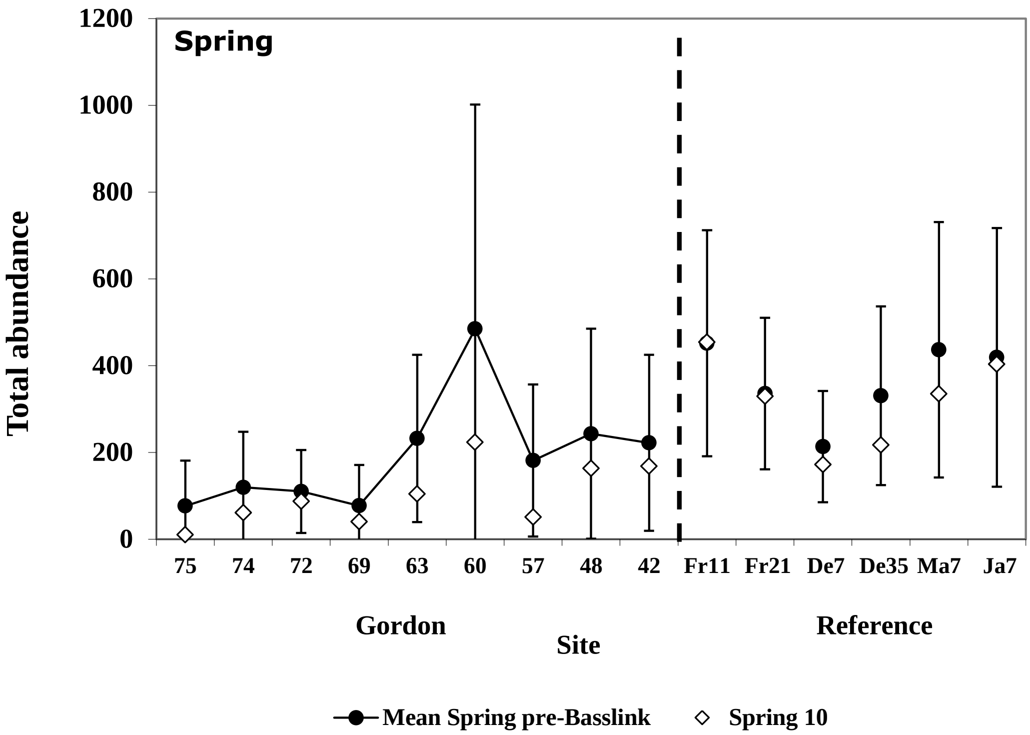
Table 7-4 RBA macroinvertebrate data (abundances per live-picked sample) for Gordon River and reference sites sampled in spring 2010

		River	Gordon R																		Franklin				Denison				Jane		Maxwell	
		Site	75		74		72		69		63		60		57		48		42		Fr11		Fr21		De7		De35		Ja7		Ma7	
Class	Order	Family	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Platyhelminthes	Turbellaria			3					1			4		1								1										
Mollusca	Gastropoda																									1					5	1
Annelida	Oligochaeta	Hydrobiidae	1		26	6	5	9	19	4	23	29	11	9	11	19	28	19	16	52	15	10	31	25	10	8	3	2	29	22	1	5
Arachnida	Acarina															1													2		3	1
Crustacea	Amphipoda	Paramelitidae										1	2	1	1	3	3	3	1	2											1	2
		Neoniphargidae	3	7	2	2				4				1		2																
	Isopoda	Janiridae	1	3	1															1	1											
		Phreatoicidea							2	3																						
Insecta	Plecoptera	Eustheniidae	2	2		2						1					3	3		1	1	2	1	4	4		8	16		2		1
		Austroperlidae	1		1							1																			1	
		Gripopterygidae		3	26	33	40	41	20	23	49	9	22	7	11	4	19	4	4	8	2	8	7	6	15	2	13	15	6	19	45	25
		Notonemouridae								2						1																
	Ephemeroptera	Leptophlebiidae	2	4	1	1	8	21	7	12	25	38	47	42	27	47	61	47	38	19	40	55	47	70	60	56	41	53	46	62	34	28
		Baetidae									1		2	1	6	2	3	2	1		8	8		1	2	1	17	10	9	18	16	11
	Odonata	Telephlebiidae															1															
	Diptera	Chironomidae: *sub-fam Chironominae*							4	7		2		1		1			3	4	1	1	3		3		1		1		6	2
		Sub-fam Orthocladiinae	6	6	4	4	5	5	4	2	4	2	1		3	1		1	1			1	1	1	1	2	2	7		4	7	8
		Sub-fam Podonominae	4	2	2	5	8	7	12	26	4	2	27	39	37	29	24	66	20	16	23	18	13	12	64	22	22	13	16	23	17	2
		Sub-fam Tanypodinae			1																											
		Sub-fam Diamesinae		3		2	4	2																								
		Simuliidae					1	1					21	16	14	16	14	28	10	8	44	41	29	35	50	10	32	29	14	35	6	9

		River	Gordon R																		Franklin				Denison				Jane		Maxwell	
		Site	**75**		**74**		**72**		**69**		**63**		**60**		**57**		**48**		**42**		**Fr11**		**Fr21**		**De7**		**De35**		**Ja7**		**Ma7**	
Class	**Order**	**Family**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**
Insecta (cont)	Diptera (cont)	Tipulidae					2	2	4	5		2		2	1	4						1					3					
		Athericidae							1										1													
		Blephariceridae	1		1										1	1	3				2	2	20	16			1		1	1		
		Ceratopogonidae																			1	2										
		Chaoboridae		2																												
		Empididae			1	1		2																								1
		Dip. Unid. Pup.							2		1						1		3											1		
	Trichoptera	Calocidae										1						1													1	
		Conoesucidae			1	1	46	27	3	4	4	3	1			1		1		3	1		1	1				1		1	8	12
		Glossosomatidae										1										10				2					6	1
		Helicopsychidae																													1	
		Hydrobiosidae	20	38	26	32	15	12	11	21	20	12	30	29	13	17	35	19	8	8	17	18	27	30	21	7	23	13	12	15	11	14
		Hydropsychidae			73	40	41	13	3	2		3					1	1			1										12	9
		Leptoceridae	3							1			1	1						2		4	1	1			2	3				
		Philopotamidae				1							1																			
		Philorheithridae								2			1	1				3	1	1	1	3				1	2	3			5	
		Trich. Unid. Pup.			1		3				1			3	1		2	4	8	2		5	1	2						1	1	
	Coleoptera	ElmidaeA				1	1	1	1	3			11	2	1	2			2	4	2	25	1	1	25	14	18	9	7	12	24	17
		ElmidaeL		1				1	1				1								1	1				4			2		2	1
		ScirtidaeL	1					1	1	1						2							1	4		1			1			
		PsepheniidaeL																				2		1							3	1
		DytiscidaeL																								1						
		N Taxa	**12**	**12**	**15**	**14**	**13**	**15**	**17**	**17**	**10**	**16**	**15**	**16**	**13**	**18**	**14**	**15**	**15**	**15**	**17**	**21**	**15**	**16**	**11**	**15**	**15**	**13**	**13**	**14**	**23**	**20**

Table 7-5 O/Epa and O/Erk values for all sites sampled in spring and autumn 2010–11, for individual replicate samples, and averages. Impairment bands also indicated

			Spring 2010				Autumn 2011			
River	**Site**	**Replicate**	**O/Epa**	**Band**	**O/Erk**	**Band**	**O/Epa**	**Band**	**O/Erk**	**Band**
Gordon	75	1	0.68	B	0.50	B	0.68	B	0.56	B
		2	0.45	B	0.47	B	0.59	B	0.45	B
		Mean	**0.56**	**B**	**0.49**	**B**	**0.64**	**A**	**0.50**	**B**
	74	1	0.66	B	0.71	B	0.68	B	0.50	B
		2	0.66	B	0.69	B	0.68	B	0.40	C
		Mean	**0.66**	**B**	**0.70**	**B**	**0.68**	**A**	**0.45**	**B**
	72	1	0.73	A	0.75	B	1.17	A	0.81	B
		2	0.87	A	0.91	A	1.08	A	0.76	B
		Mean	**0.80**	**A**	**0.83**	**A**	**1.12**	**X**	**0.78**	**B**
	69	1	0.91	A	0.91	A	1.08	A	0.83	A
		2	0.98	A	1.01	A	1.17	A	0.83	A
		Mean	**0.95**	**A**	**0.96**	**A**	**1.12**	**A**	**0.83**	**A**
	63	1	0.59	B	0.65	B	0.98	A	0.66	B
		2	0.97	A	0.98	A	1.37	X	0.96	A
		Mean	**0.78**	**A**	**0.82**	**A**	**1.17**	**A**	**0.81**	**A**
	60	1	0.97	A	1.10	A	1.27	X	0.96	A
		2	0.90	A	1.00	A	1.17	A	1.06	A
		Mean	**0.94**	**A**	**1.05**	**A**	**1.22**	**X**	**1.01**	**A**
	57	1	0.82	A	1.00	A	0.98	A	0.71	B
		2	1.12	A	1.23	X	1.47	X	0.91	A
		Mean	**0.97**	**A**	**1.12**	**X**	**1.22**	**X**	**0.81**	**A**
	48	1	0.88	A	1.06	A	1.37	X	1.06	A
		2	0.96	A	0.98	A	1.27	X	1.06	A
		Mean	**0.92**	**A**	**1.02**	**A**	**1.32**	**X**	**1.06**	**A**
	42	1	0.90	A	0.91	A	1.27	X	0.91	A
		2	0.90	A	0.88	A	1.27	X	0.96	A
		Mean	**0.90**	**A**	**0.90**	**A**	**1.27**	**X**	**0.93**	**A**
Franklin	Fr11	1	1.12	A	1.29	X	1.37	X	1.11	A
		2	1.27	X	1.35	X	1.37	X	1.16	A
		Mean	**1.20**	**X**	**1.32**	**X**	**1.37**	**X**	**1.13**	**A**
	Fr21	1	0.90	A	1.11	A	1.17	X	0.91	A
		2	1.05	A	1.12	A	1.57	X	1.06	A
		Mean	**0.97**	**A**	**1.11**	**A**	**1.37**	**X**	**0.98**	**A**
Denison	De7	1	0.68	B	0.88	A	1.27	X	0.96	A
		2	0.99	A	0.94	A	1.47	X	1.01	A
		Mean	**0.83**	**A**	**0.91**	**A**	**1.37**	**X**	**0.98**	**A**
	De35	1	1.03	A	1.17	A	1.47	X	1.01	A
		2	0.95	A	1.03	A	1.17	A	0.86	A
		Mean	**0.99**	**A**	**1.10**	**A**	**1.32**	**X**	**0.93**	**A**
Maxwell	Ma7	1	1.35	X	1.33	X	1.47	X	1.06	A
		2	1.20	X	1.35	X	1.56	X	1.01	A
		Mean	**1.28**	**X**	**1.34**	**X**	**1.52**	**X**	**1.03**	**A**
Jane	Ja7	1	0.87	A	1.06	A	1.47	X	1.26	X
		2	0.87	A	1.03	A	1.37	X	0.96	A
		Mean	**0.87**	**A**	**1.04**	**A**	**1.42**	**X**	**1.11**	**A**



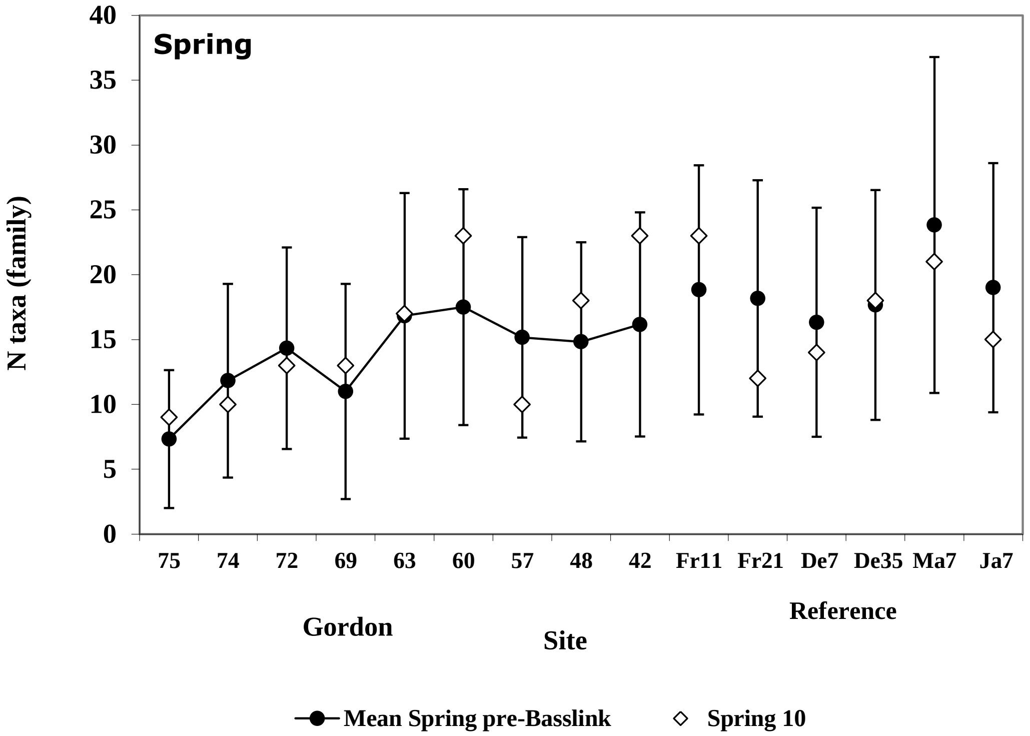
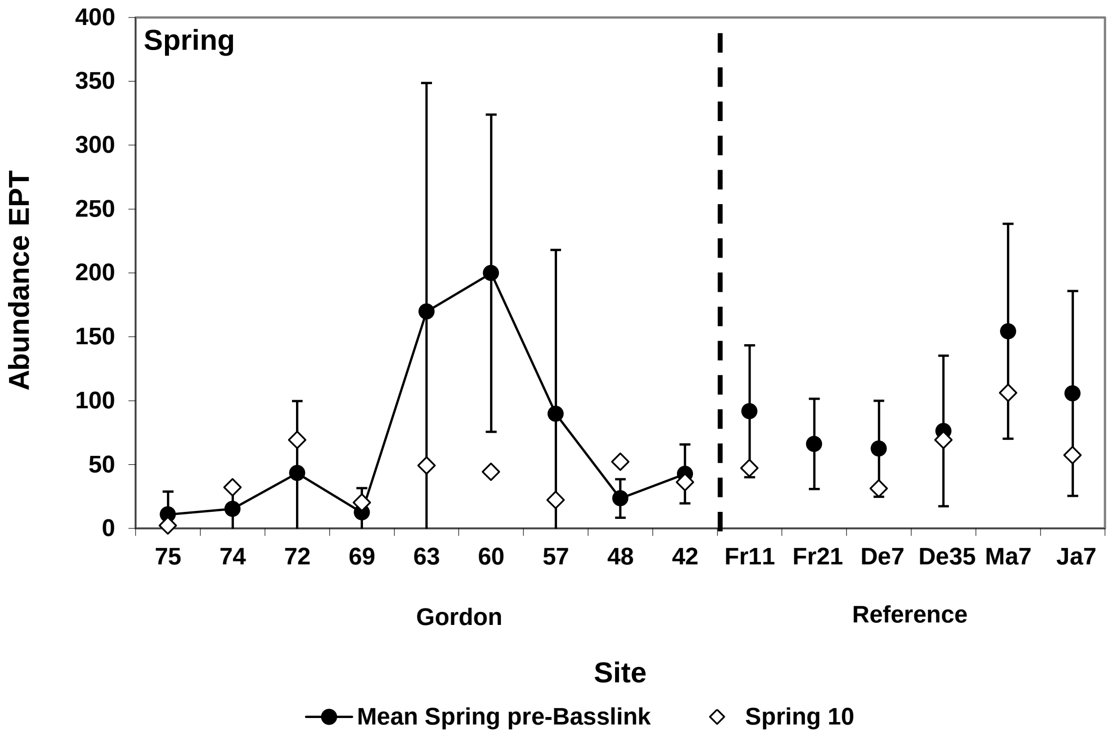


Figure 7-1 Comparison of total abundance of all benthic macroinvertebrates and diversity (number of taxa at family level) for spring 2010 with spring values from previous years. Error bars indicate standard deviations around the pre-Basslink 2002–05 mean



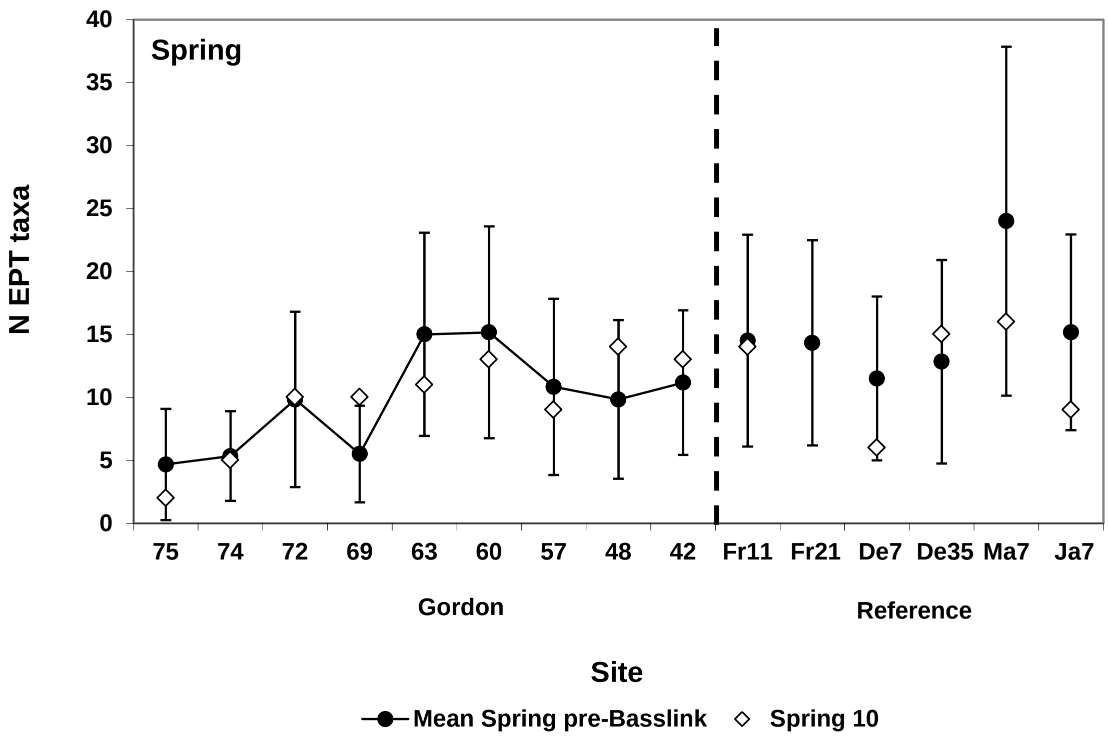


Figure 7-2 Comparison of total abundance and number of benthic EPT taxa (genus and species) for spring 2010 with spring values from previous years. Error bars indicate standard deviations around the pre-Basslink 2002–05 mean

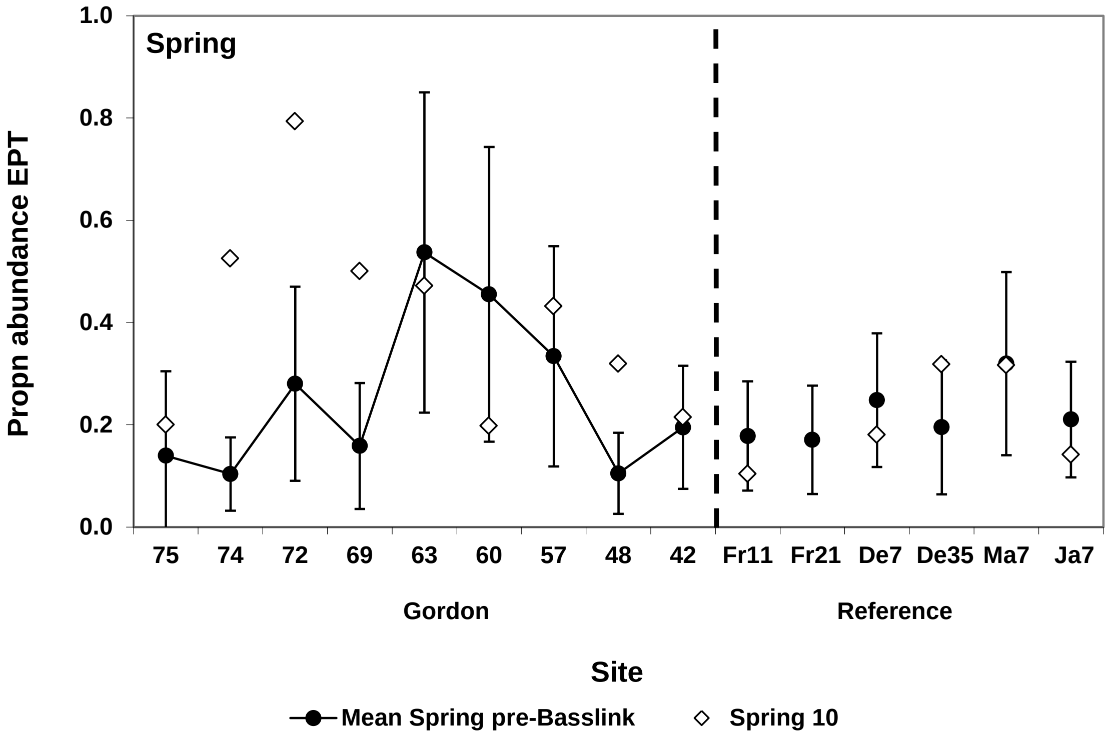
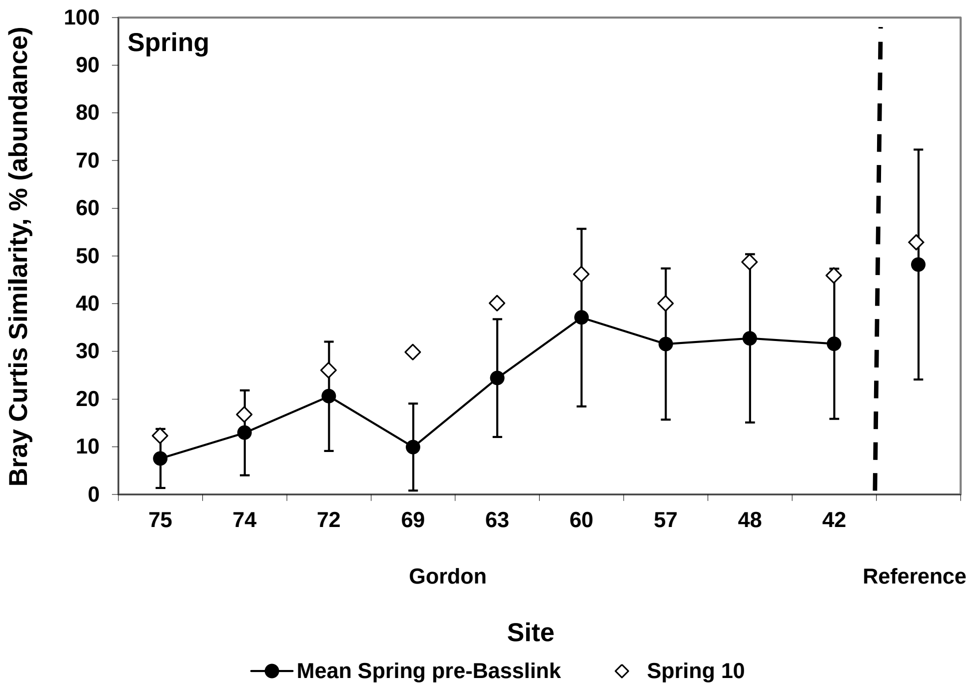


Figure 7-3 Comparison of proportion of total benthic macroinvertebrate abundance represented by EPT species for spring 2010 with spring values from previous years. Error bars indicate standard deviations around the pre-Basslink 2002–05 mean



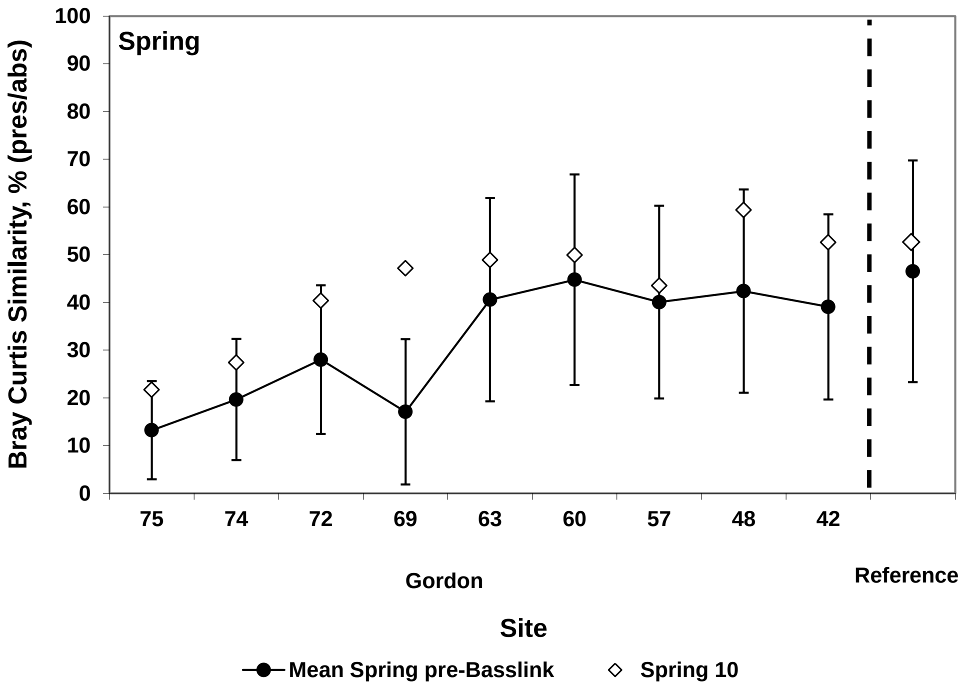
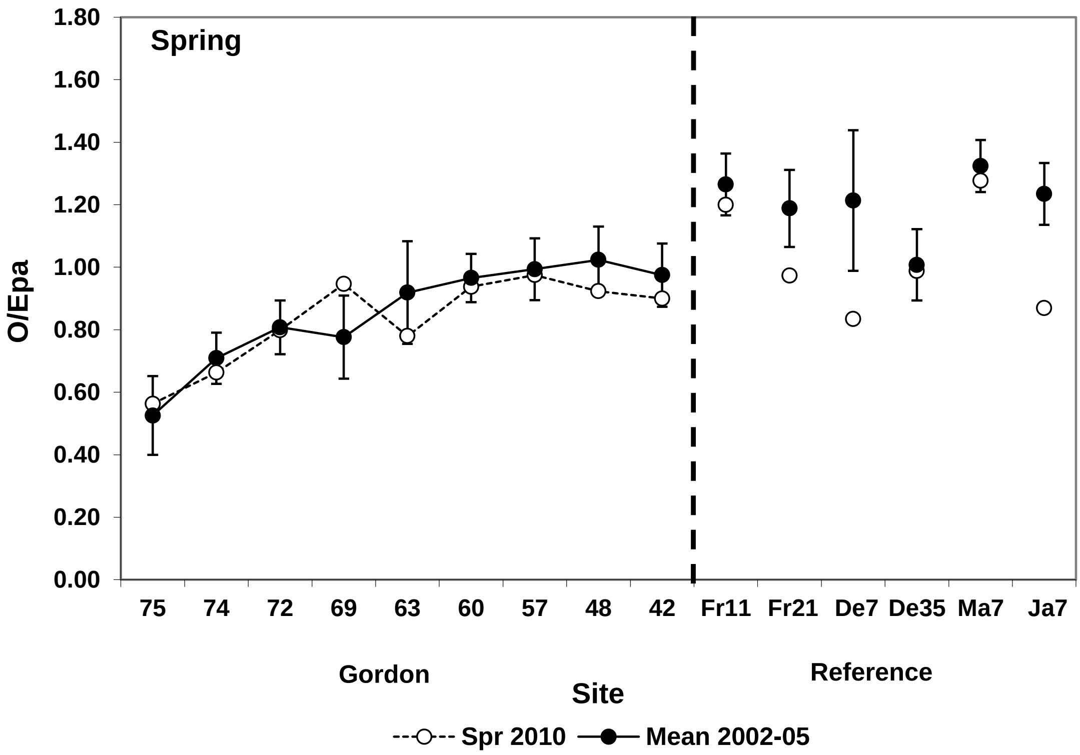


Figure 7-4 Comparison of values for the mean Bray Curtis Similarity between each sampled site and the reference sites for spring 2010 with spring values from previous years. Similarities are calculated with either abundance data (square root transformed) or presence/absence data. Error bars indicate standard deviations around the pre-Basslink 2002–05 mean. Note that the value for reference sites represents the mean of similarities between each reference site and the other reference sites



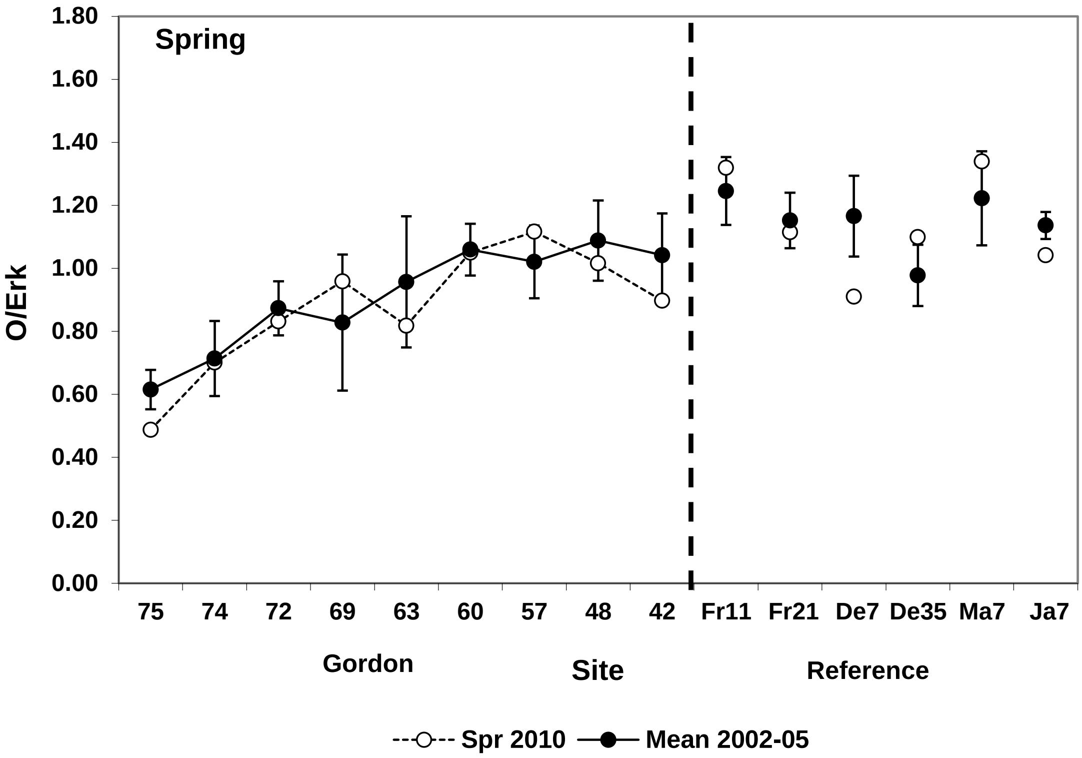


Figure 7-5 Comparison of O/Epa and O/Erk values for spring 2010 with values from previous years. Note consistently high O/Epa values at sites 69–75 upstream of Denison. Error bars indicate standard deviations around the pre-Basslink 2002–05 mean

Table 7-6 Quantitative macroinvertebrate ‘family level’ data (abundances as n per 0.18 m^2) for Gordon River and reference sites sampled in autumn (February) 2011

		River	**Gordon**									**Franklin**		**Denison**		**Maxwell**	**Jane**
		Site code	**75**	**74**	**72**	**69**	**63**	**60**	**57**	**48**	**42**	**Fr11**	**Fr21**	**De7**	**De35**	**Ma7**	**Ja7**
		Old site code	**G4**	**G4a**	**G5**	**G6**	**G7**	**G9**	**G10**	**G11B**	**G15**	**G19**	**G20**	**G21**	**D1**	**M1**	**J1**
Class	**Order**	**Family**															
Platyhelminthes	Turbellaria			1			2			2	3	5	1		1	1	4
Nematoda				1	1		1				2			1		6	9
Mollusca	Bivalvia	Sphaeriidae															1
	Gastropoda	Hydrobiidae		5		7	4	2	4	8	4			3	1	81	
		Ancylidae										7					
		Glacidorbidae			1												
Annelida	Oligochaeta		1	31	21	6	35	24	102	65	112	60	228	17	49	96	368
Arachnida	Acarina											1				2	
Crustacea	Amphipoda	Paramelitidae					4	3	1	1						1	
		Neoniphargidae		2		2											
	Isopoda	Janiridae	2	13					1		1	1			2	5	
	Ostracoda									1							
Insecta	Plecoptera	Eustheniidae		1											1	2	
		Austroperlidae		1	1	1											
		Gripopterygidae		18	6	2	10	10	6	1	7	4			12	4	7
		Notonemouridae											1				
	Ephemeroptera	Leptophlebiidae			9	2	12	26	25	12	21	31	25	30	57	68	165
		Baetidae					1	2	2	2		14	14	8	10	28	36
	Diptera	Chironomidae:															
		Chironominae		1		1	14	6	1	1	71	4	12		21	24	8
		Orthocladiinae		13	1	4	6	2		1	2	24	3	1	7	5	1
		Podonominae					1	1			3	5	1		4		3

Table 7-6 continued next page

		River	Gordon									Franklin		Denison		Maxwell	Jane
		Site code	**75**	**74**	**72**	**69**	**63**	**60**	**57**	**48**	**42**	**Fr11**	**Fr21**	**De7**	**De35**	**Ma7**	**Ja7**
		Old site code	**G4**	**G4a**	**G5**	**G6**	**G7**	**G9**	**G10**	**G11B**	**G15**	**G19**	**G20**	**G21**	**D1**	**M1**	**J1**
Class	**Order**	**Family**															
Insecta (cont)	Diptera (cont)	Diamesinae							1			6					
		Aphroteniinae															1
		Simuliidae	1	4	2		18	112	69	89	168	105	194	5	318	73	35
		Tipulidae		1	1	1	6	1	1							1	1
		Athericidae												3			
		Blephariceridae						1	1	3	2	14					1
		Ceratopogonidae											1		5		
		Empididae					1		1	2	1				3	2	
		Tanyderidae						1									
		Dip. Unid. Pup.		2			3	2	1		6	8	7	2	1	1	
	Trichoptera	Calocidae							1				1			1	2
		Conoesucidae		3	1	3	7	2	1			7				27	
		Glossosomatidae									1	3	1			2	4
		Helicophidae														2	
		Hydrobiosidae		4	5	1	2	6	6	2	5	4	4		8	6	12
		Hydropsychidae		155	9	18	6	4	1		14		1		1	11	
		Leptoceridae			1		3		2		1	4	2	1	10	18	37
		Philorheithridae			1				1	2		1	6	2	1	8	1
		Trich. Unid. Pup.		5	1			3	3	2	1	1				1	
	Coleoptera	ElmidaeA			2	2	1	5	8	5	3	23	2	15	35	55	57
		ElmidaeL			3	1	5	6	14	8		41	12	95	41	104	112
		ScirtidaeL			1		1		1	3	1	28	71	29	35	18	46
		PsepheniidaeL				1					2		1	1	1	3	9
		Total abundance	**4**	**261**	**67**	**52**	**143**	**219**	**254**	**210**	**431**	**401**	**588**	**213**	**624**	**656**	**920**
		N Taxa (families)	**3**	**18**	**18**	**15**	**22**	**20**	**24**	**19**	**22**	**24**	**21**	**15**	**23**	**30**	**23**

Table 7-6 continued

Table 7-7 Quantiative ‘species level’ data for EPT taxa (Ephemeroptera, Plecoptera and Trichoptera) for Gordon River and reference sites sampled in autumn (February) 2011 (abundances as n per 0.18 m^2)

		River	Gordon									Franklin		Denison		Maxwell	Jane
		Site code	**75**	**74**	**72**	**69**	**63**	**60**	**57**	**48**	**42**	**Fr11**	**Fr21**	**De7**	**De35**	**Ma7**	**Ja7**
		Old site code	**G4**	**G4a**	**G5**	**G6**	**G7**	**G9**	**G10**	**G11B**	**G15**	**G19**	**G20**	**G21**	**D1**	**M1**	**J1**
Order	**Family**	**Genus/Species**															
Plecoptera	Eustheniidae	*Eusthenia costalis*														1	
		Eusthenia spectabilis		1											1	1	
	Gripopterygidae	*Cardioperla incerta*	1		2											1	
		Cardioperla media/lobata						1								1	
		Dinotoperla serricauda			1											1	1
		Leptoperla varia													1		
		Trinotoperla tasmanica					2										
		Trinotoperla zwicki		18	3	2	8	9	6	1	7	4			11	1	6
	Austroperlidae	*Tasmanoperla thalia*		1	1	1											
	Notonemouridae	*Austrocercoides* sp											1				
Ephemeroptera	Baetidae	*Baetid Genus 2 MV* sp. 3					1	2	2	2		14	14	8	10	28	36
	Leptophlebiidae	*Nousia* sp. AV5/6			8		6	21	21	12	14	25	12	28	42	45	165
		Nousia sp. AV7				1	6	2	2		4		5		7	4	
		Nousia sp. AV9							1			4				19	
		Tillyardophlebia sp AV2			1	1		3	1		3	2	8	2	8		
Trichoptera	Calocidae	*Tamasia variegata*							1				1			1	2
	Conoesucidae	*Conoesucus brontensis*						2				4					
		Conoesucus digitiferus		1	1	1	3									2	
		Conoesucus nepotulus		2		2	4		1							5	
		Conoesucus norelus										3					
		Costora delora														1	

Table 7-7 continued next page

		River	**Gordon**									**Franklin**		**Denison**		**Maxwell**	**Jane**
		Site code	**75**	**74**	**72**	**69**	**63**	**60**	**57**	**48**	**42**	**Fr11**	**Fr21**	**De7**	**De35**	**Ma7**	**Ja7**
		Old site code	**G4**	**G4a**	**G5**	**G6**	**G7**	**G9**	**G10**	**G11B**	**G15**	**G19**	**G20**	**G21**	**D1**	**M1**	**J1**
Order	**Family**	**Genus/Species**															
Trichoptera (cont)	Conoesucidae (cont)	*Costora rotosca*														16	
		Matasia satana														3	
	Glossosomatidae	*Agapetus* sp. AV1									1	3	1			2	4
	Helicophidae	*Allocoella longispina*														2	
	Hydrobiosidae Includes all#	*Ethochorema nesydrion*													1		3
		Moruya opora		2	1		1	1	2		2						
		# *Taschorema apobamum*		2	3			1	1		1				1	1	
		# *Taschorema asmanum*			1		1	1	1		2	1			2		3
		Taschorema ferulum grp				1		3	1	2		1	4		3	4	6
		Ulmerochorema rubiconum							1			2			1	1	
	Hydropsychidae	*Asmicridea* sp. AV1		155	9	18	6	4	1		14		1		1	10	
		Smicrophylax sp AV3														1	
	Leptoceridae	*Notalina* sp.AV1			1		2		2		1	4	2	1	9	18	37
		Triplectides australis					1										
		Triplectides sp.													1		
	Philorheithridae	*Tasmanthrus galbinomaculats*								2							
		Tasmanthrus sp.			1				1			1	6	2	1	8	1
		Abundance EPT	**1**	**182**	**33**	**27**	**41**	**50**	**45**	**19**	**49**	**68**	**55**	**41**	**100**	**177**	**264**
		N EPT Taxa	**1**	**8**	**13**	**8**	**12**	**12**	**16**	**5**	**10**	**13**	**11**	**5**	**16**	**25**	**11**

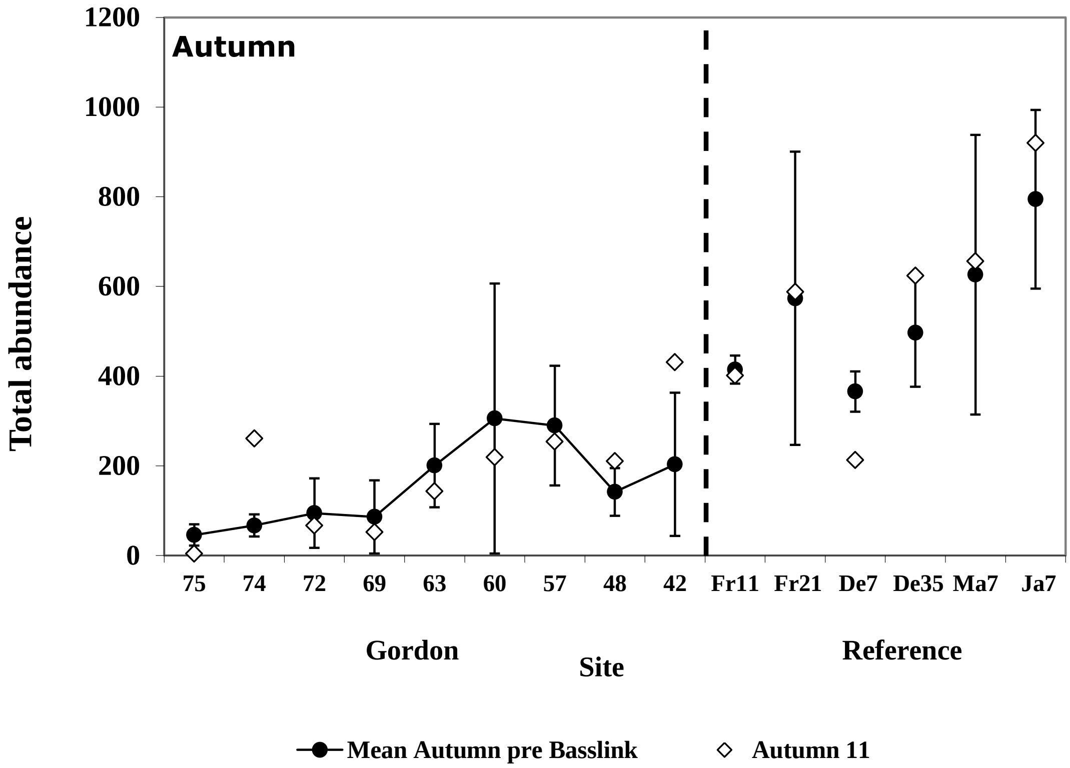
Table 7-7 continued

Table 7-8 RBA macroinvertebrate data (abundances per live-picked sample) for Gordon River and reference sites sampled in autumn 2011

		River	Gordon																		Franklin				Denison				Jane		Maxwell	
		Site	**75**		**74**		**72**		**69**		**63**		**60**		**57**		**48**		**42**		**Fr11**		**Fr21**		**De7**		**De35**		**Ja7**		**Ma7**	
Class	**Order**	**Family**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**
Platyhelminthes	Turbellaria			2								1		1												1						
Mollusca	Gastropoda	Hydrobiidae											3	1												1					14	1
Annelida	Oligochaeta				1	4	8	28	11	3	10	10	25	23	15	4	20	13	15	20	1	2	4	6	4	10	13	3	7	13	2	3
Arachnida	Acarina												1									2		1	1				1		1	
Crustacea	Amphipoda	Paramelitidae											2	3	1	1	4	2	1					2	4	2					4	1
		Paracalliopidae									1									1												
		Neoniphargidae	2	1	4	4	1	1	1	3	1	1			1																	
	Isopoda	Janiridae	6	2																												
		Phreatoicidea						1	3				1		1																	
Insecta	Plecoptera	Eustheniidae			4	4			1	1			1	2	3	2	1	4	4	3	3	1	3	5	3	1	4	10		2		4
		Austroperlidae								1				2																		
		Gripopterygidae	2	4	19	22	22	15	3		4	6	5	4	3	4	4	9	3	3	9	7	3	2			7	17	7	11	3	9
	Ephemeroptera	Leptophlebiidae	5	3	1	2	55	67	23	27	29	25	57	42	59	95	67	33	40	15	38	41	12	66	58	87	73	64	26	100	50	80
		Baetidae										1	5		1	2	4	5	5	1	21	24	5	21	7	16	22	5	15	32	17	42
	Odonata	Telephlebiidae															1											1				
	Diptera	Chironomidae *Sub-fam Chironominae*											1		1		1	1	1	2		2	2	1	2	3	3	2	4	1	1	1
		Sub-fam Orthocladiinae	3	22		2	2	2	1	1	2	1		2			3	1		1	12	16	2				1	5	6	5	1	5
		Sub-fam Podonominae	1					1			1	1	16	11	5	9	11	1	4	5	5	1	7	12	4	15	8	6	2	8	1	2
		Sub-fam Tanypodinae					1			1																						
		Sub-fam Diamesinae	1	2																	4	5										
		Simuliidae	1	1			4	5		3	5	3	9	5	9	27	17	32	17	18	34	39	21	21	7	6	32	44	17	13	3	9
		Tipulidae			1		5	4		9		1		2		1					1			1			1		2			
		Athericidae					1																		1	1						
		Blephariceridae					1											1		1	9	5	2	1								

		River	**Gordon**																		**Franklin**				**Denison**				**Jane**		**Maxwell**	
		Site	**75**		**74**		**72**		**69**		**63**		**60**		**57**		**48**		**42**		**Fr11**		**Fr21**		**De7**		**De35**		**Ja7**		**Ma7**	
Class	**Order**	**Family**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**
		Ceratopogonidae								1				1											4							
Insecta (cont)	Diptera (cont)	Chaoboridae		1																												
		Empididae														1																
		Dip. Unid. Pup.								1				1	1																	
	Trichoptera	Calocidae															1													1		
		Conoesucidae					2	1	4		3	3							1	1											8	9
		Ecnomidae																													1	
		Glossosomatidae									1									1			1	1		1			1	3		
		Hydrobiosidae	8	22	14	3	11	17	12	39	13	8	18	20	7	8	19	19	17	5	14	34	16	43	18	26	25	13	27	30	13	27
		Hydropsychidae			10	46	3	3		2		1	1	1				1	1			2									2	
		Hydroptilidae									1																					
		Leptoceridae	2						1	14	1	2				2	5	3	1		4	4		11	16	7	14	6	6	6	14	10
		Philorheithridae							1	6		1	1	3		2	4	2	1							10	2		2	1	23	1
		Trich. Unid. Pup.			2	2	4		1				1	3	2	2	3	1	1			2										
	Coleoptera	ElmidaeA		1			1	1	6	2	1	1	7	5	14	7	11			1	5	13	7	6	14	35	13	19	16	25	19	15
		DytiscidaeA																							2							
		ElmidaeL							1	1			1			1	1				5	1		1	4	11	5	1	2	4		2
		ScirtidaeL	1				1									1	4				12	4	6	9	9	6	11		7	6	1	3
		PsepheniidaeL						1				1								1					1	2	1	1	4		5	2
		N Taxa	**12**	**12**	**10**	**10**	**17**	**15**	**15**	**18**	**15**	**18**	**19**	**20**	**16**	**18**	**20**	**17**	**16**	**17**	**17**	**20**	**15**	**19**	**19**	**20**	**18**	**16**	**19**	**18**	**21**	**20**

Table 7-8 continued



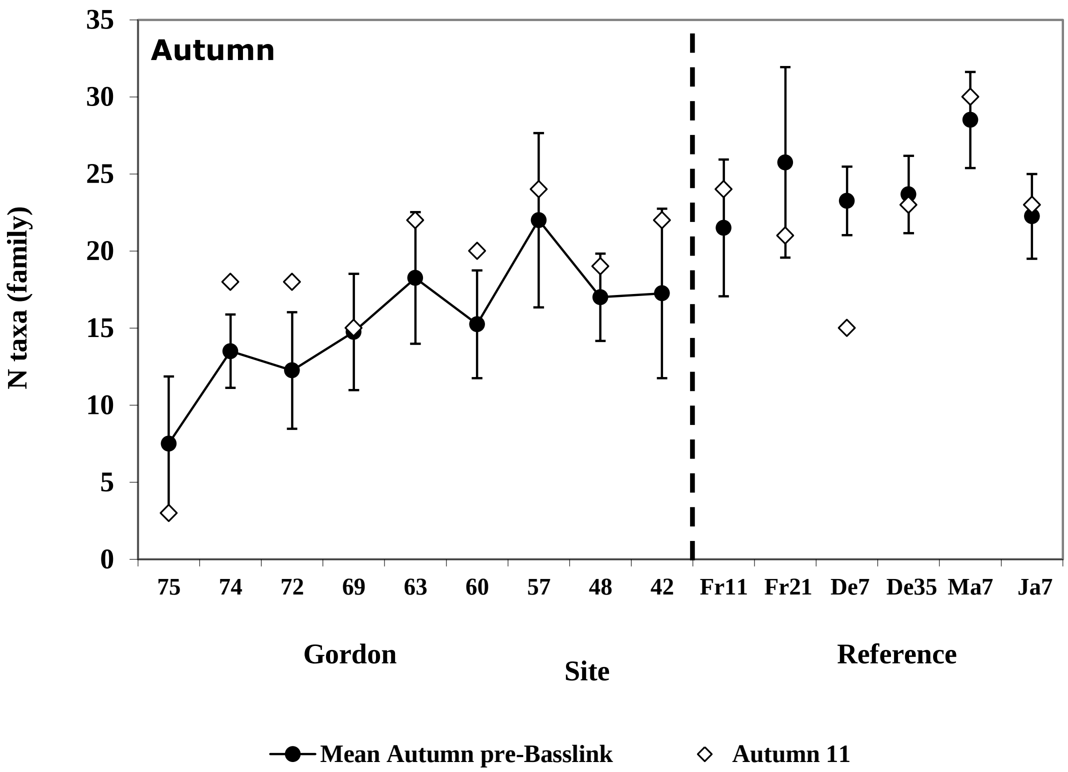
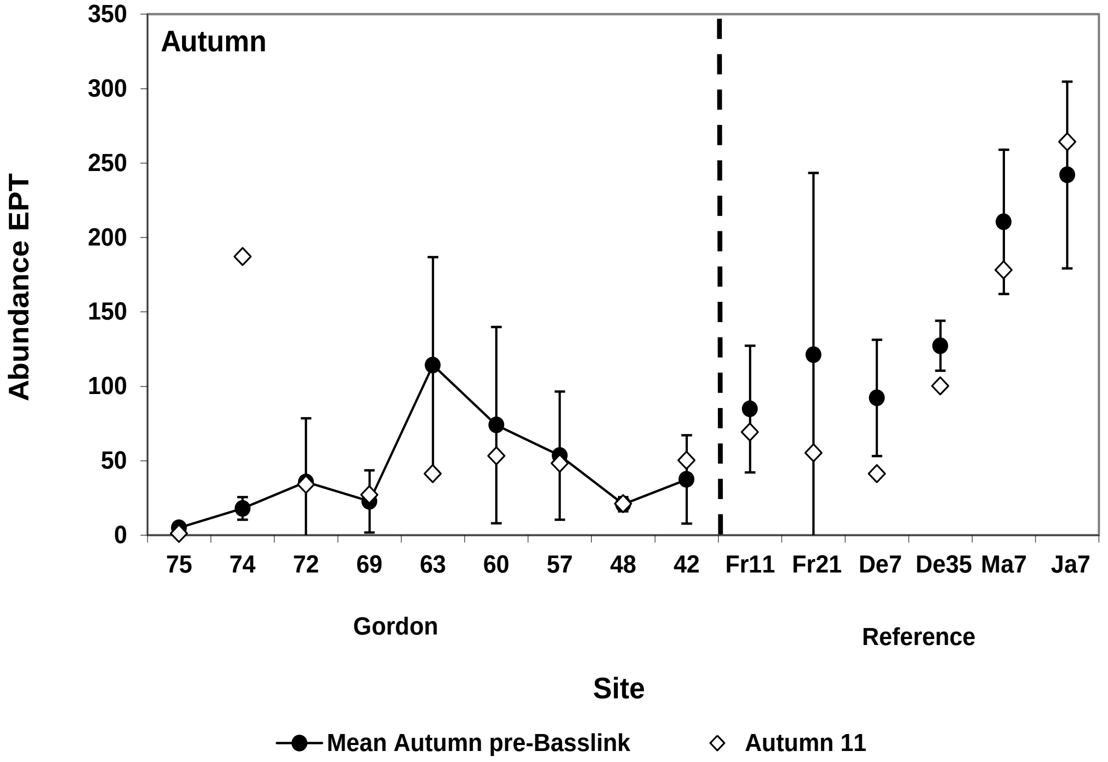


Figure 7-6 Comparison of total abundance and diversity (number of taxa at family level) for autumn 2011 with autumn values from previous years. Error bars indicate standard deviations around the pre-Basslink 2002–05 mean



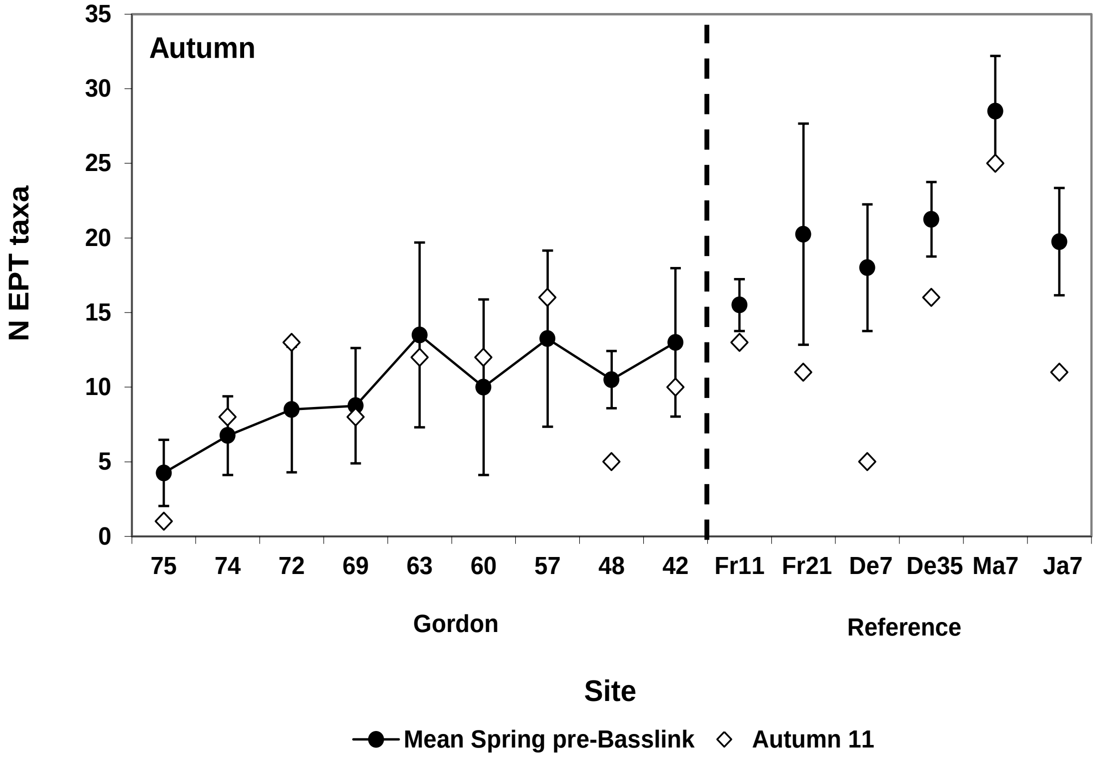


Figure 7-7 Comparison of total abundance and number of benthic EPT species for autumn 2011 with autumn values from previous years. Error bars indicate standard deviations around the pre-Basslink 2002–05 mean

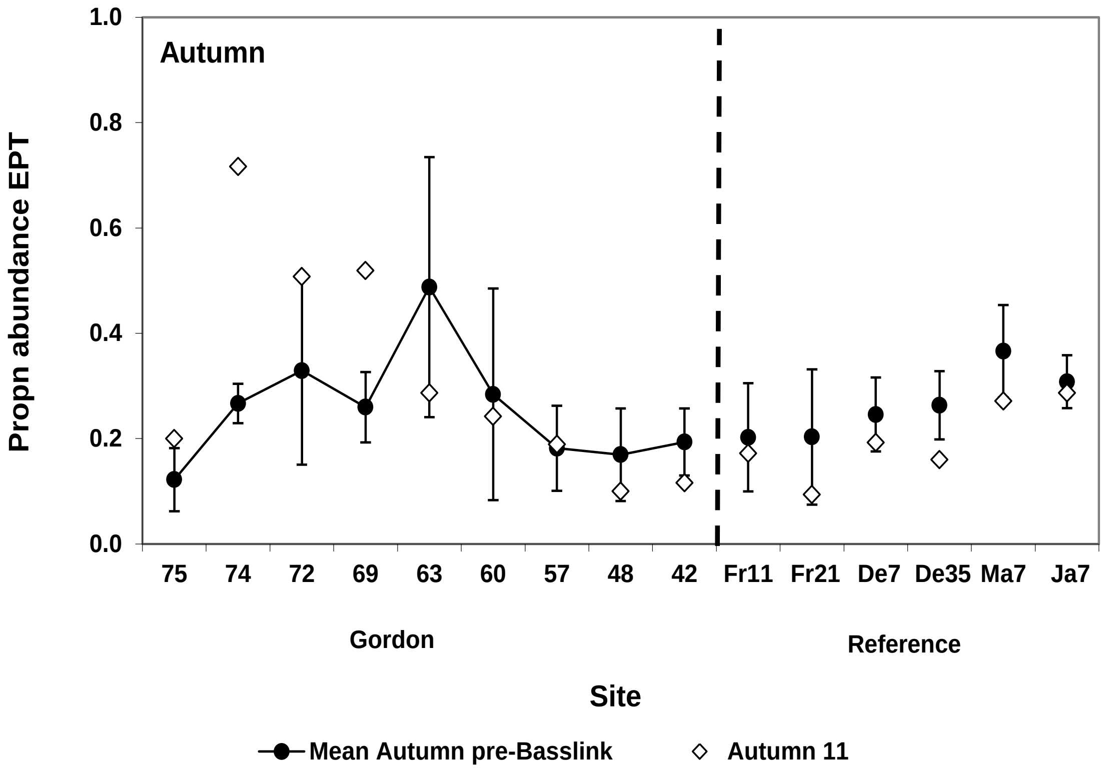
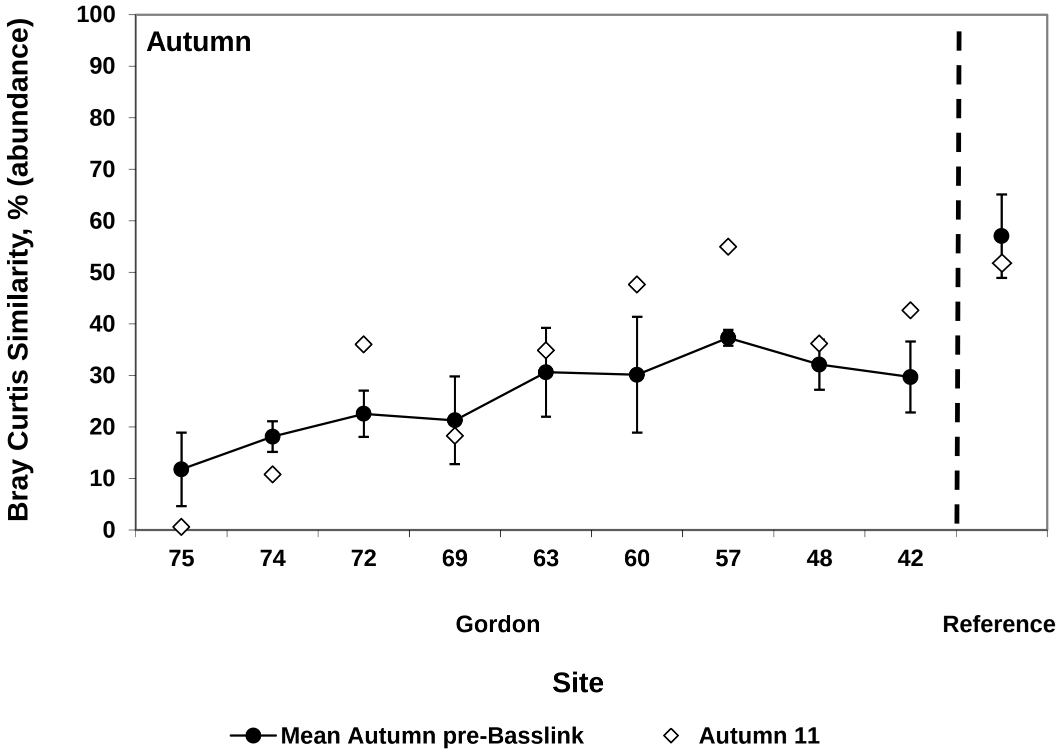


Figure 7-8 Comparison of proportion of total benthic macroinvertebrate abundance represented by EPT species for autumn 2011 with autumn values from previous years. Error bars indicate standard deviations around the pre-Basslink 2002–05 mean



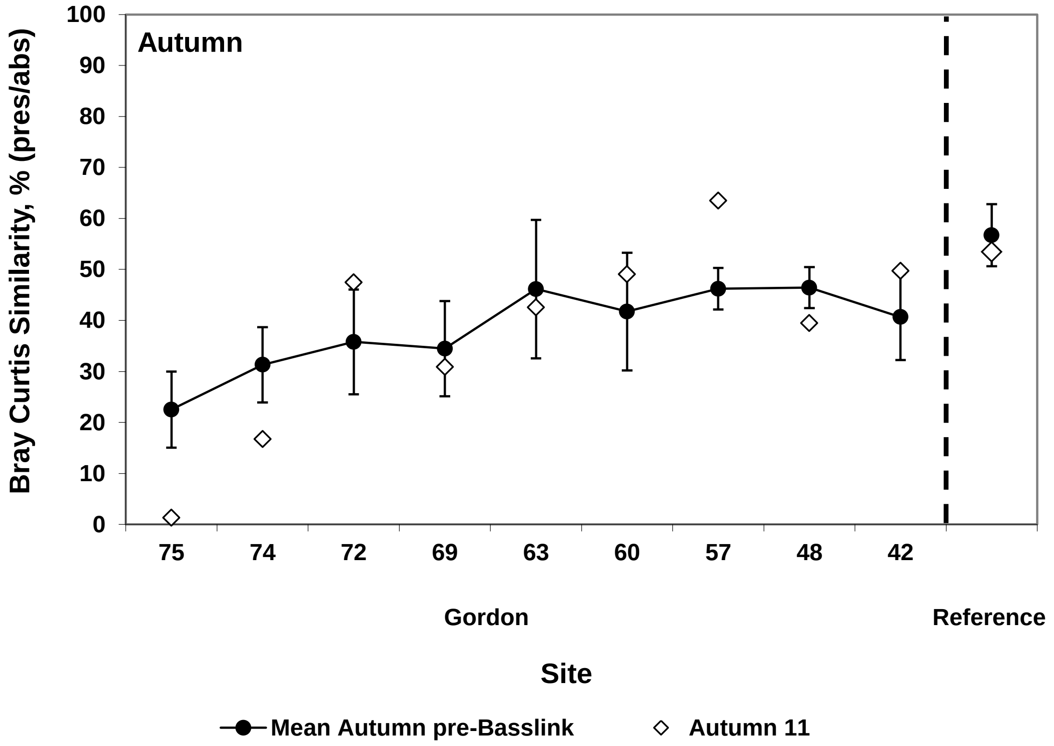
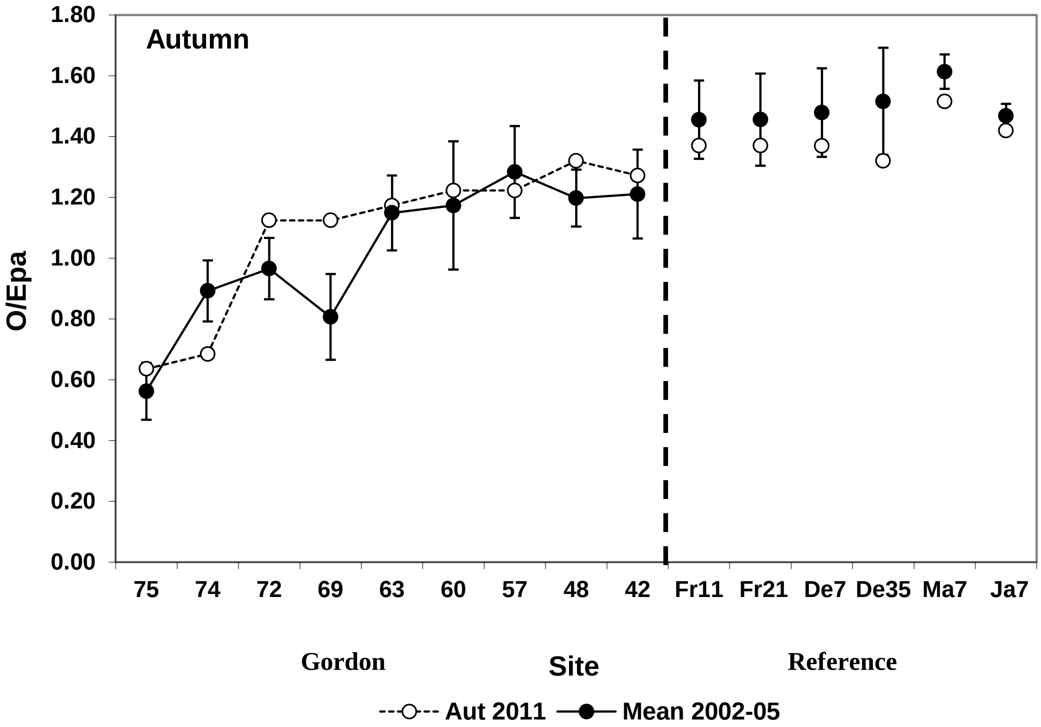


Figure 7-9 Comparison of values for the mean Bray Curtis Similarity between each sampled site and the reference sites for autumn 2011 with autumn values from previous years. Similarities are calculated with either abundance data (square root transformed) or with presence/absence data. Error bars indicate standard deviations around the pre-Basslink 2002–05 mean. Note that the value for reference sites represents the mean of similarities between each reference site and the other reference sites



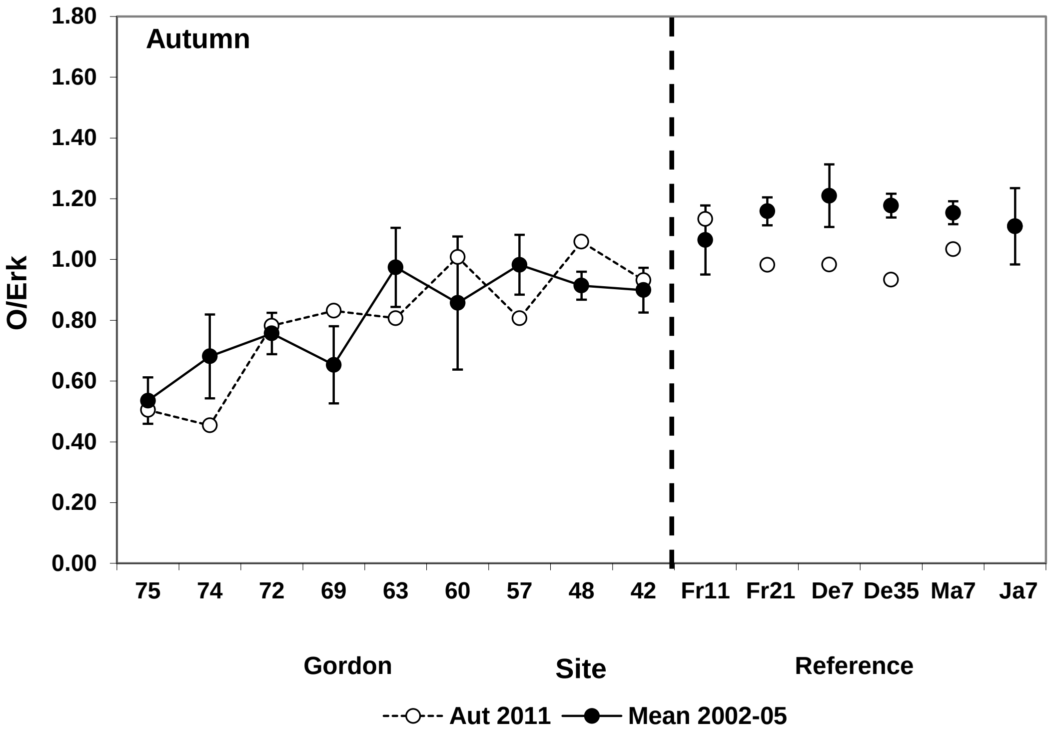


Figure 7-10 Comparison of O/Epa and O/Erk values for autumn 2011 with values from previous years. Note consistently high O/Epa values at sites 69 –75 upstream of Denison. Error bars indicate standard deviations around the pre-Basslink 2002–05 mean

7.4 Comparisons with triggers

7.4.1 Results

Nine metrics have been identified for assessing the degree of any changes in benthic macroinvertebrates in the Gordon River due to Basslink operations. These metrics are grouped into five overall components as follows:

1. Community Structure
   - Bray Curtis (abundance)
   - O/Erk
2. Community Composition
   - Bray Curtis (pres/abs data)
   - O/Epa
3. Taxonomic richness
   - N Taxa (fam)
   - N EPT Species
4. Ecologically significant species
   - Proportion of total Abundance as EPT
   - Abundance EPT
5. Biomass / productivity
   - Total abundance

Trigger values for these metrics have been established based on the 95th percentile of pre-Basslink values (Appendix 10). These trigger values are used in reporting on whether Limits of Acceptable Change (LOAC) have been exceeded or not post-Basslink. Triggers have been developed for each individual site in the Gordon River, as well as for the entire river ('whole-of-river', WOR) and zones within the river. Seasonal differences are also taken into account for the WOR case. Two zones have been described for benthic macroinvertebrates – zone 1 (upstream of the Denison confluence, incorporating sites 69–75) and zone 2 (downstream of the Denison confluence, incorporating sites 42 to 60).

Values of all metrics for 2010–11 are shown in Table 7-9. Plots of the trigger levels for each metric are shown along with the value for the metric recorded in 2010–11, at individual site level (Figure 7-11 to Figure 7-15) and at whole-of-river (WOR) and zone level (Figure 7-16 to Figure 7-20). Similar plots are shown for trigger bounds and the mean value of each metric for the four-year post-Basslink period 2006–07 to 2010–11, again at individual site level (Figure 7-21 to Figure 7-25) and at whole-of-river (WOR) and zone level (Figure 7-26 to Figure 7-30).

Table 7-9 Values of all metrics for each site sampled in spring 2010 and autumn 2011. X indicates species data rejected due to poor sample quality

Key : BP = biomass/productivity, BCPA = Bray Curtis (pres/abs data), NTF = N Taxa (fam)

			Spring 2010									Autumn 2011								
			Community Structure		Community Composition		Taxonomic richness		Ecologically significant species		BP	Community Structure		Community Composition		Taxonomic richness		Ecologically significant species		BP
River	Site code	Old code	Bray Curtis (abund)	O/Erk	BCPA	O/Epa	NTF	N EPT Spec.	Propn Abund EPT	Abund EPT	Density (Total abund)	Bray Curtis (abund)	O/Erk	BCPA	O/Epa	NTF	N EPT Spec.	Propn Abund EPT	Abund EPT	Density (Total abund)
Gordon	75	G4	12.28	0.49	21.70	0.56	9	2	0.200	2	10	0.61	0.50	1.28	0.64	3	1	0.250	1	4
	74	G4a	16.73	0.70	27.38	0.66	10	5	0.508	31	61	10.76	0.45	16.71	0.68	18	8	0.716	187	261
	72	G5	26.01	0.83	40.39	0.80	13	10	0.770	67	87	36.02	0.78	47.47	1.12	18	13	0.507	34	67
	69	G6	29.83	0.96	47.12	0.95	13	10	0.500	20	40	18.24	0.83	30.86	1.12	15	8	0.519	27	52
	63	G7	40.10	0.82	48.88	0.78	17	11	0.471	49	104	34.83	0.81	42.58	1.17	22	12	0.287	41	143
	60	G9	46.17	1.05	49.94	0.94	23	13	0.193	43	223	47.65	1.01	49.08	1.22	20	12	0.242	53	219
	57	G10	40.01	1.12	43.52	0.97	10	9	0.431	22	51	54.97	0.81	63.49	1.22	24	16	0.189	48	254
	48	G11B	48.72	1.02	59.35	0.92	18	14	0.294	48	163	36.18	1.06	39.45	1.32	19	5	0.100	21	210
	42	G15	45.92	0.90	52.58	0.90	23	13	0.190	32	168	42.62	0.93	49.75	1.27	22	10	0.116	50	431
Reference																				
Franklin	Fr11	G19	42.58	1.32	48.05	1.20	23	14	0.104	47	454	54.55	1.13	58.00	1.37	24	13	0.172	69	401
	Fr21	G20	x	1.11	x	0.97	12	x	x	x	329	53.48	0.98	58.75	1.37	21	11	0.094	55	588
Denison	De7	G21	39.76	0.91	41.60	0.83	14	6	0.180	31	172	48.48	0.98	48.47	1.37	15	5	0.192	41	213
	De35	D1	53.69	1.10	61.83	0.99	18	15	0.318	69	217	56.38	0.93	56.37	1.32	23	16	0.160	100	624
Maxwell	Ma7	M1	54.29	1.34	59.77	1.28	21	16	0.316	106	335	45.61	1.03	45.54	1.52	30	25	0.271	178	656
Jane	Ja7	J1	52.09	1.04	54.87	0.87	15	9	0.141	57	403	49.33	1.11	57.91	1.42	23	11	0.287	264	920

7.4.2 Trigger status

The following section summarises and comments on the observations for 2010–11 in comparison with the trigger values.

7.4.2.1 Community structure

Bray Curtis (abundance): All sites and zones fall within the trigger bounds except site 57 which shows a minor exceedance, while a minor exceedance is observed for the Whole-of-river (WOR) case (Figure 7-11 and Figure 7-16).

Comment – Compliant, and represents a minor positive post-Basslink change due to increased abundance and number of aquatic insect species, but of limited ecological significance.

O/Erk All sites compliant at site and WOR and zone levels (Figure 7-11 and Figure 7-16).

Comment – Consistent with pre-Basslink conditions.

7.4.2.2 Community composition

Bray Curtis (pres/abs data) All sites compliant (Figure 7-12 and Figure 7-17), though exceeding upper trigger for zone 2 (all year case).

Comment – As for Bray Curtis (abundance) indicator.

O/Epa All sites compliant (Figure 7-12 and Figure 7-17).

Comment – Consistent with pre-Basslink conditions.

7.4.2.3 Taxonomic richness

N Taxa (fam): All sites and zones compliant, with an exceedance for the WOR autumn season (Figure 7-13 and Figure 7-18).

Comment – Consistent with pre-Basslink conditions but improvement overall in autumn.

N EPT Species: All sites and zones compliant, though site 75 falling just above lower trigger bound (Figure 7-13 and Figure 7-18).

Comment – Within pre-Basslink ranges, though watching brief for site 75 recommended.

7.4.2.4 Ecologically significant species

Proportion of total abundance as EPT: All sites in zone 2 were compliant, as well as for WOR spring and autumn. All values were above or at upper trigger levels for 1 sites 69–75 (Figure 7-14 and Figure 7-19).

Comment – Consistent with pre-Basslink conditions for zone 2, improvement above trigger bounds for zone 1.

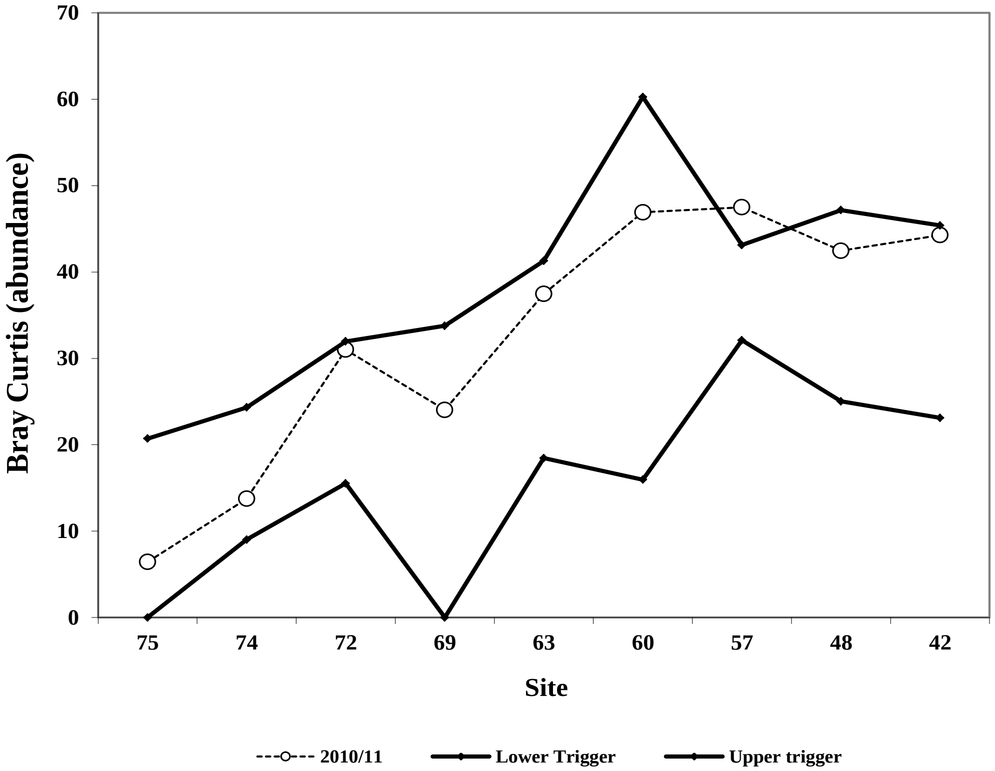
Abundance EPT: High at all sites except site 60, exceeding or falling on upper trigger bound at sites 63, 72, and 74 (zone 1) and 42–57 (zone 2); exceeds for WOR (all year and both seasons) and zone 1 and falls at upper bound for zone 2 (Figure 7-14 and Figure 7-19). Value is low for site 75, but still compliant.

Comment – High densities of *Asmicridea* caddis, especially at sites 69–74, contribute to this metric, though other taxa now also contribute (e.g. Grypopterygidae, Hydrobiosidae). Enhanced densities are a product of post-Basslink environmental flow constancy, interacting with food inputs from the tributary streams.

7.4.2.5 Biomass/productivity

Total abundance: All sites compliant, with low value at site 75. Value close to upper bound for WOR in autumn.

Comment – Compliant.



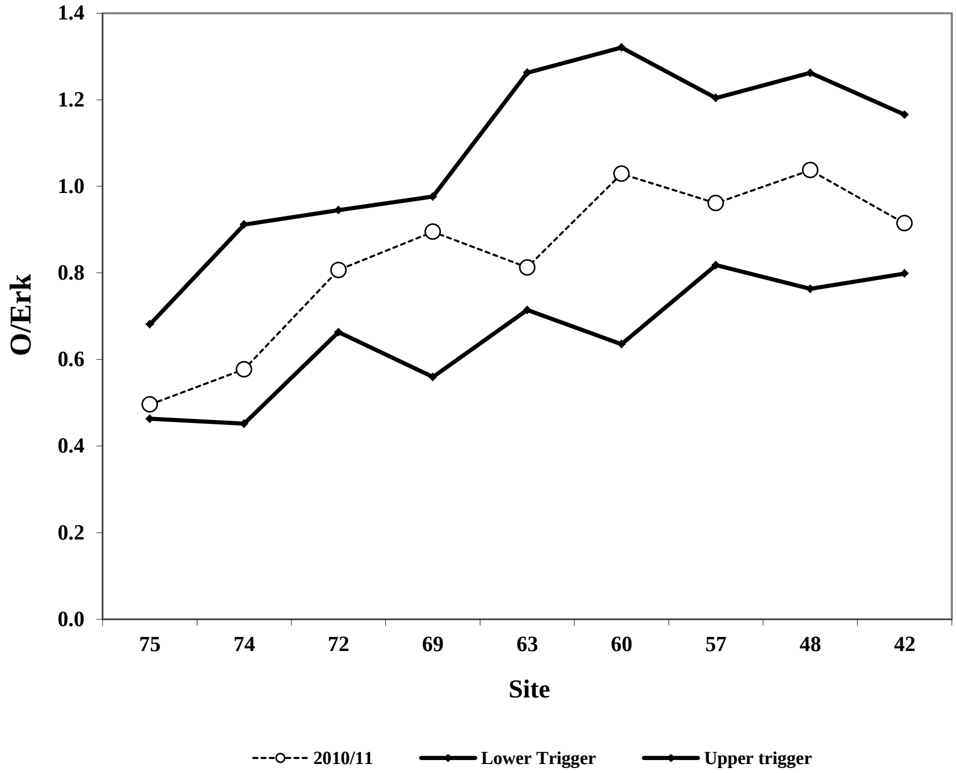
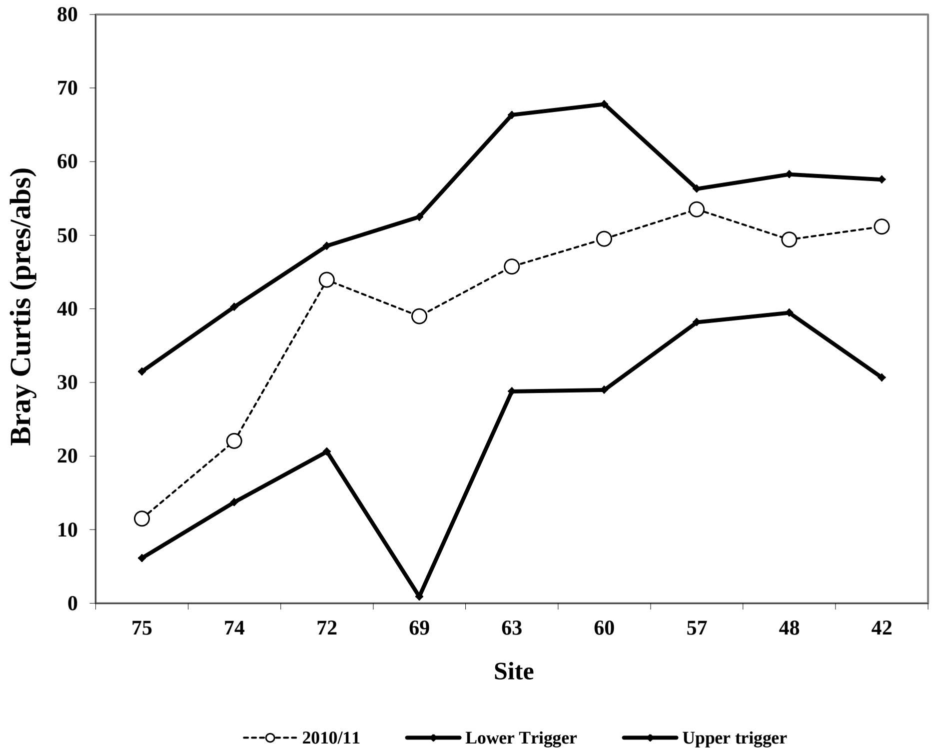


Figure 7-11 Community structure metric values for 2010–11 compared with upper and lower LOAC trigger values for each site in the Gordon River. Trigger values based on the 95th percentile of pre-Basslink data



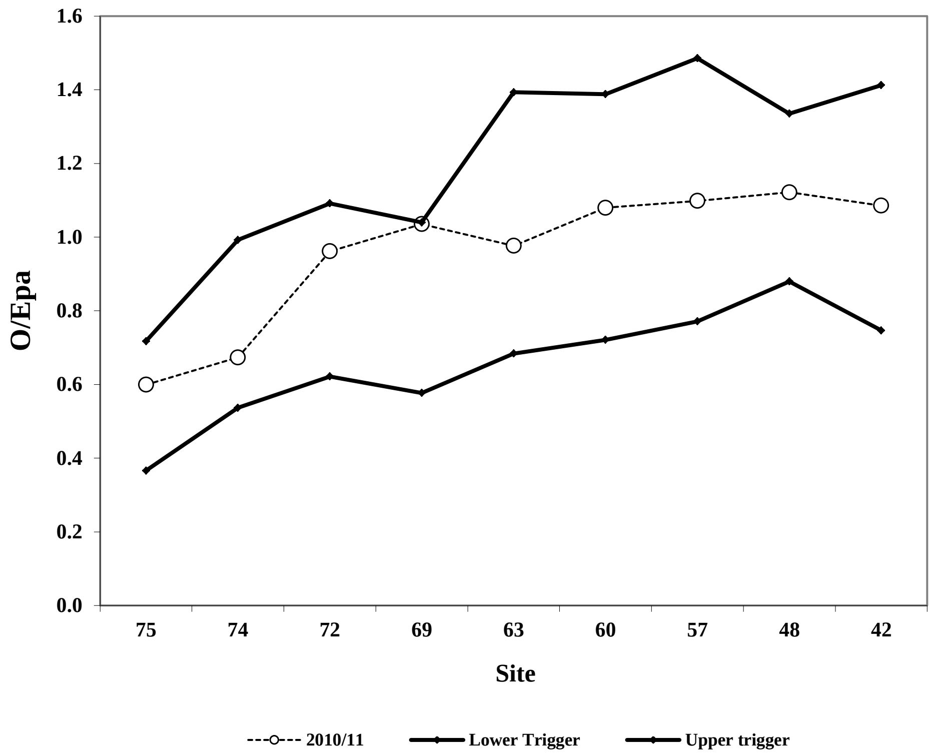
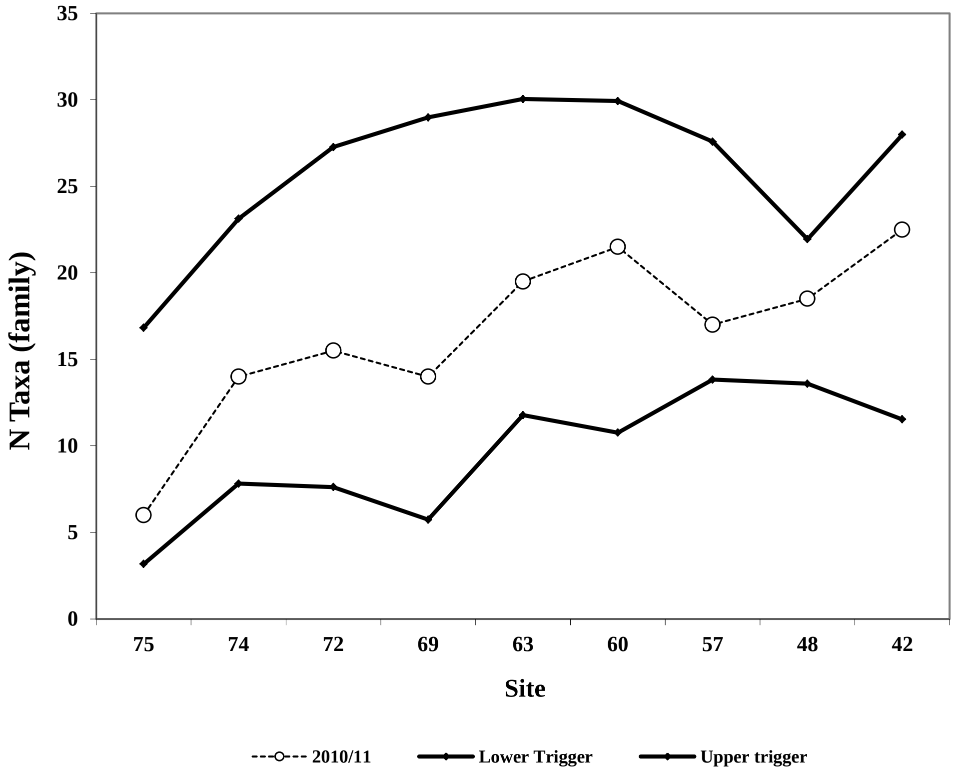


Figure 7-12 Community composition metric values for 2010–11 compared with upper and lower LOAC trigger values for each site in the Gordon River. Trigger values based on the 95th percentile of pre-Basslink data



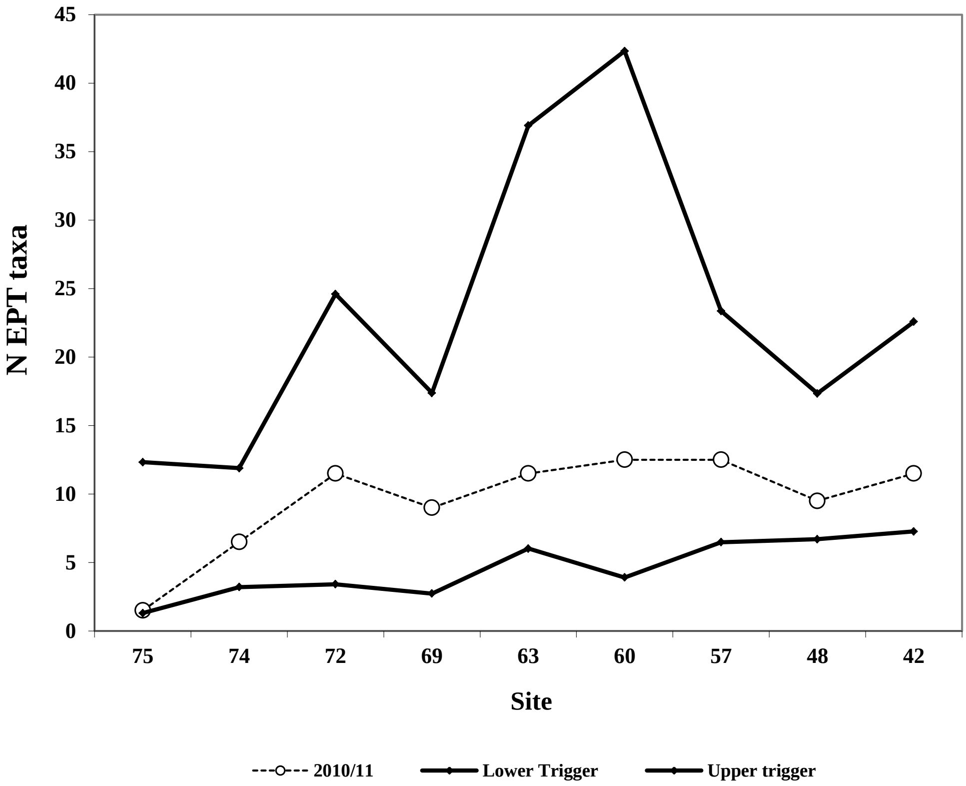
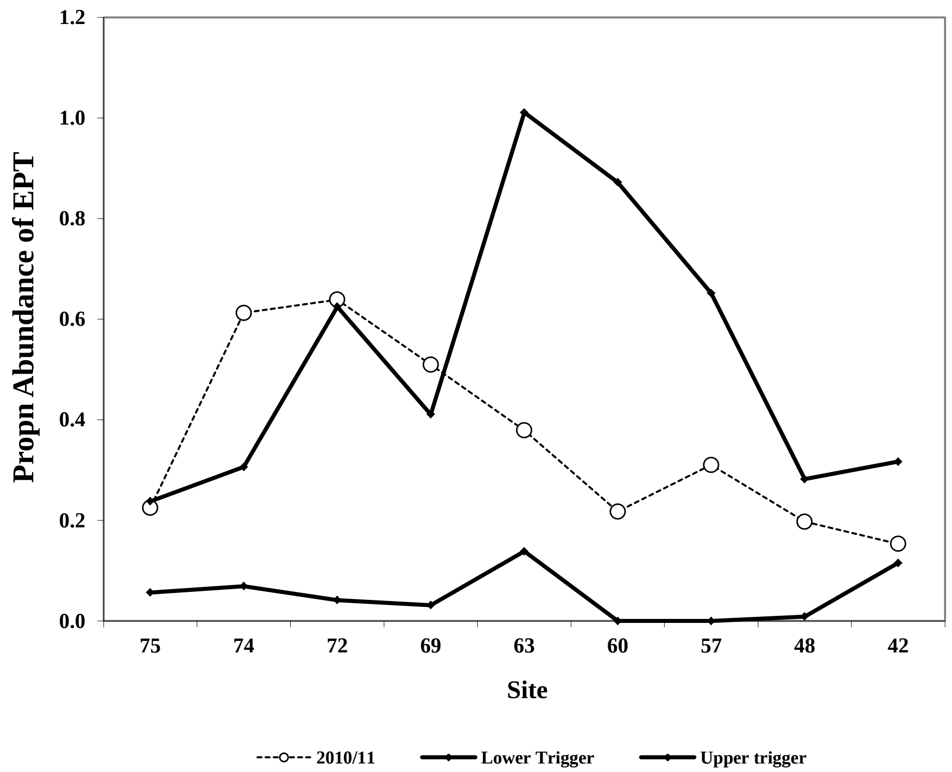


Figure 7-13 Taxonomic richness metric values for 2010–11 compared with upper and lower LOAC trigger values for each site in the Gordon River. Trigger values based on the 95th percentile of pre-Basslink data



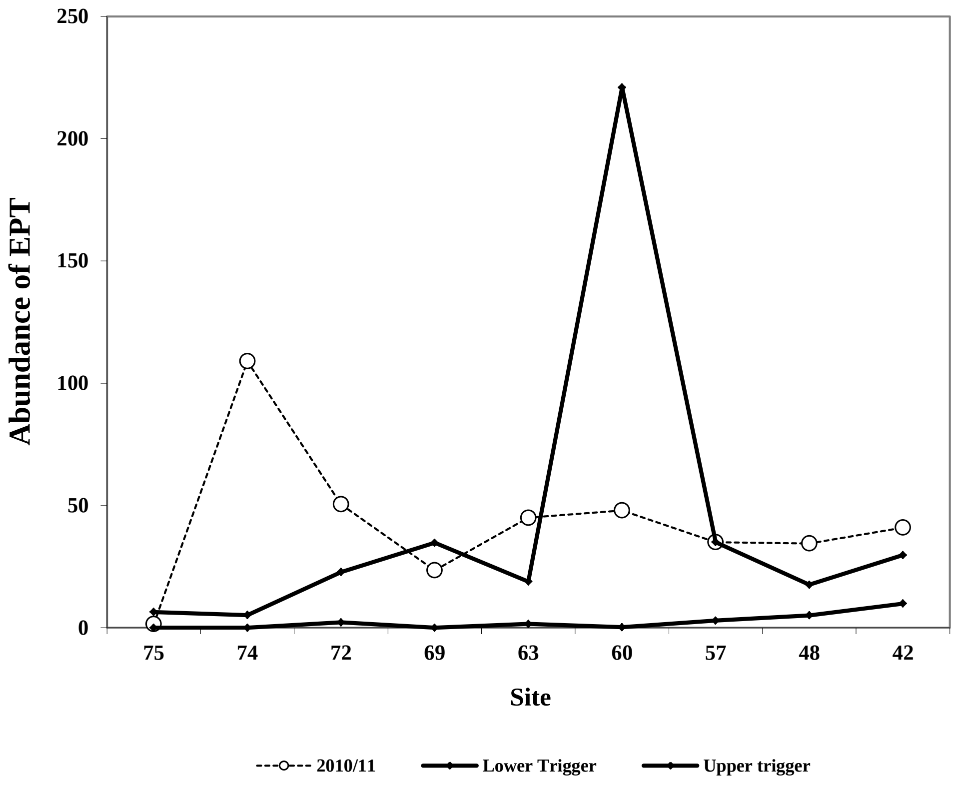


Figure 7-14 Ecologically signicant species metric values for 2010–11 compared with upper and lower LOAC trigger values for each site in the Gordon River. Trigger values based on the 95th percentile of pre-Basslink data

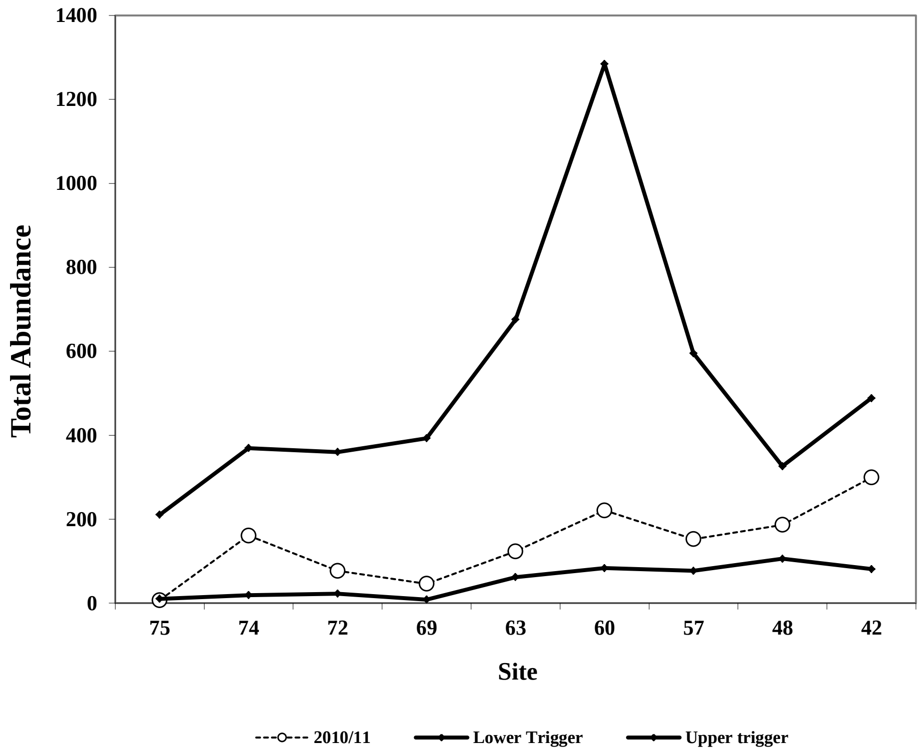
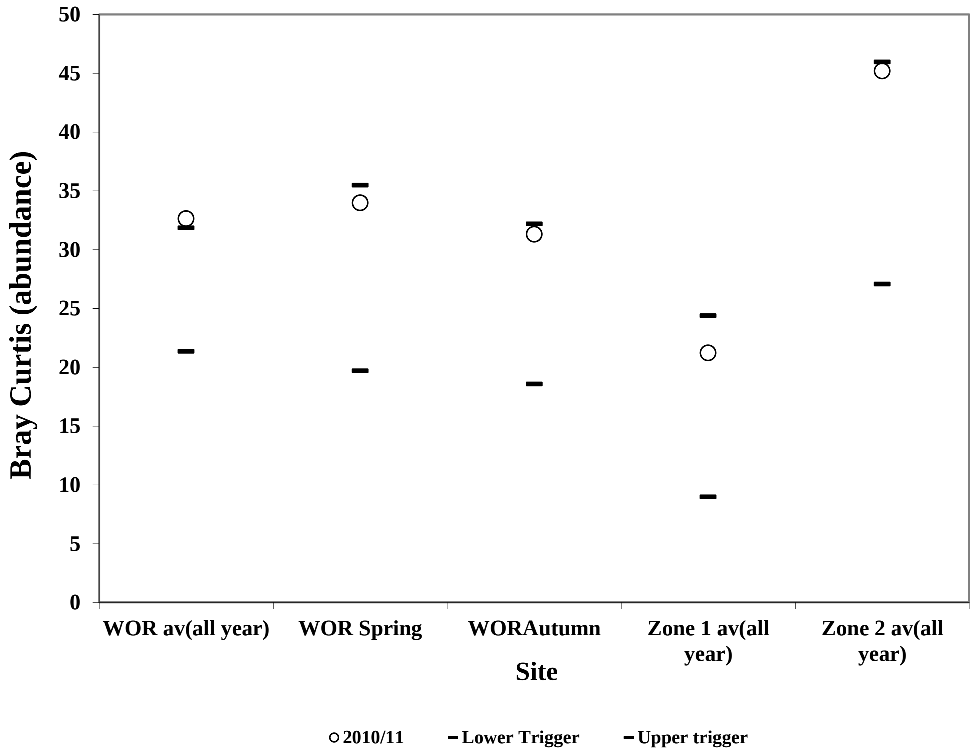


Figure 7-15 Biomass/Productivity metric values for 2010–11 compared with upper and lower LOAC trigger values for each site in the Gordon River. Trigger values based on the 95th percentile of pre-Basslink data



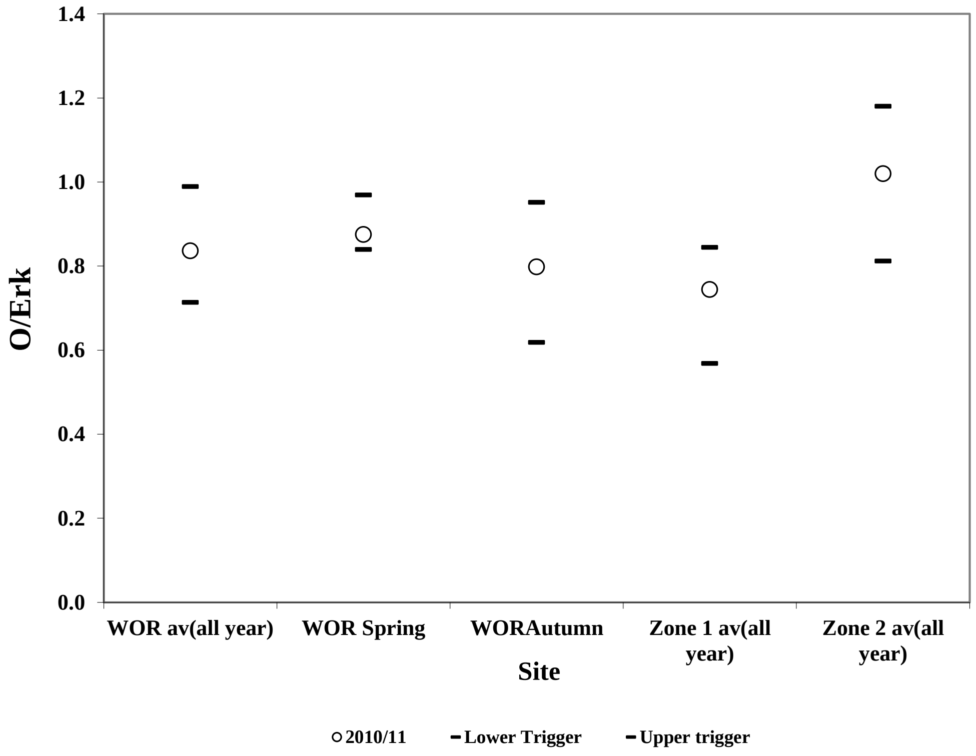
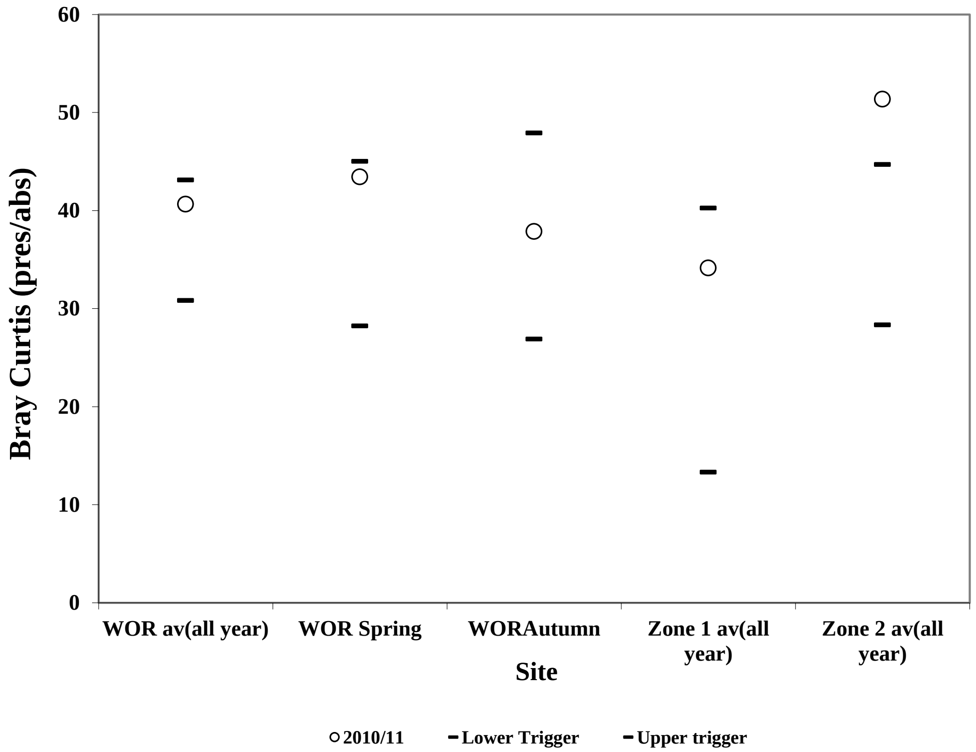


Figure 7-16 Community structure metric values for 2010–11 compared with upper and lower LOAC trigger values in the Gordon River for the following cases: WOR = Whole-of-river (year = seasons combined, spring and autumn), zones 1 and 2 (year). Trigger values based on the 95th percentile of pre-Basslink data



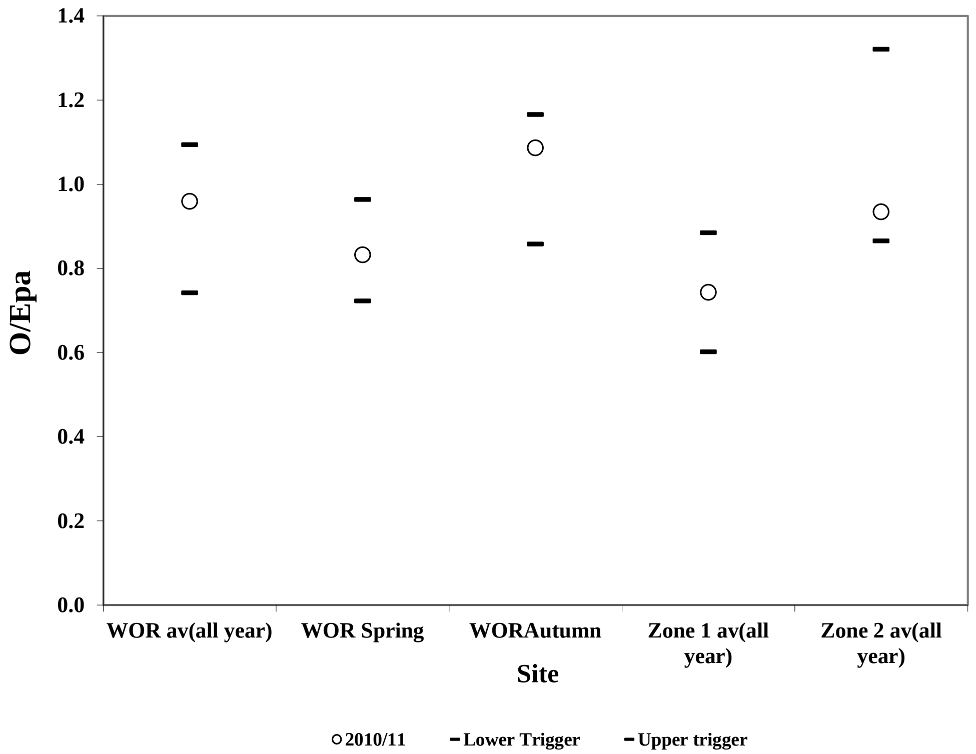
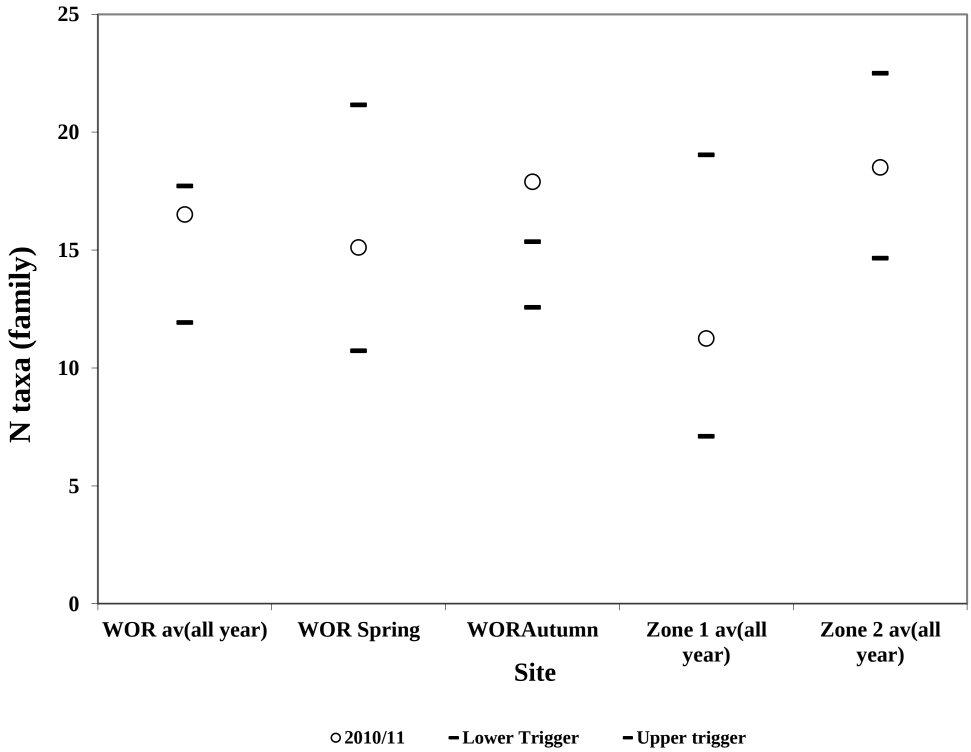


Figure 7-17 Community composition metric values for 2010–11 compared with upper and lower LOAC trigger values in the Gordon River for the following cases: Whole-of-river (year = seasons combined, spring and autumn), zones 1 and 2 (year). Trigger values based on the 95th percentile of pre-Basslink data



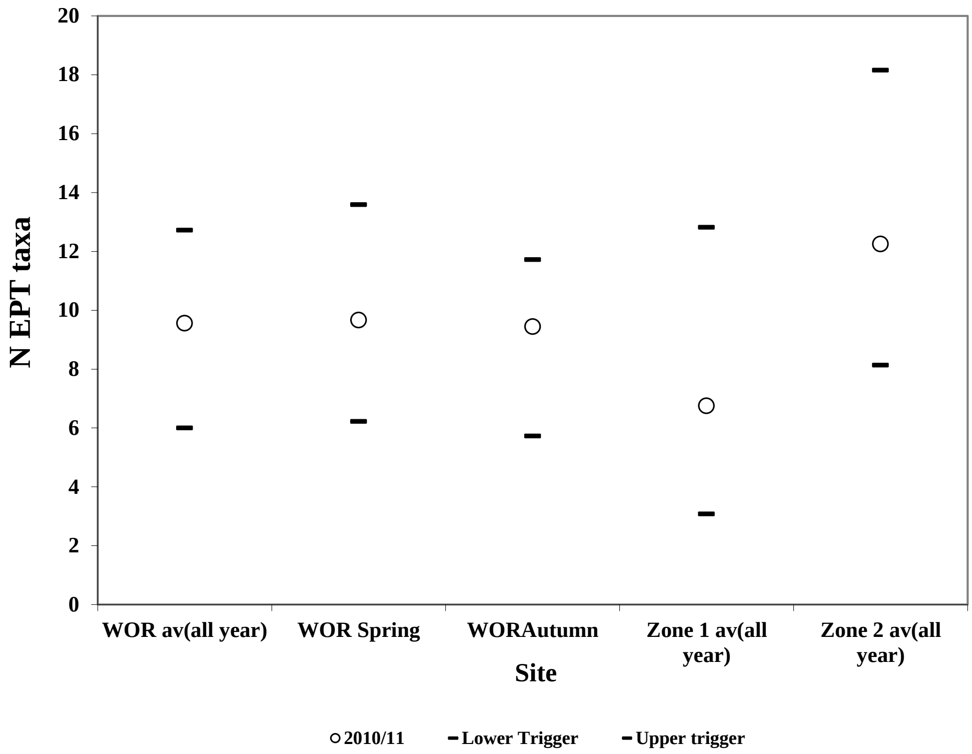
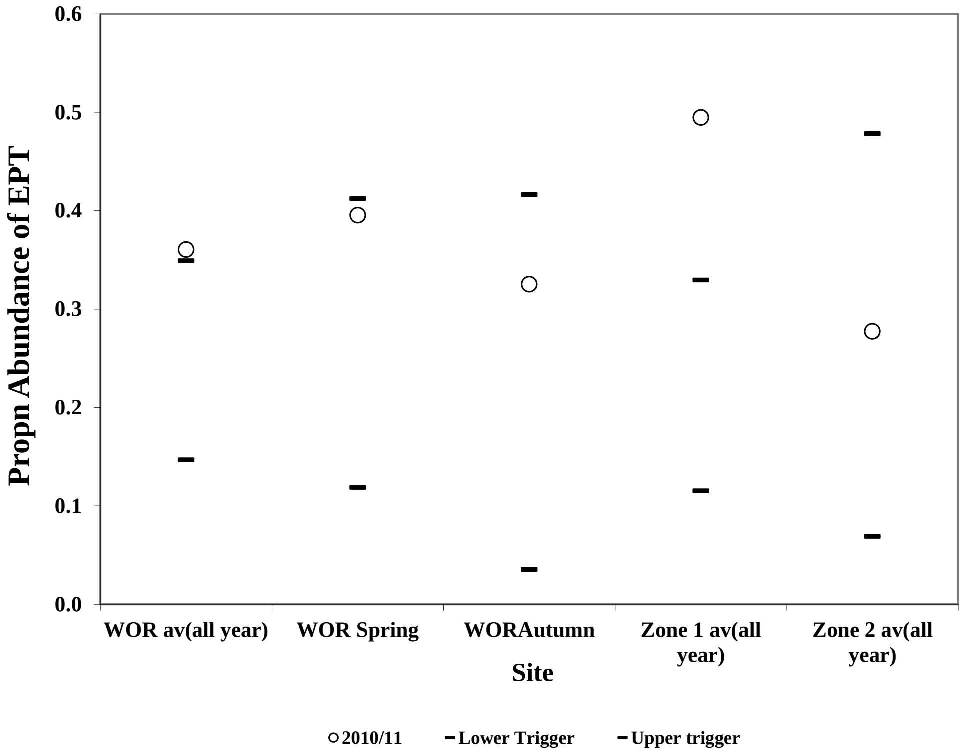


Figure 7-18 Taxonomic richness metric values for 2010–11 compared with upper and lower LOAC trigger values in the Gordon River for the following cases: Whole-of-river (year = seasons combined, spring and autumn), zones 1 and 2 (year). Trigger values based on the 95th percentile of pre-Basslink data



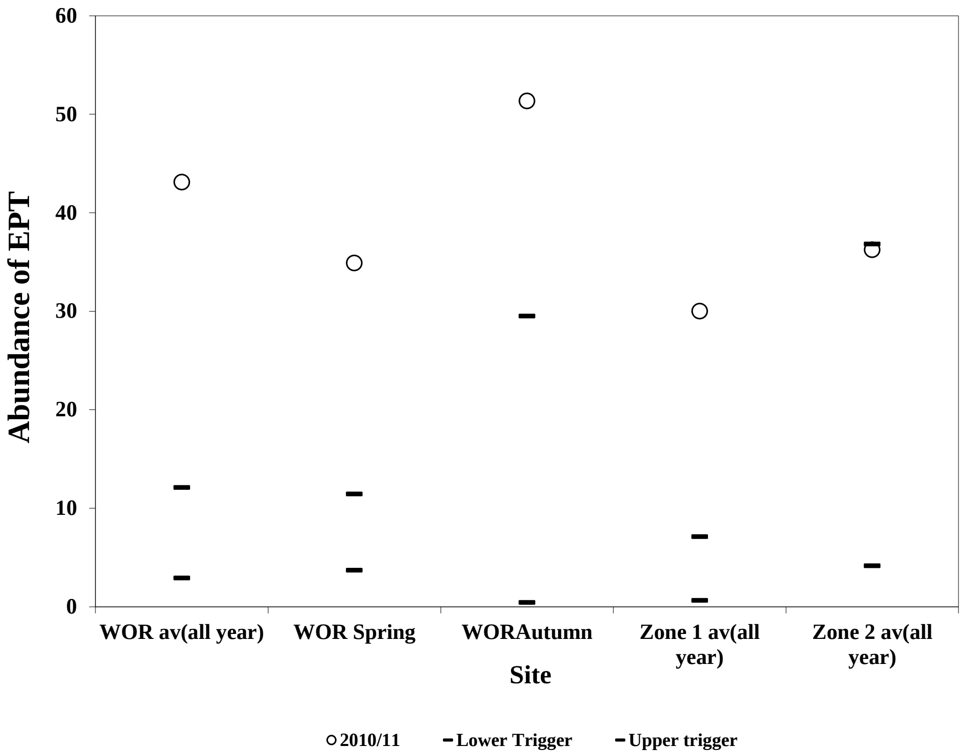


Figure 7-19 Ecologically signicant species metric values for 2010–11 compared with upper and lower LOAC trigger values in the Gordon River for the following cases: Whole-of-river (year = seasons combined, spring and autumn), zones 1 and 2 (year). Trigger values based on the 95th percentile of pre-Basslink data

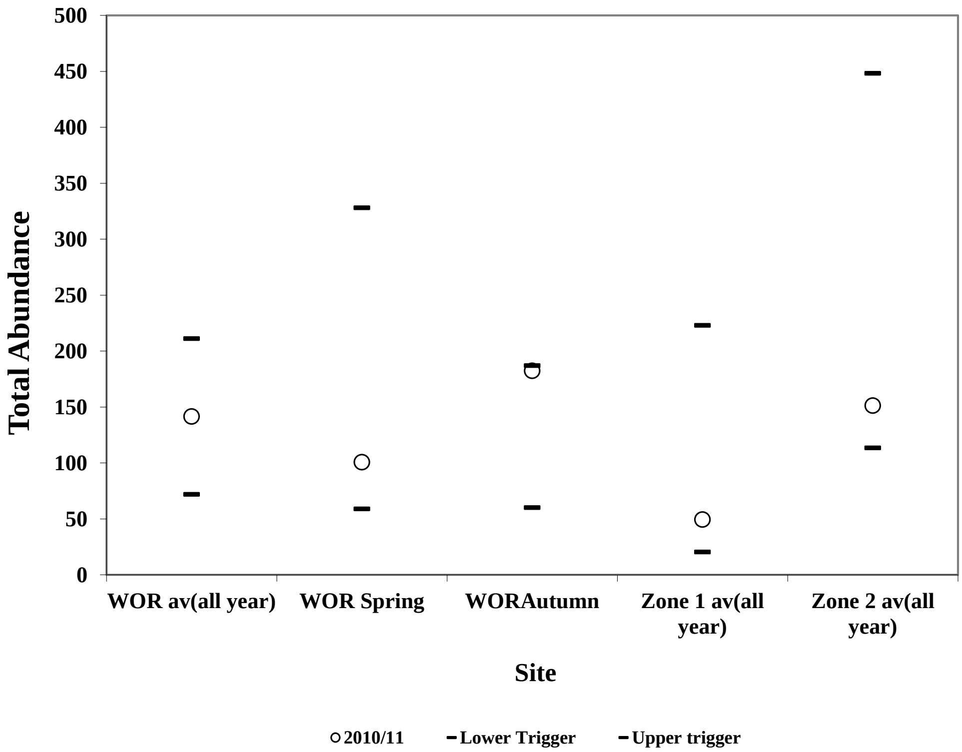


Figure 7-20 Biomass/Productivity metric values for 2010–11 compared with upper and lower LOAC trigger values in the Gordon River for the following cases: Whole-of-river (year = seasons combined, spring and autumn), zones 1 and 2 (year). Trigger values based on the 95th percentile of pre-Basslink data

7.4.3 Trigger status – five-year (2006–07 to 2010–11)

The following section summarises and comments on the mean observations for 2006–07 to 2010–11 in comparison with the five-year trigger values (see Figure 7-21 to Figure 7-30, and Table 7-9).

7.4.3.1 Community structure

Bray Curtis (abundance): All sites within trigger bounds (Figure 7-21). Zone 1 falls above upper bound, reflecting a slight improvement in community composition (Figure 7-26).

Comment – Generally consistent with pre-Basslink conditions, with improvement in zone 1 relative to pre-Basslink.

O/Erk: All sites within trigger bounds (Figure 7-21). Zone 1 falls above upper bound, reflecting a slight improvement in community composition (Figure 7-26).

Comment – Generally consistent with pre-Basslink conditions, with improvement in zone 1 relative to pre-Basslink.

7.4.3.2 Community composition

Bray Curtis (pres/abs data): All sites within trigger bounds (Figure 7-21). Zone 1 falls above upper bound, reflecting a slight improvement in community composition relative to pre-Basslink. (Figure 7-26).

Comment – Generally consistent with pre-Basslink conditions, with some improvement in zone 1 relative to pre-Basslink.

O/Epa All sites compliant, with site 75 exceeding upper bound (slight improvement, Figure 7-22). WOR values falling within bounds (all year) with some seasonal variation (Figure 7-27). Zone 1 values above upper bound, and zone 2 values fell at lower bound.

Comment – Generally consistent with pre-Basslink conditions, with some improvement in zone 1.

7.4.3.3 Taxonomic richness

N Taxa (fam): All sites (Figure 7-23 and Figure 7-28), with sites 75 and 48 falling close to upper bound. Both zone and WOR values compliant, with later showing minor exceedance of upper trigger bound in autumn (slight improvement).

Comment – Generally consistent with pre-Basslink conditions.

N EPT Species: All sites compliant (Figure 7-23). Values for WOR and zone 1 compliant, with zone 2 value falling at lower bound (Figure 7-28).

Comment – Generally consistent with pre-Basslink conditions.

7.4.3.4 Ecologically significant species

Proportion of total abundance as EPT: Most sites, both zones and WOR values compliant (Figure 7-24 and Figure 7-29), with minor exceedances at sites 74 and 69 and minor excursion below lower trigger bound for site 42.

Comment – Raised relative densities of *Asmicridea* caddis and mayflies in middle zone 1 sites in 2008–09 and 2010–11 contribute to this metric. This represents a sustained improvement in community composition in zone 1 relative to pre-Basslink period - otherwise consistent with pre-Basslink conditions. Enhanced zone 1 values relative to pre-Basslink are a product of baseflow constancy from power station release combined with food input from tributaries. Highly likely to be a result of sustained environmental baseflows post-Basslink.

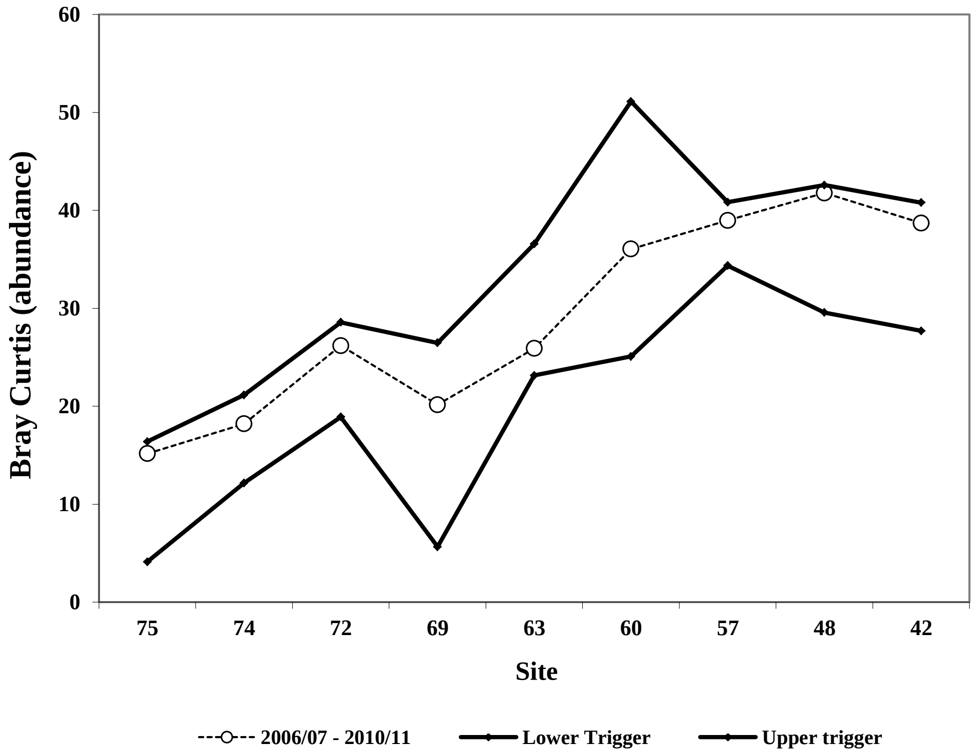
Abundance EPT: High at zone 1 sites, with slight exceedances at sites 74 and 48 (Figure 7-24). Values show exceedances for WOR and zone 1, all year and in both seasons (Figure 7-29). Value is compliant for zone 2.

Comment – Enhanced zone 1 densities relative to pre-Basslink are a product of baseflow constancy from power station release combined with food input from tributaries. Highly likely to be a result of sustained environmental baseflows post-Basslink.

7.4.3.5 Biomass / productivity

Total abundance: All sites compliant with exception of exceedance of upper trigger bound at site 48 (Figure 7-25). Exceedance for WOR (all year and in autumn) and in zone 1 (Figure 7-30), mainly driven by raised EPT group densities.

Comment – Represents an improvement in the macroinvertebrate community (in biomass and productivity relative to the pre-Basslink condition.



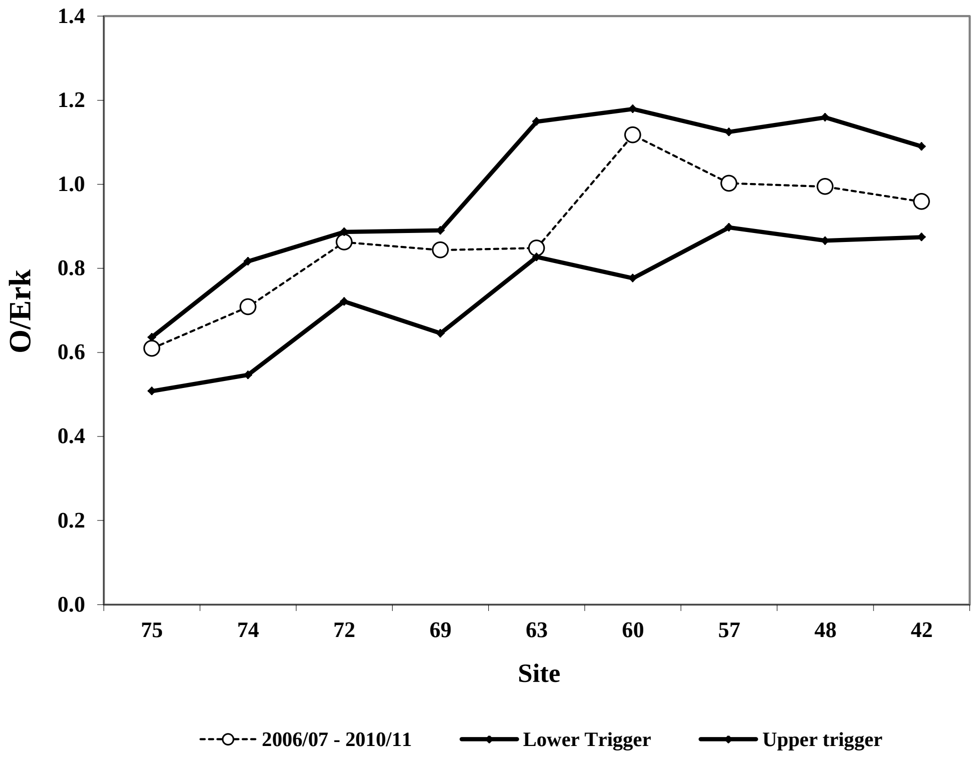
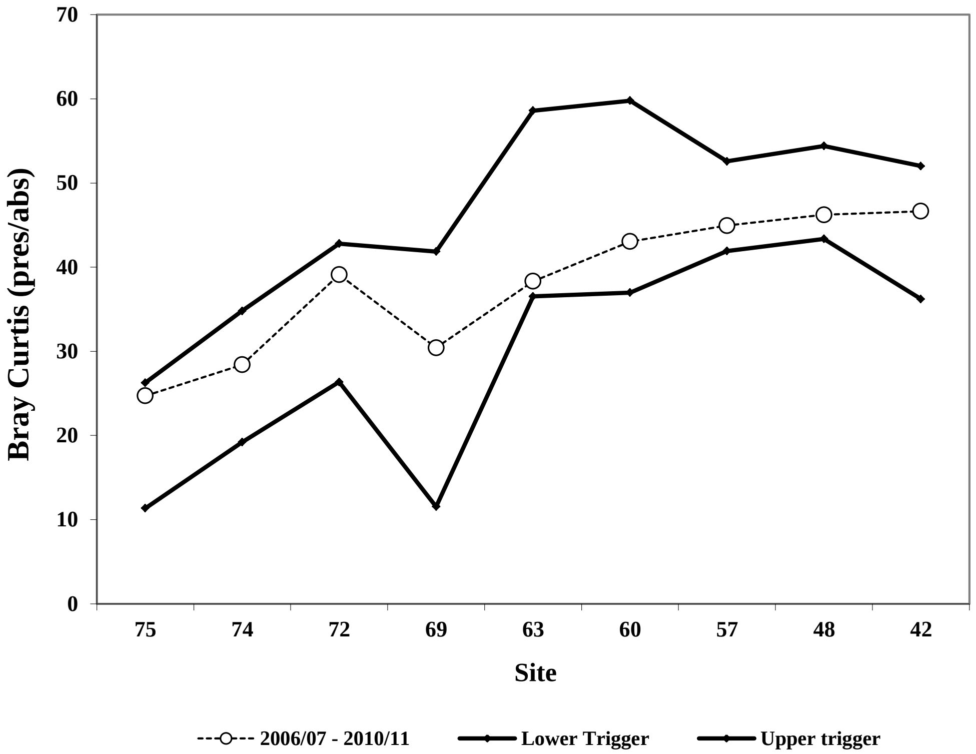


Figure 7-21 Community structure metric values, as means for 2006–07 to 2010–11, compared with upper and lower LOAC five-year trigger values for each site in the Gordon River. Trigger values based on the 95th percentile of pre-Basslink data



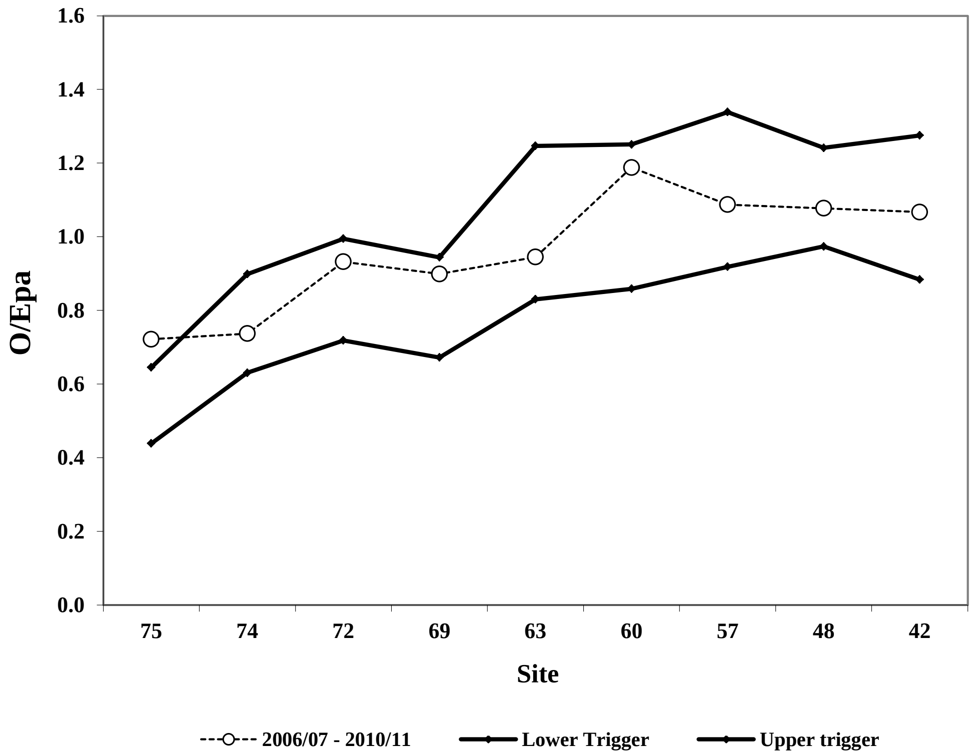
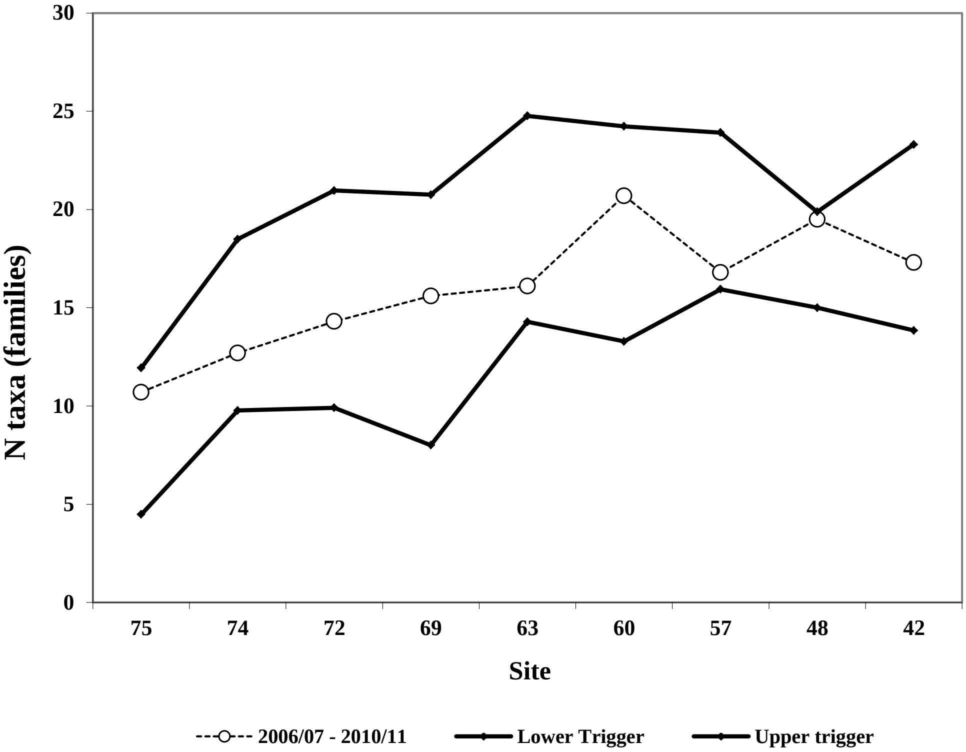


Figure 7-22 Community composition metric values, as means for 2006–07 to 2010–11, compared with upper and lower LOAC five-year trigger values for each site in the Gordon River. Trigger values based on the 95th percentile of pre-Basslink data



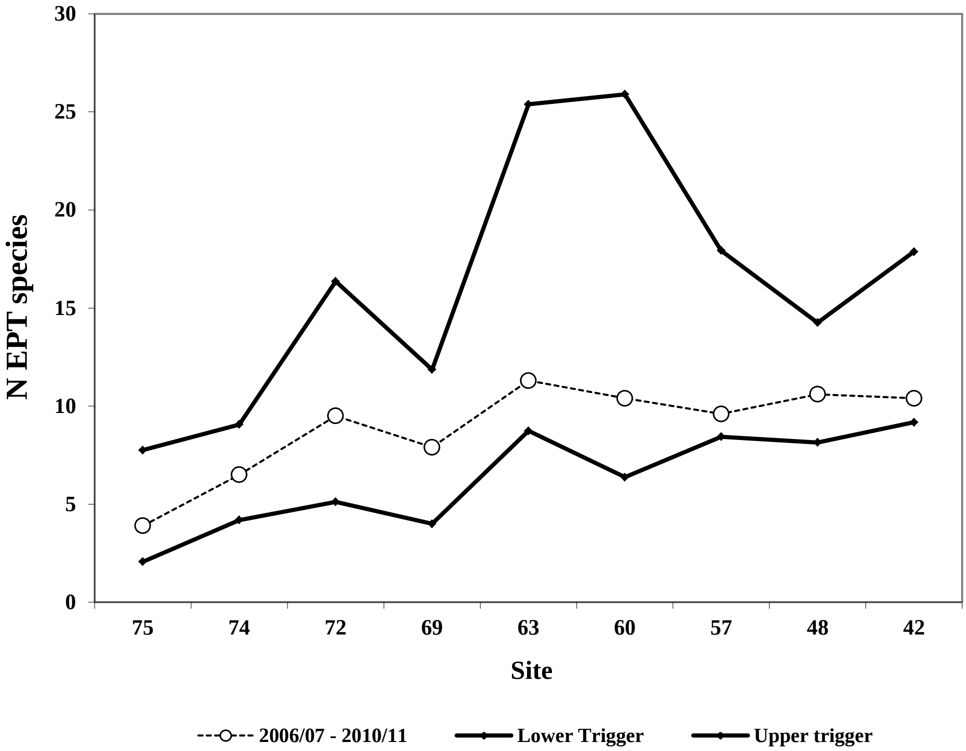
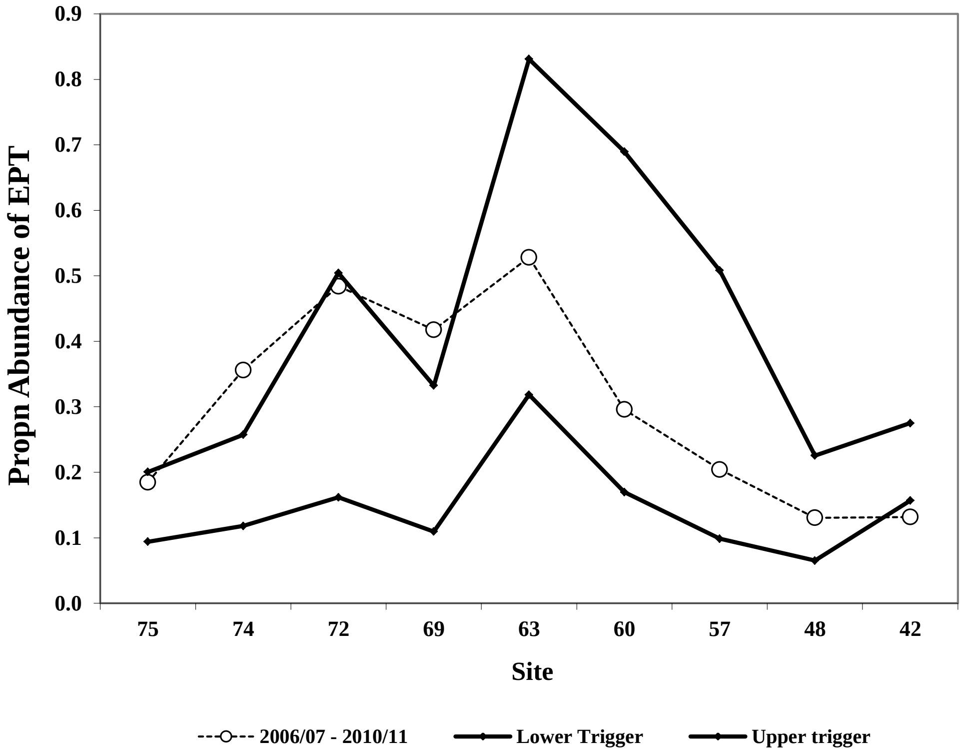


Figure 7-23 Taxonomic richness metric values, as means for 2006–07 to 2010–11, compared with upper and lower LOAC five-year trigger values for each site in the Gordon River. Trigger values based on the 95th percentile of pre-Basslink data



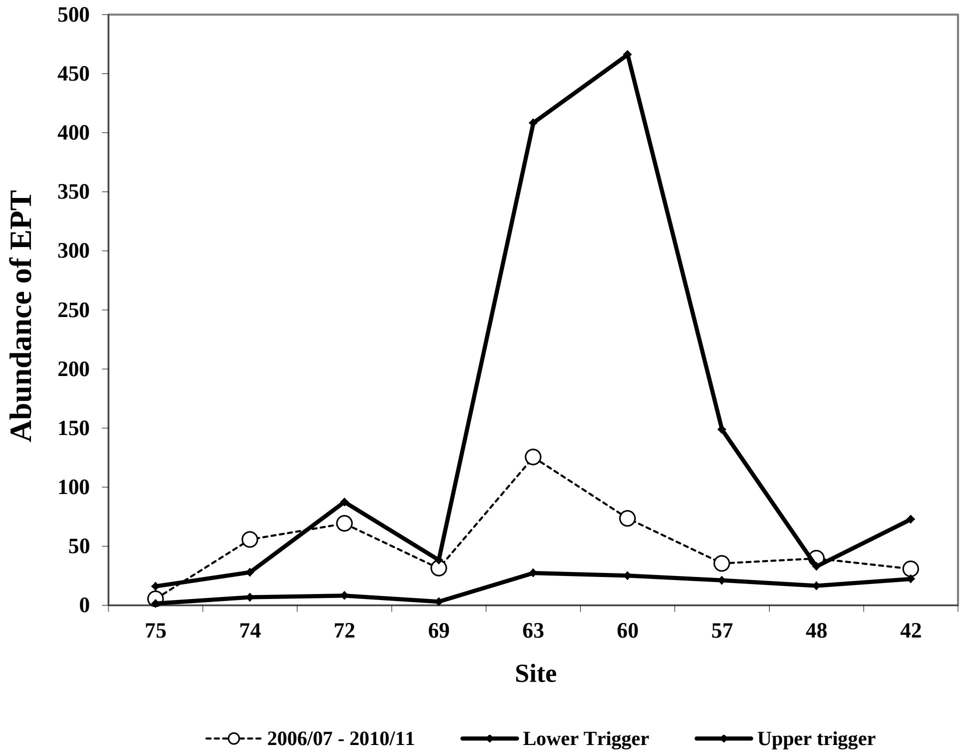


Figure 7-24 Ecologically signicant species metric values, as means for 2006–07 to 2010–11, compared with upper and lower LOAC five-year trigger values for each site in the Gordon River. Trigger values based on the 95th percentile of pre-Basslink data

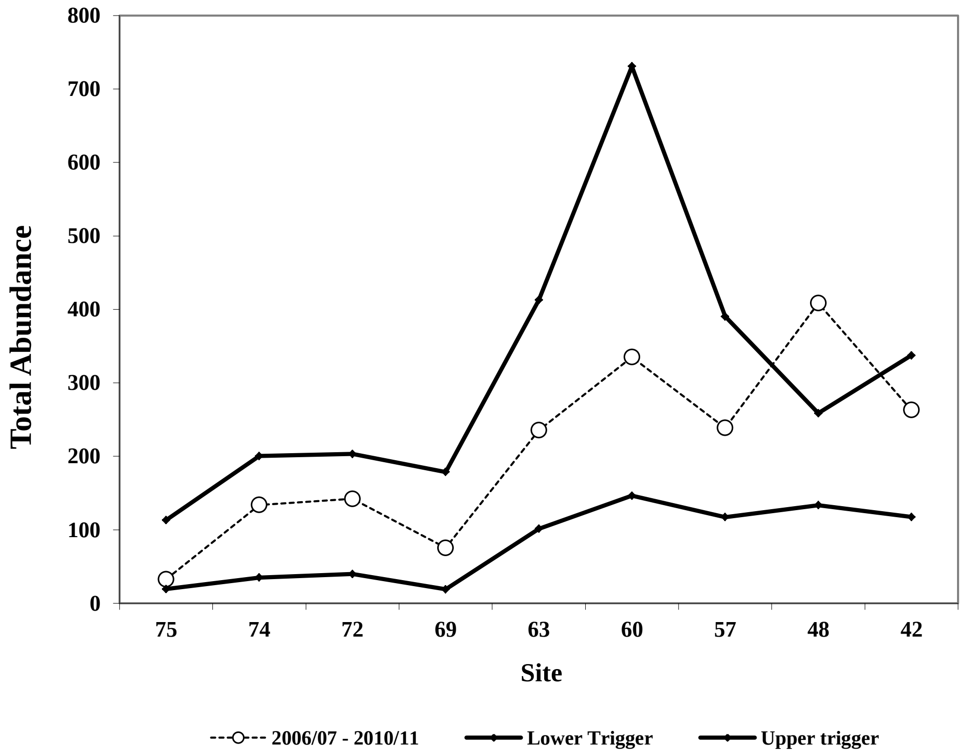
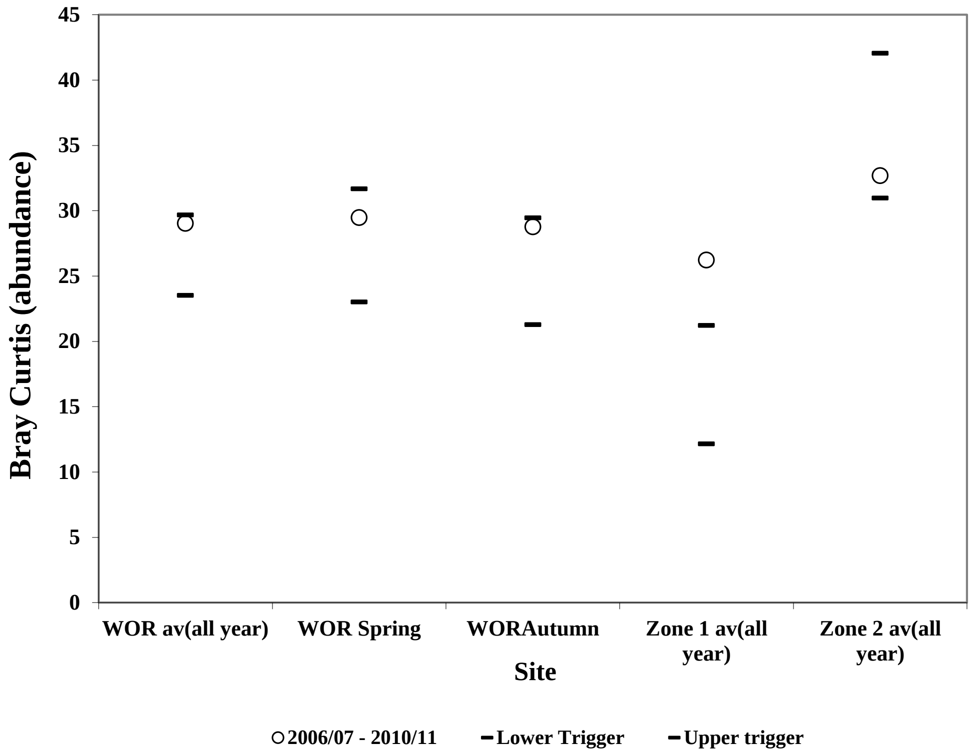


Figure 7-25 Biomass/productivity metric values, as means for 2006–07 to 2010–11, compared with upper and lower LOAC five-year trigger values for each site in the Gordon River. Trigger values based on the 95 percentile of pre-Basslink data



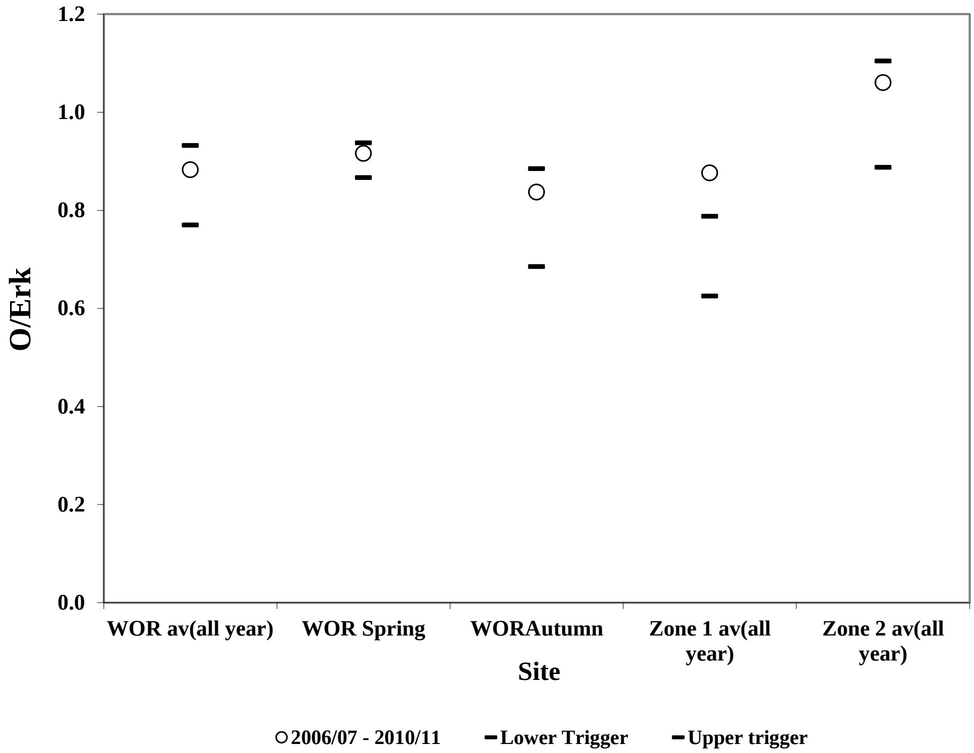


Figure 7-26 Community structure metric values, as means for 2006–07 to 2010–11, compared with upper and lower LOAC five-year trigger values in the Gordon River for the following cases: WOR = Whole-of-river (year = seasons combined, spring and autumn), zones 1 and 2 (all year). Trigger values based on the 95th percentile of pre-Basslink data

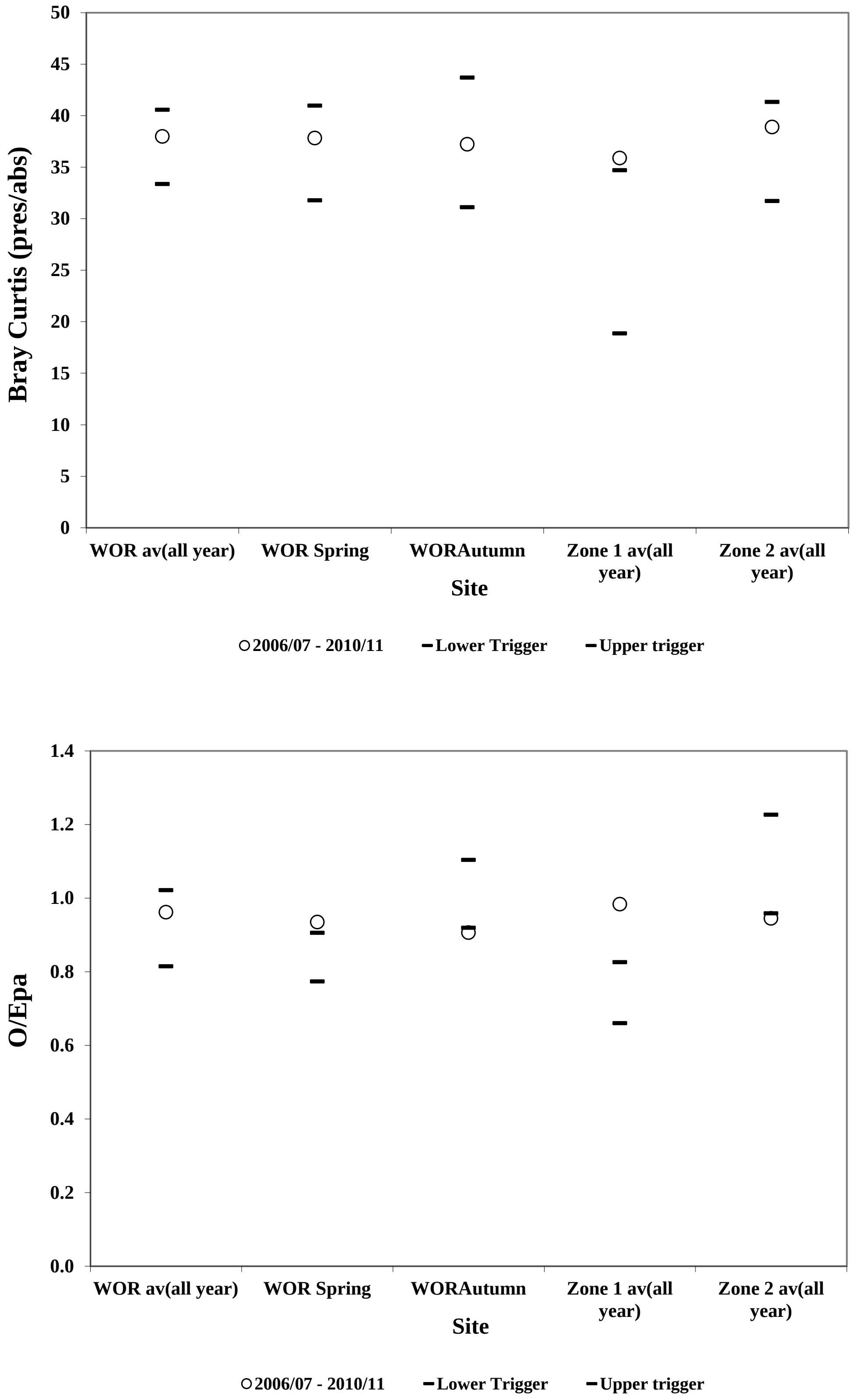
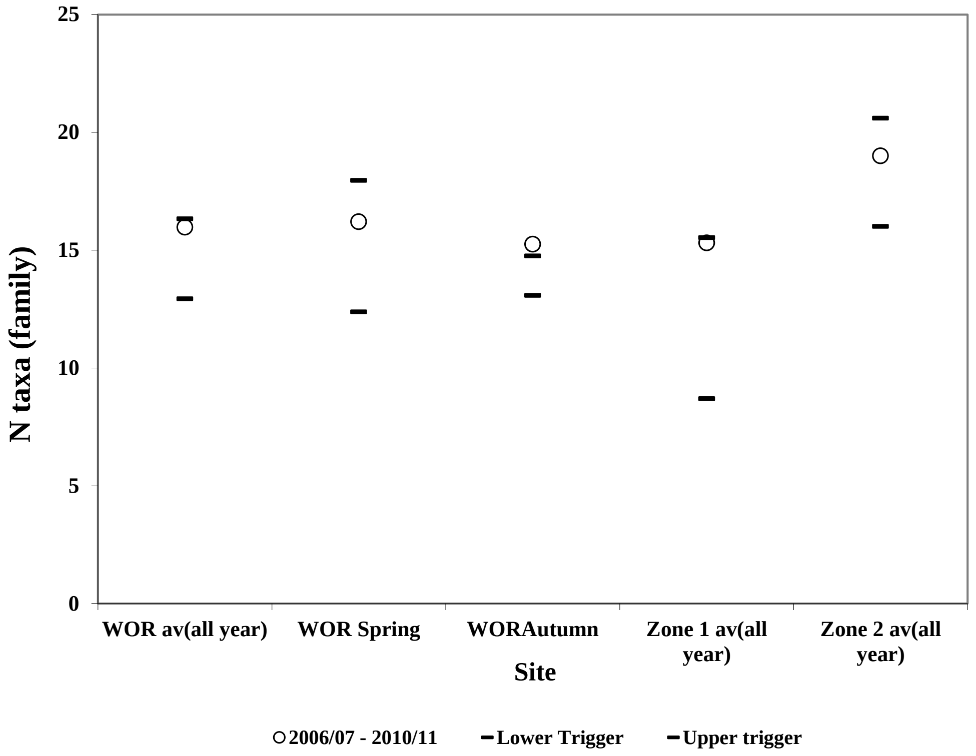


Figure 7-27 Community composition metric values, as means for 2006–07 to 2010–11, compared with upper and lower LOAC five-year trigger values in the Gordon River for the following cases: Whole-of-river (year = seasons combined, spring and autumn), zones 1 and 2 (all year). Trigger values based on the 95th percentile of pre-Basslink data



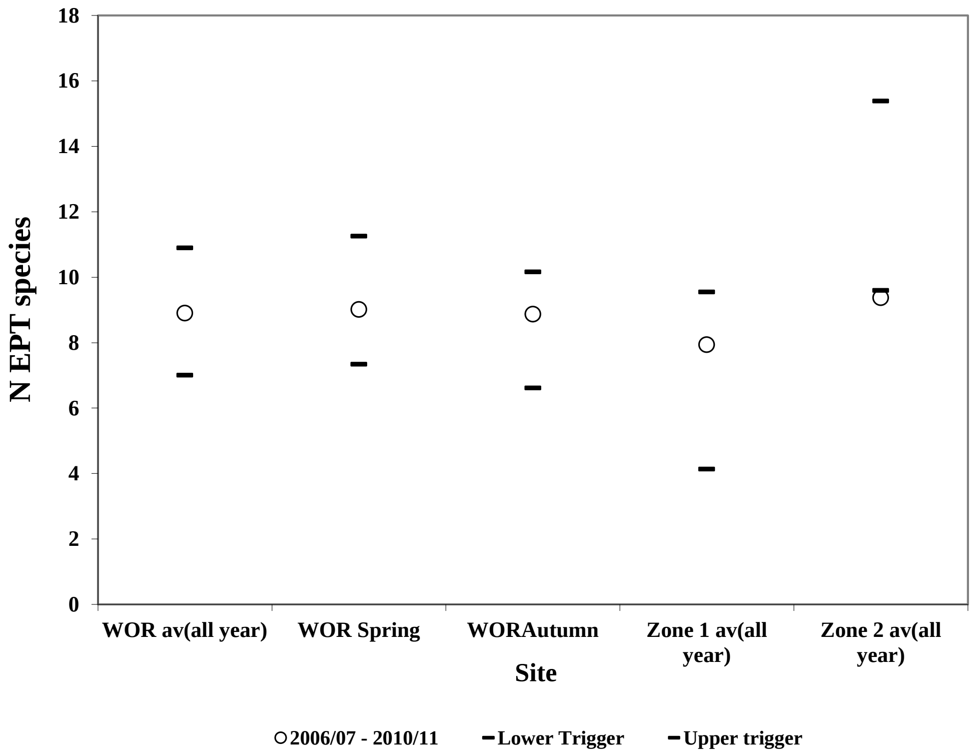
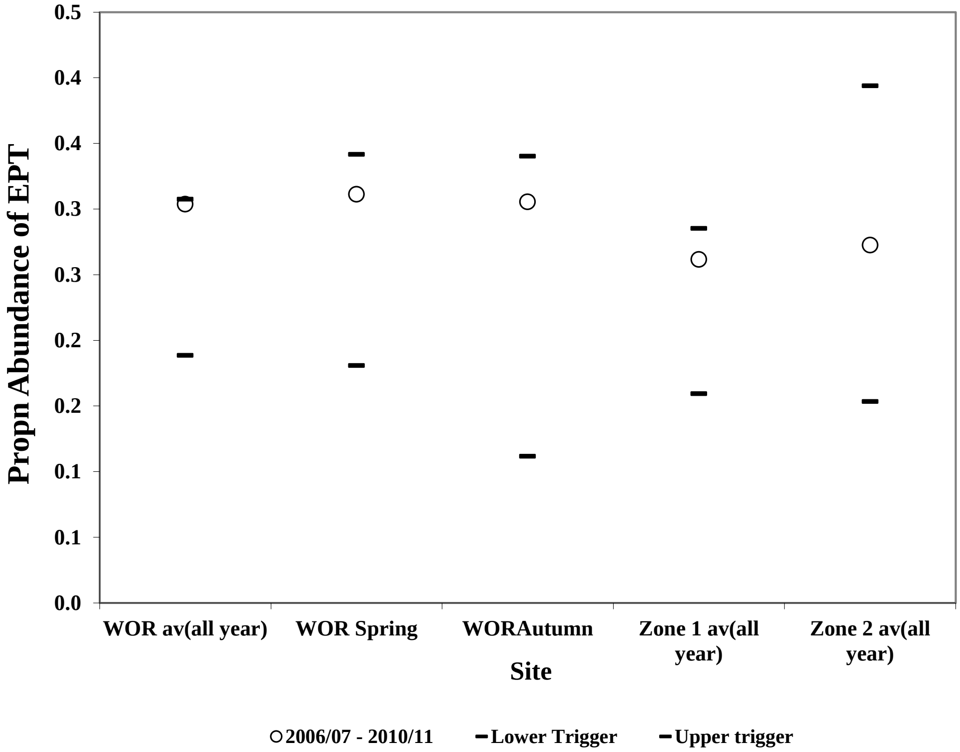


Figure 7-28 Taxonomic richness metric values, as means for 2006–07 to 2010–11, compared with upper and lower LOAC five-year trigger values in the Gordon River for the following cases: Whole-of-river (year = seasons combined, spring and autumn), zones 1 and 2 (all year). Trigger values based on the 95th percentile of pre-Basslink data



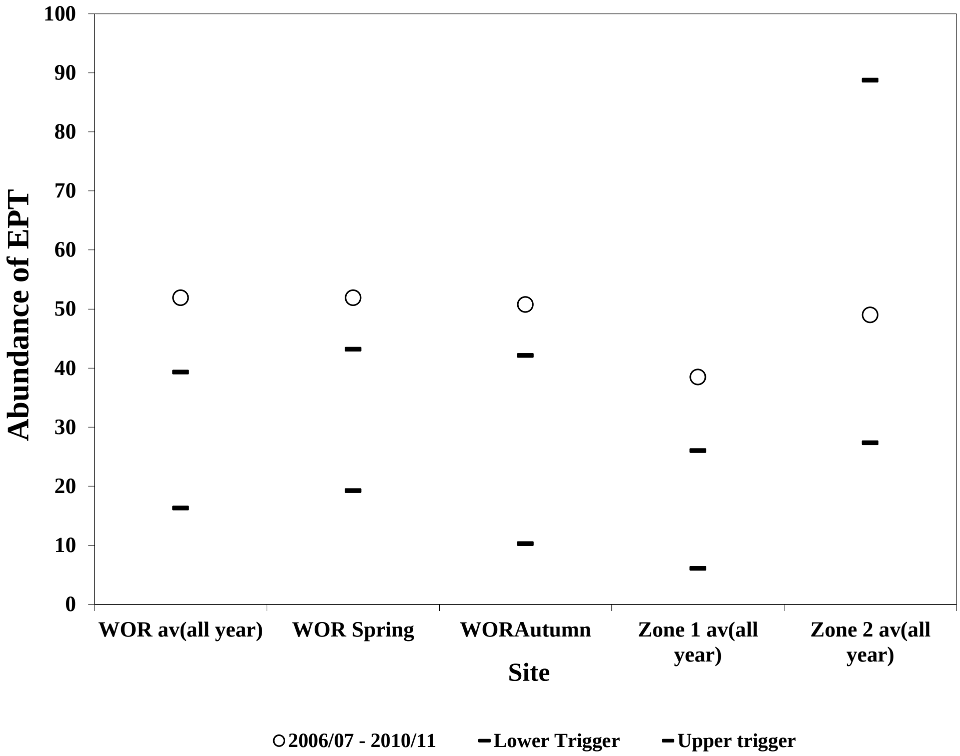


Figure 7-29 Ecologically signicant species metric values, as means for 2006–07 to 2010–11, compared with upper and lower LOAC five-year trigger values in the Gordon River for the following cases: Whole-of-river (year = seasons combined, spring and autumn), zones 1 and 2 (all year). Trigger values based on the 95th percentile of pre-Basslink data

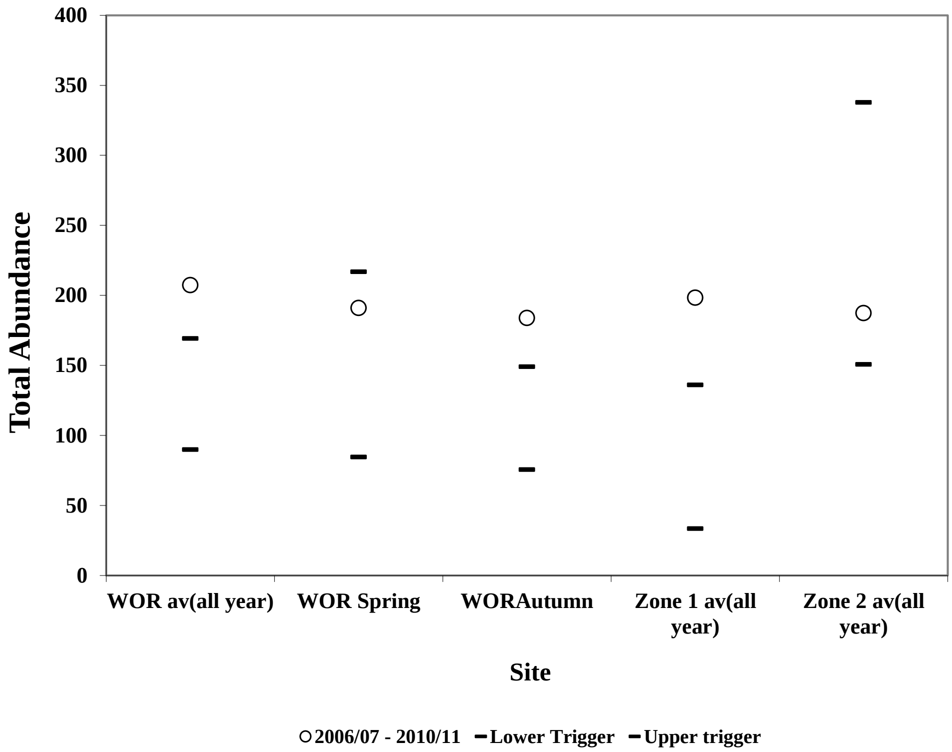


Figure 7-30 Biomass/productivity metric values, as means for 2006–07 to 2010–11, compared with upper and lower LOAC five-year trigger values in the Gordon River for the following cases: Whole-of-river (year = seasons combined, spring and autumn), zones 1 and 2 (all year). Trigger values based on the 95th percentile of pre-Basslink data

7.5 Long-term trends

7.5.1 Univariate indicators

Trends in all metrics are shown in Figure 7-31 to Figure 7-35. As expected, the value of all metrics is predominantly highest in reference sites, lowest in zone 1 and intermediate in zone 2. Most metrics show no monotonic trend over the entire sampling period in the Gordon River, and are generally consistent in values with time.

However, some metrics have shown a post-Basslink rise in value for zone 1 over the period 2007–08 to 2009–10. These included the proportional and total abundance of EPT species, the number of EPT species, the number of macroinvertebrate families and the Bray Curtis similarity to reference (based on both abundance and presence/absence data) (Figure 7-32 to Figure 7-34). However all zone 1 metrics declined markedly in 2010–11 compared to the immediately preceding years, reversing any rising post-Basslink trends. None of these declines have resulted in values lower than occurred pre-Basslink, though several metrics have now fallen into the lower end of the pre-Basslink range. Only the metrics O/Erk and proportional abundance of EPT species have maintained their previous values in zone 1 in 2010–11 (Figure 7-34).

No overall post-Basslink increases in metric values were observed in zone 2. Also unlike zone 1, zone 2 metrics have not shown a marked decline in value in 2010–11. Two zone 2 metrics have been observed to decline in value post-Basslink – the proportional and total abundance of EPT species – but the former rose in value in 2010–11 (Figure 7-34). Overall in zone 2, both the trends in metric values and the temporal variation in abundance of several dominant taxa (see next section) have tended to follow those of reference rivers. Zone 2 appears to be biologically intermediate between zone 1 and reference rivers in its composition and temporal dynamics, which is unsurprising as it receives substantial inflows from the Denison and other tributary rivers. This is reflected in its Bray Curtis similarity values which are generally higher than for zone 1. It is also worth noting that the abundance-based value of this metric has sustained higher values than pre-Basslink values since early (autumn) 2009 (Figure 7-32).

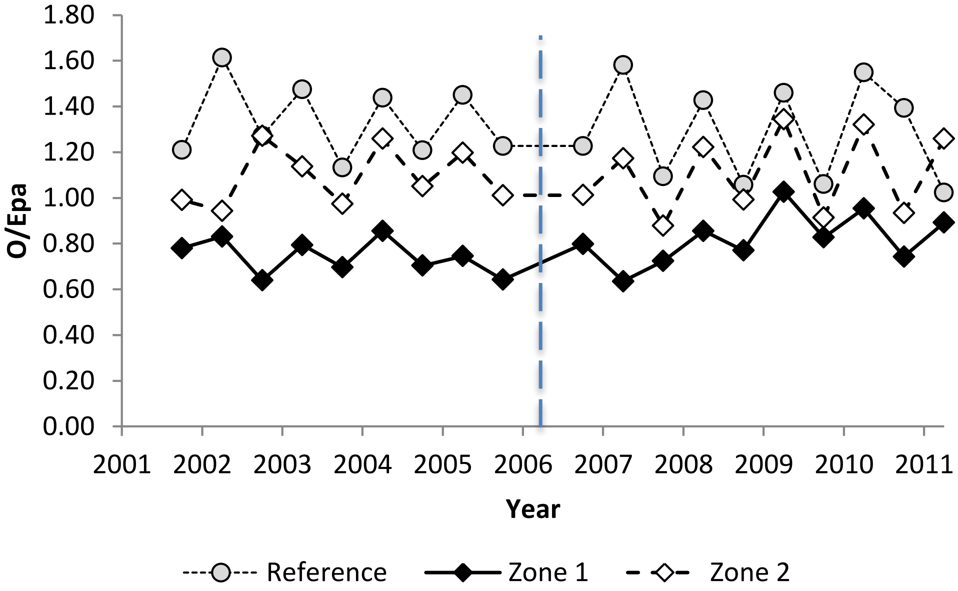
Reference rivers experienced a decline over the monitoring period between 2001 and 2011 in the number of family taxa, the number and abundance of EPT species, and total macroinvertebrate abundance (Figure 7-33 to Figure 7-35). This was also accompanied by a decline of around 0.2 units in both O/Epa and O/Erk, for both seasons (Figure 7-31). This is believed to have been related to the dry conditions experienced during much of the program which led to lower than normal flows in reference rivers. No metric rose substantively in 2010–11 in reference river sites, and several continued to decline.

Trends in the Gordon River which are likely to indicate responses to post-Basslink conditions are:

- an increase in O/Epa and O/Erk in zone 1 between 2007–08 and 2009–10 followed by a decline in 2010–11 (Figure 7-31);
- an increase in community compositional similarities between Gordon River and reference sites in zone 1 between 2007–08 and 2009–10 followed by a decline in 2010–11 (Figure 7-32);
- an increase in community compositional similarities between Gordon River and reference sites in zone 2 since 2007–08 (Figure 7-32);
- an increase in the number of families and EPT species between 2007–08 and 2009–10 followed by a decline in 2010–11 (Figure 7-33);
- a major increase in the absolute and proportional abundance of the EPT group in zone 1 since spring 2007, not observed in zone 2 or reference site data (Figure 7-34), followed by a decline in absolute abundance of EPT species in 2010–11; and
- increases in total benthic macroinvertebrate abundance in both zones 1 and 2 from 2007 to early 2010, followed by a decline in 2010–11 (Figure 7-35).

These metrics all showed a lagged response to post-Basslink conditions, with a growing number of metrics showing increases between 2007–08 and 2009–10. This may have been an artefact of the flow conditions post-Basslink which were more stable than anticipated. Flow conditions in

2010–11 more closely resemble the originally expected Basslink flow regime, appear to have led to a decline in most metrics in 2010–11 compared to 2009–10. Though there was a decline in 2010–11, the results remain an improvement on the pre-Basslink condition.



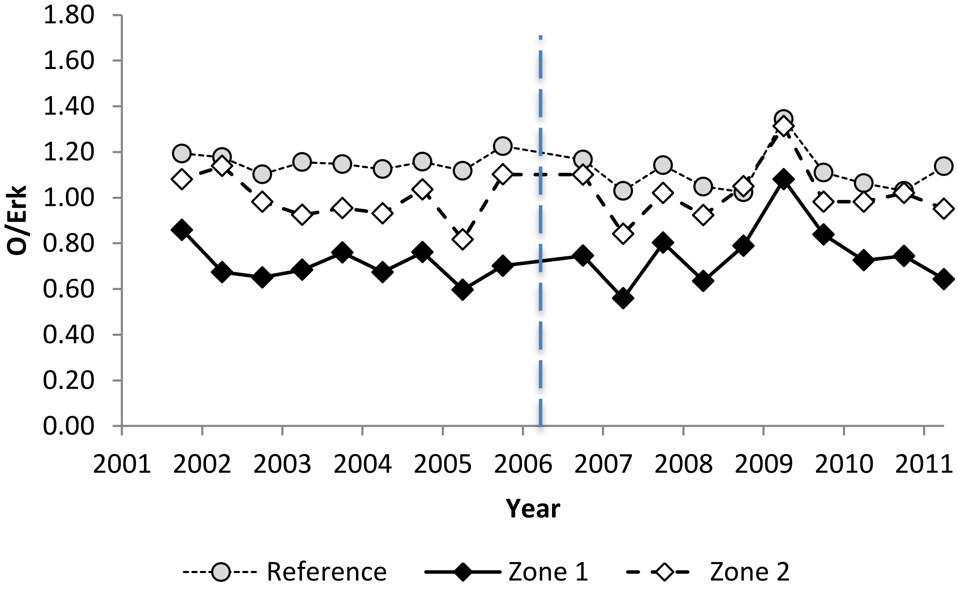


Figure 7-31 Mean O/Epa and O/Erk indicator values for each zone in the Gordon River and reference rivers on each sampling occasion. Vertical dashed line indicates initiation of Basslink operations

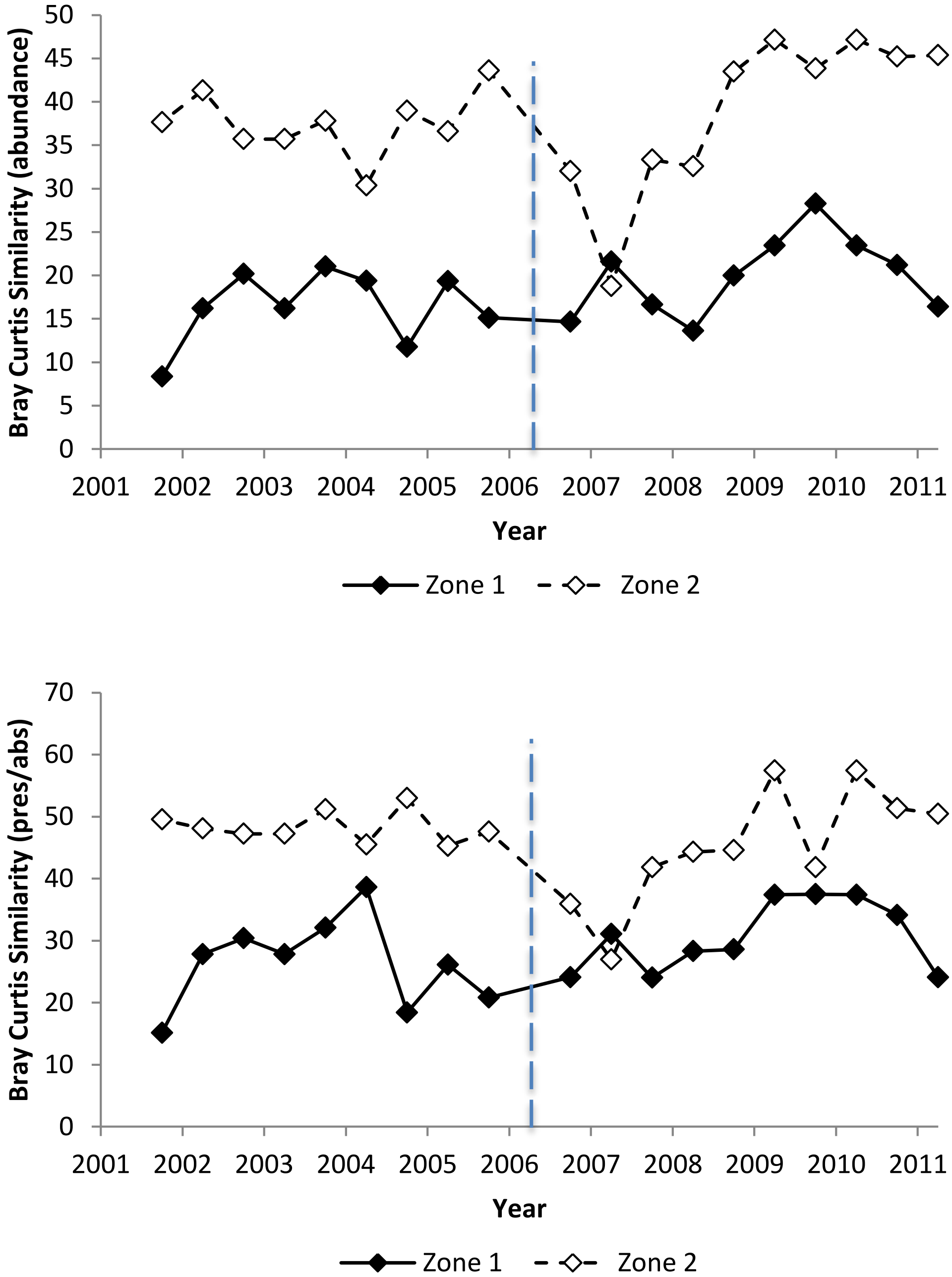
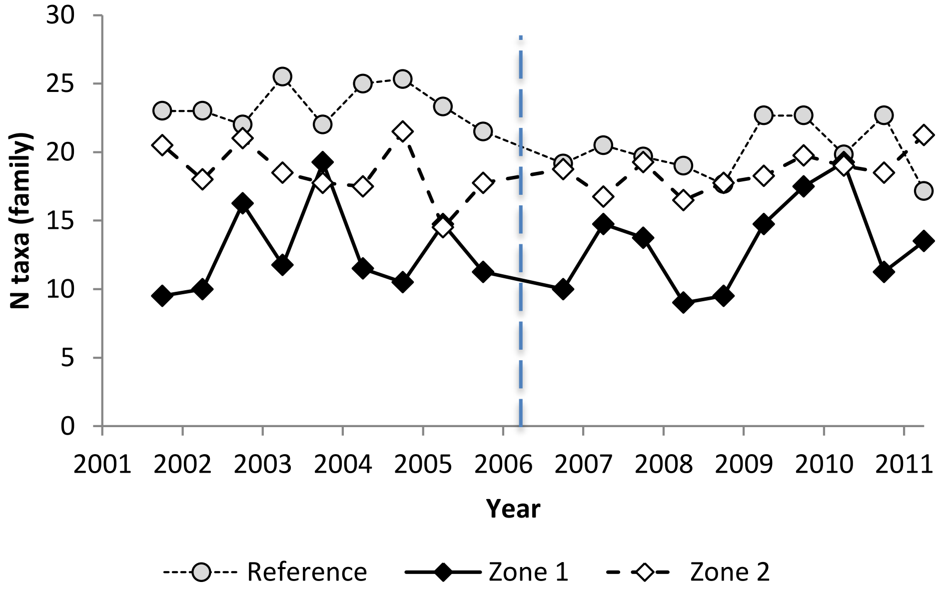


Figure 7-32 Mean Bray Curtis Similarity indicator values between each zone in the Gordon River and the reference rivers on each sampling occasion. Vertical dashed line indicates initiation of Basslink operations



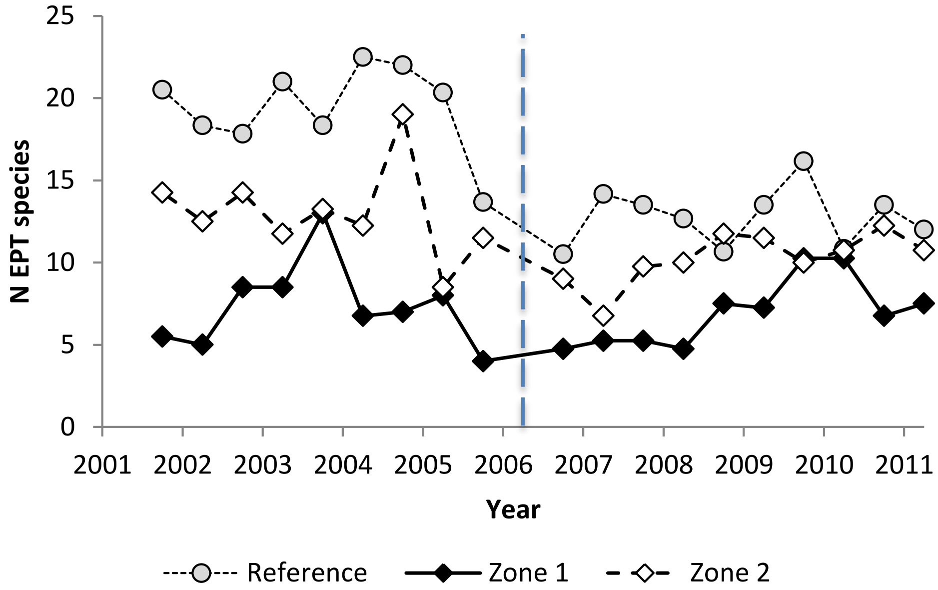
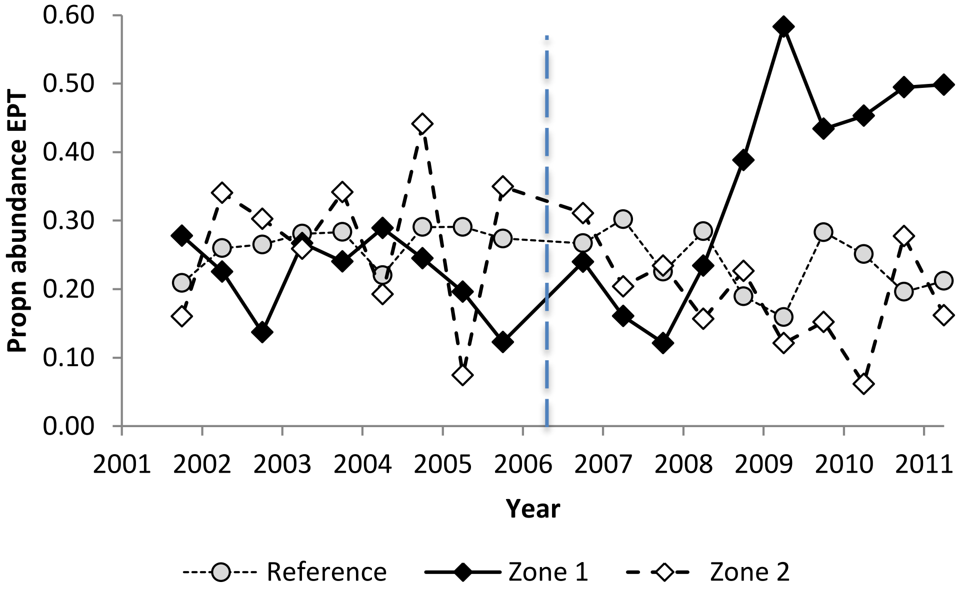


Figure 7-33 Mean N taxa (family) and N EPT species indicator values for each zone in the Gordon River and reference rivers on each sampling occasion. Vertical dashed line indicates initiation of Basslink operations



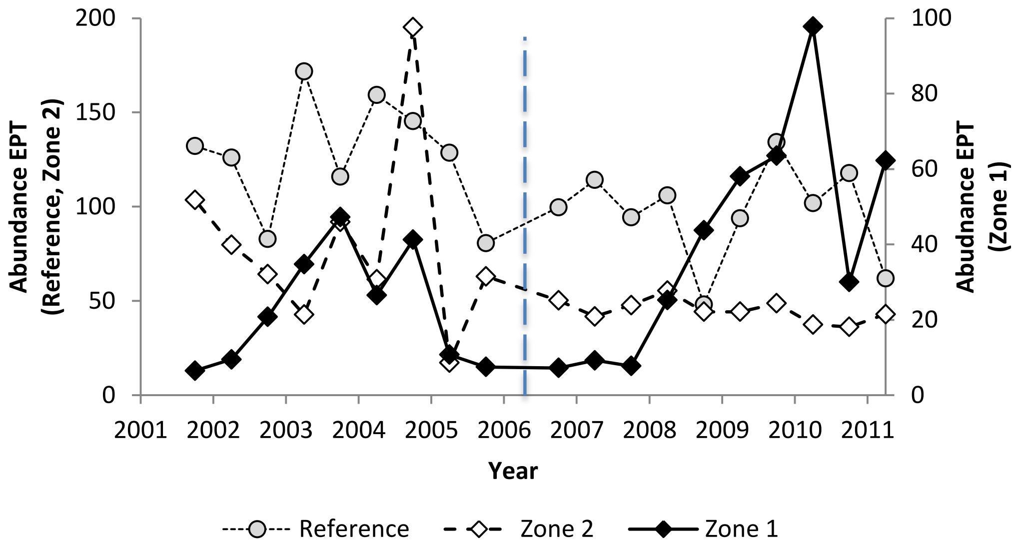


Figure 7-34 Mean proportional abundance and absolute abundance of EPT taxa indicator values for each zone in the Gordon River and reference rivers on each sampling occasion. Vertical dashed line indicates initiation of Basslink operations

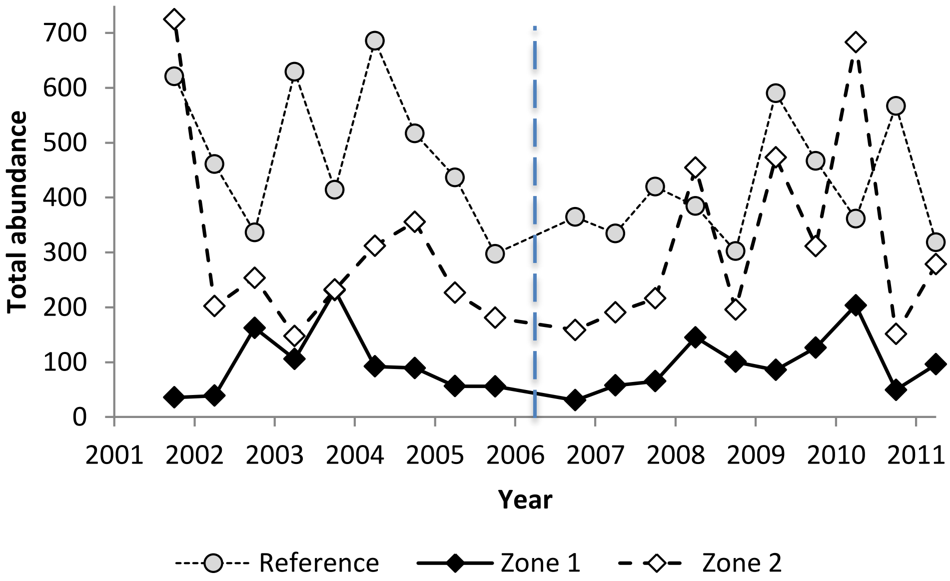


Figure 7-35 Mean total benthic macroinvertebrate abundance indicator values for each zone in the Gordon River and reference rivers on each sampling occasion. Vertical dashed line indicates initiation of Basslink operations

7.5.2 Individual taxon abundances

Trends have been evident over the monitoring period in several of the numerically dominant macroinvertebrate taxa in the Gordon River (Figure 7-36 to Figure 7-37).

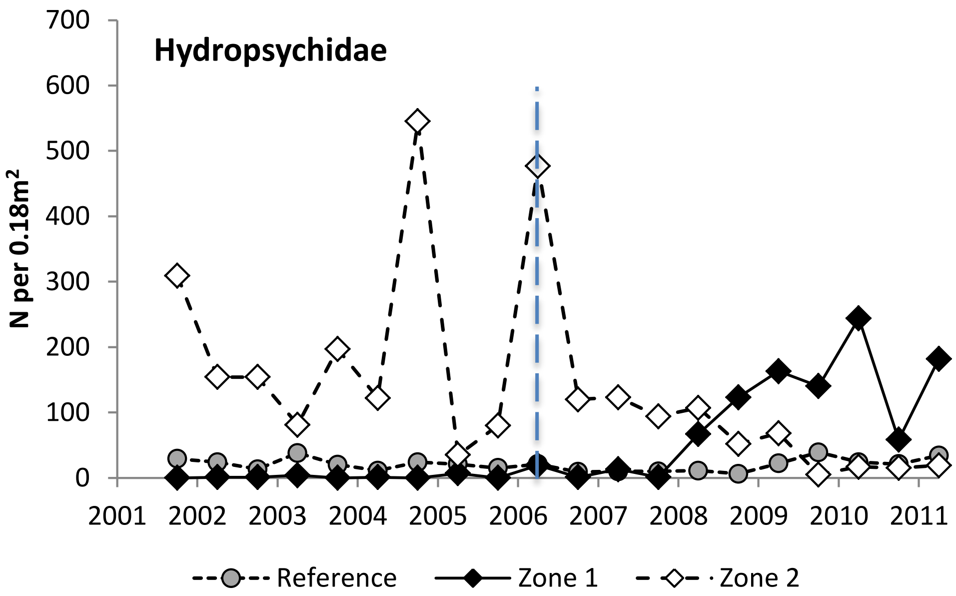
The taxon primarily responsible for the change in the absolute and proportional abundance of EPT taxa indicators in zone 1 is the caddis family Hydropsychidae (especially *Asmicridea*, the snowflake caddis), for which an increasing abundance was observed between spring 2008 and autumn 2010 in zone 1 (Figure 7-36). Both Gripopterygidae and Hydrobiosidae also increased in abundance in zone 1 and continue to contribute to the observed increase in proportional EPT representation and to community compositional similarity to reference sites (Figure 7-36 and Figure 7-37). These taxa are favoured by uninterrupted, steady flow conditions combined with abundant food resources in the form of particulate organic material – especially the net building filter feeder *Asmicridea*. After Basslink operations commenced, these conditions were increasingly being met upstream of the Denison confluence in zone 1 due to the presence of an environmental flow, especially between sites 63 and 74 downstream of the tributaries of the Orange, Albert and Piguenit Rivers. The timing and rate of these abundance increases were consistent with a lagged response to post-Basslink environmental flows controlled by recruitment and responses to food availability.

Abundances of all these groups declined in 2010–11 in zone 1, particularly for the Hydrobiosidae (Figure 7-36 and Figure 7-37). This group had shown significant increases from 2008 to 2010, and the decline in 2010–11 is highly likely due to the changed nature of the flow regime, which more closely approximates the hydro-peaking pattern expected for Basslink operations, and which is likely to particularly affect these flow-sensitive taxa.

By contrast, numbers have been stable or declining slightly during the 2008–10 period in zone 2, and this has continued in 2010–11.

An increase in simuliid (blackfly) larval densities post-Basslink was evident for zone 2 from spring 2007 to autumn 2010, with a marked seasonal cycle (Figure 7-37). This has now reversed with substantially lower densities recorded in 2010–11.

Overall, there was a post-Basslink increase in abundance of the aquatic insect families Hydropsychidae, Gripopterygidae and Hydrobiosidae in zone 1, with indications of other taxa showing a lagged increase in zone 2. This process has now been reversed, with most taxa in decline in 2010–11, which is likely to be due to a change in power station operations and hence the flow regime. No similar declines were observed in reference sites in 2010–11, discounting any effect of background changes in catchment conditions.



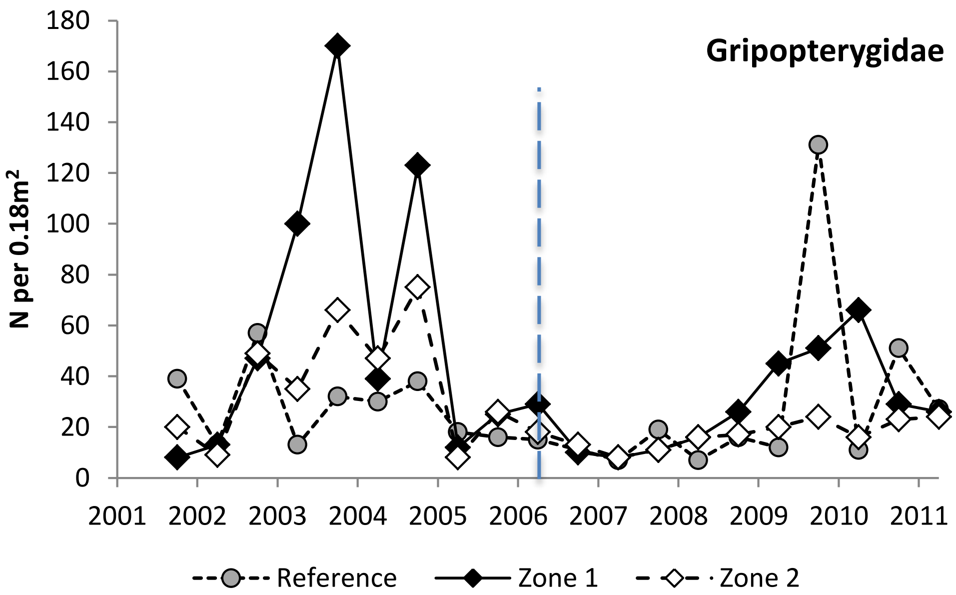


Figure 7-36 Mean abundance of two key taxa for zones 1 and 2 in the Gordon River and for the reference river sites against time. Dashed vertical line indicates initiation of Basslink operations

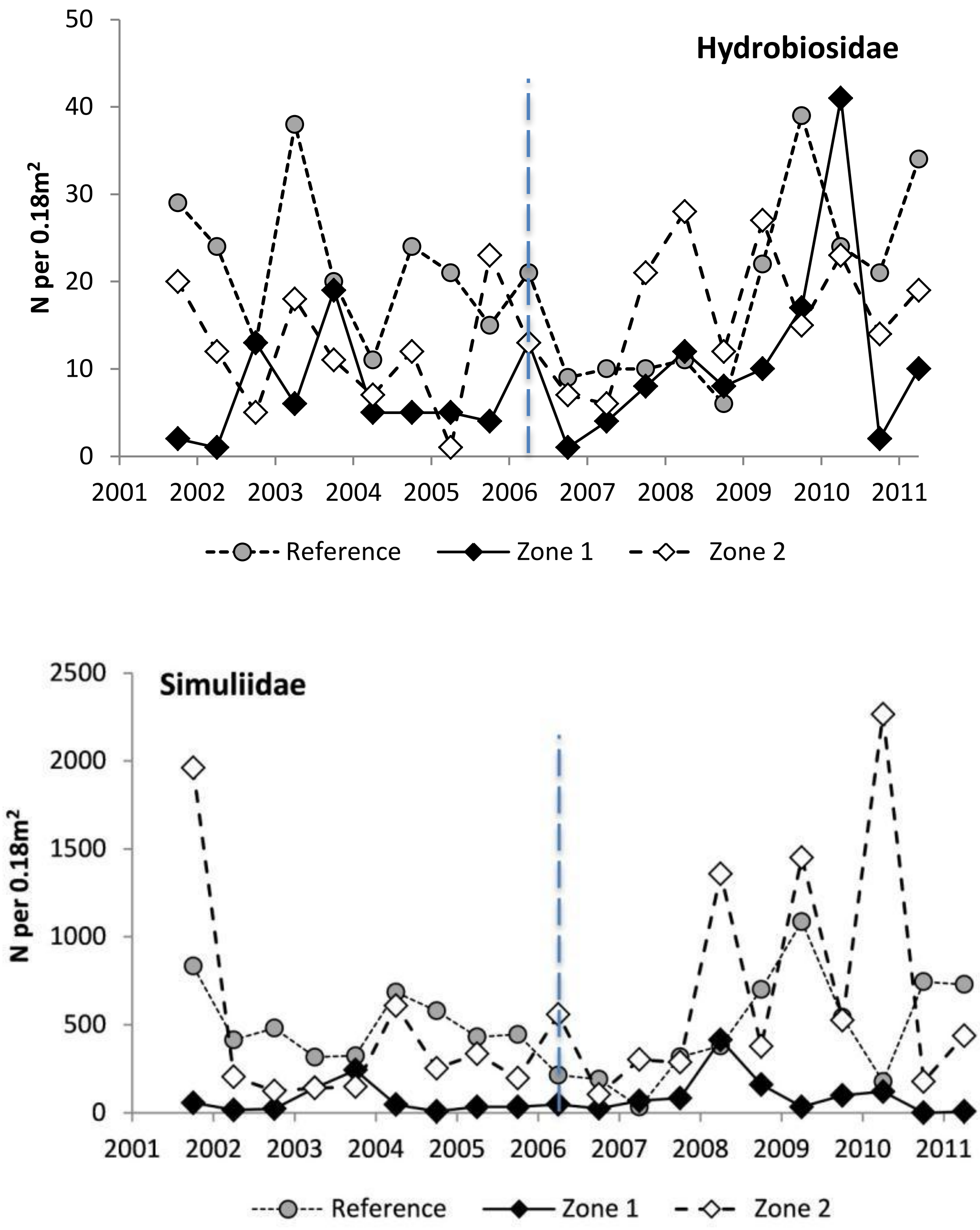


Figure 7-37 Mean abundance of two key taxa for zones 1 and 2 in the Gordon River and for the reference river sites against time. Dashed vertical line indicates initiation of Basslink operations

7.6 Conclusions

Spring 2010 and autumn 2011 constitute the fifth full year of the post-Basslink monitoring period.

Overall, trigger compliance was high. Some upper trigger exceedances reflect substantive, lagged post-Basslink increases in abundance and diversity of aquatic insects. These changes have been particularly strong in zone 1, and increasingly extended upstream with time until 2010–11, accompanied by a substantive increase in macroinvertebrate community compositional similarity to reference sites. Changed flow conditions in 2010–11 have partially reversed these trends.

The current status for the five-year post-Basslink period is:

- trigger exceedances for the total and proportional abundance of EPT species and Bray Curtis similarity to reference sites, especially in zone 1; and
- trigger compliance for all other metrics.

The exceedances represent improvement in biological condition relative to pre-Basslink conditions. Most of this improvement occurred prior to 2010–11, and has now been partially reversed. The environmental flow continues to mitigate post-Basslink operation effects on instream biota.

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8 Algae and moss

8.1 Introduction

Aquatic benthic algae and moss were surveyed in spring (October) 2010 and autumn (February) 2011 in accordance with the requirements of the Basslink Monitoring Program for the Gordon River. Fixed-transect, quantitative (quadrat-based) assessment of aquatic benthic algal and moss cover was conducted at nine 'monitoring' sites in the Gordon River between the power station and the Franklin confluence. Three reference sites were also sampled.

This constitutes year five (2010–11) of the post-Basslink phase of algal monitoring being conducted in the Gordon River catchment.

8.2 Methods

8.2.1 Sample sites

Survey sites were the same as for the Basslink monitoring benthic macroinvertebrate sampling being conducted in the Gordon River, as shown in Map 8-1 and Table 8-1.

8.2.1.1 Gordon River

Sampling was conducted once in each of spring (on 18 and 26 October) 2010 and autumn (on 26 February) 2011. All aquatic benthic algal and moss assessment at Gordon River sites was conducted by measuring percentage area of cover at fixed distances along existing transects across the river, with one transect assessed at each site.

All Gordon River data was collected as follows:

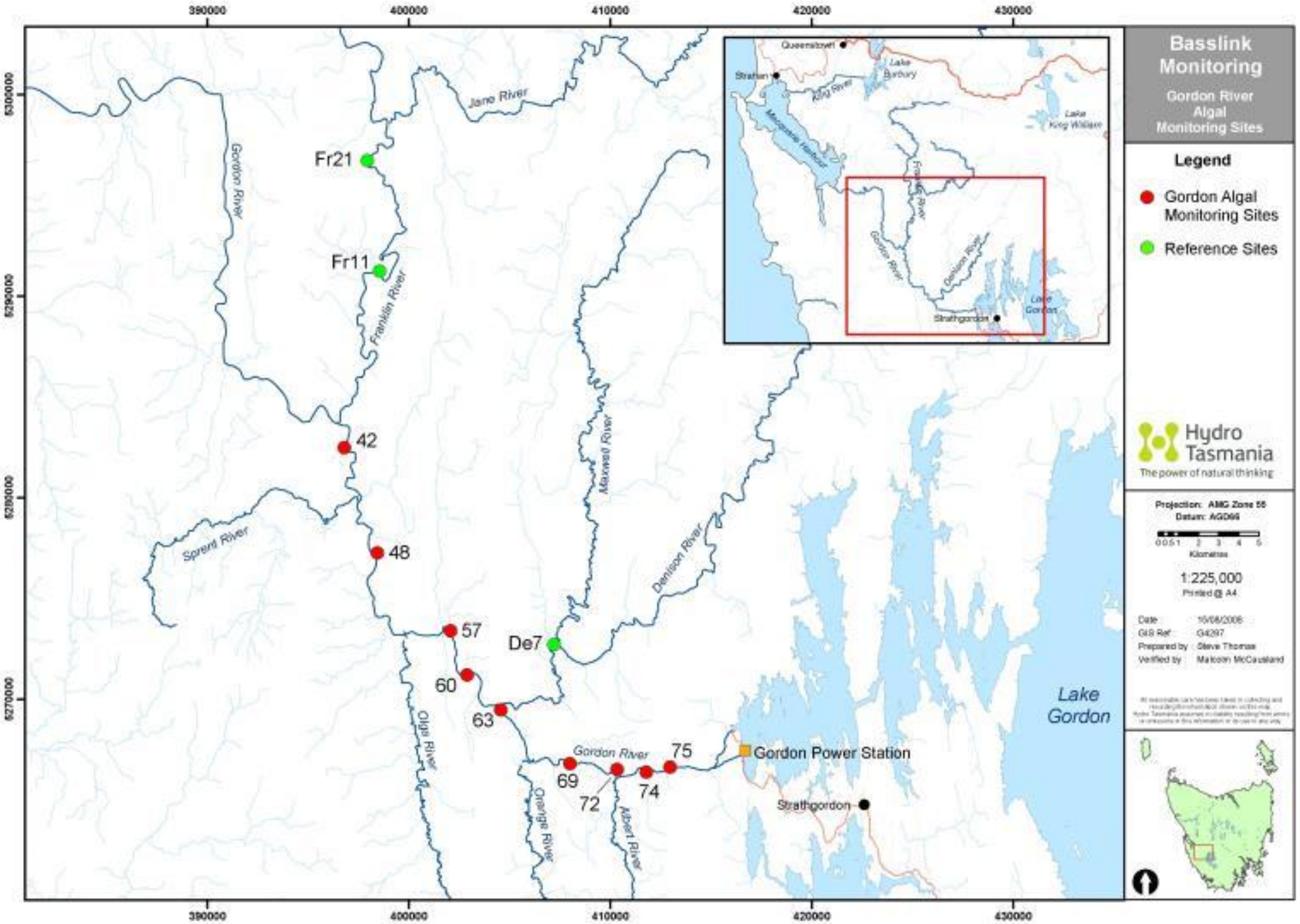
- transects were re-established, at existing locations perpendicular to the direction of river flow, by running a measuring tape across the river from the existing transect head-peg (which was designated as the zero distance offset) to a fixed peg on the opposite bank;
- algal and moss density, as per cent cover, was recorded using a 30 cm x 30 cm quadrat at 2.5 m intervals in three locations:
    1. 1 m upstream of the transect line;
    2. on the transect line, and
    3. 1 m downstream of the transect lines
- within each quadrat, density was reported for four broad floristic groups:
    1. filamentous algae;
    2. characeous algae;

3. moss; and
4. macrophytes.

The transect was also divided into broadly similar ‘zones’, characterised by consistency of benthic substrate composition. Zones were defined following visual inspection of the channel substrate, and defined in terms of their dominant substrate composition, e.g. cobble/gravel, sand/silt, sand/snags, bedrock etc.

8.2.1.2 Reference sites

Reference site sampling was conducted on the same dates as for the Gordon River sites. Plant cover was assessed at 30 randomly chosen locations across the channel on the dominant substrate (typically cobbles and boulders) using the same quadrat procedure described above. It should be noted that bedrock substrate and backwater features were not sampled, due to high variability in the nature of these substrates at reference sites and their frequent morphological dissimilarity from those observed in the Gordon River. This was not the case for the dominant river bed substrate of cobbles and boulders. Data comparability between these sample sets and those for the Gordon River is, therefore, restricted to filamentous algae only, as mosses favour bedrock habitats.



Map 8-1 Sites sampled in 2010–11 for aquatic benthic algae, moss and macrophytes

Table 8-1 Sites sampled in 2010–11 for aquatic benthic algae, moss and macrophytes

River	Site code	Site name (old code)	Easting	Northing
Gordon	75	Gordon R d/s Albert Gorge (G4)	412980	5266630
	74	Gordon R d/s Piguenit R (G4A)	412311	5266383
	72	Gordon R in Albert Gorge (G5)	410355	5266524
	69	Gordon R u/s Second Split (G6)	408005	5266815
	63	Gordon R u/s Denison R (G7)	404584	5269469
	60	Gordon R d/s Denison R (G9)	402896	5271211
	57	Gordon R u/s Smith R (G10)	402083	5273405
	48	Gordon R d/s Olga R (G11b)	398450	5277275
	42	Gordon R @ Devil's Teapot (G15)	396804	5282486
Franklin	Fr11	Franklin R d/s Blackman's bend (G19)	398562	5291239
	Fr21	Franklin R @ Flat Is (G20)	397939	5296733
Denison	De7	Denison d/s Maxwell R (G21)	407206	5272718

8.2.2 Analysis

Mean plant cover scores were derived for the main channel bed (bank toe to bank toe). These were plotted and compared to trigger levels to assess any exceedances.

8.3 Results

8.3.1 Spring 2010 results

Surveys were successfully completed across the entire river channel for sites 75, 74, 72, 69 and 63. The presence of deep, fast water prevented survey across the entire channel for sites 57, 48 and 42. An average 63 m of river bed was surveyed across all sites, ranging from 38 to 88 m.

Data from surveys are summarised in Table 8-2. Aquatic flora in the Gordon River had a consistently low to moderate cover across all sites. Moss and filamentous algae were again the dominant forms, and had low to moderate overall mean per cent cover across all sites (0.5–35 % of benthic area combined). Macrophytes were only observed at site 72 and with very low cover.

Observable filamentous algal cover was again absent to very low in the reference river samples.

Table 8-2 Summary cover data for algae, moss and macrophytes surveyed in spring 2010 for Gordon River sites

Site		Mean % cover				Width surveyed (m)
		Moss	Filamentous algae	*Nitella/Chara*	Macrophytes	
Gordon						
75	G4	5.55	7.27	0	0	67.5
74	G4A	3.65	30.83	2	0	42.5
72	G5	0.35	13.38	10.14	4	80
69	G6	0.63	2.42	0	0	80
63	G7	0.28	2.28	0	0	72.5
60	G9	0.85	0.13	0	0	87.5
57*	G10	0.05	0.48	0	0	40
48*	G11B	2.00	9.03	0	0	62.5
42*	G15	0	1.98	0	0	37.5
Reference						
Fr11	G19	0	0.035	0	0	
Fr21	G20	0	0.093	0	0	
De7	G21	0	0	0	0	

* indicates transects for which only part of the channel could be surveyed. Total distances surveyed from the transect head pegs are indicated

8.3.2 Autumn 2011 results

Surveys were successfully completed across the entire river channel for sites 60–75. The presence of deep, fast water prevented survey across the entire channel for sites 42–57. An average 67.5 m of river bed was surveyed across all sites, ranging from 50 to 88 m.

Data from surveys are summarised in Table 8-3. Aquatic flora in the Gordon River had a consistently low cover across all sites. Moss and filamentous algae were again the dominant forms, and had low overall mean per cent cover across all sites. Cover at site 74 had decreased since spring, and site 75 had the greatest cover of both moss and algae (16 % combined). Macrophytes were again observed at site 72 with very low cover.

Table 8-3 Summary cover data for algae, moss and macrophytes surveyed in autumn 2011 for Gordon River sites

Site		Mean % cover				Width surveyed (m)
		Moss	Filamentous algae	*Nitella/Chara*	Macrophytes	
Gordon						
75	G4	4.09	11.45	0.01	0.0	67.5
74	G4A	5.43	7.86	0.19	0.0	65
72	G5	0.0	9.84	2.35	2.62	80
69	G6	0.41	5.28	0.0	0.0	77.5
63	G7	1.92	7.38	0.0	0.0	75
60	G9	0.08	0.11	0.0	0.0	87.5
57*	G10	0.15	0.91	0.0	0.0	50
48*	G11B	0.34	3.76	0.0	0.0	62.5
42*	G15	0.81	1.60	0.04	0.0	42.5
Reference						
Fr11	G19	0.2	0.07	0	0	
Fr21	G20	0	0	0	0	
De7	G21	0	0.03	0	0	

* indicates transects for which only part of the channel could be surveyed. Total distances surveyed from the transect head pegs are indicated

8.3.3 Comparison with previous years

Overall mean per cent cover for moss and filamentous algae are shown for all sites for each year (as means across each transect over the two seasonal sampling occasions) in Table 8-4. There was no significant difference in per cent cover of either moss or filamentous algae between 2010–11 and pre-Basslink years for whole-of-river or in either zone.

Plots of the downstream trends in annual mean of moss and filamentous algae for all five years from 2001–02 to 2010–11 are shown in Figure 8-1.

The pattern and mean per cent cover for both moss and filamentous algae in 2010–11 were broadly similar to previous years. Site 75 (the most upstream site) had significantly lower filamentous algal cover post-Basslink (mean of 4.78 %) than pre-Basslink (mean of 10.44 %), by one-way ANOVA ($p = 0.016$, $df = 8$). Reduced algal levels are an anticipated effect of sustained minimum environmental flows post-Basslink as identified in the conceptual model in the Basslink Baseline Report (Hydro Tasmania 2005a). There were however, no statistically significant differences between 2010–11 data and the mean of either all previous or pre-Basslink years for sites other than site 75 (by paired t-test, with pairing by site, all $p > 0.25$).

Table 8-4 Annual mean per cent cover for moss and filamentous algae at all transects in 2001–02 to 2010–11 in the lower Gordon River

	Period	Mean for	Site									Whole-of-river	Zone 1 (u/s Denison)	Zone 2 (d/s Denison)
			75	74	72	69	63	60	57	48	42			
Algae	Pre-Basslink	2001–02	7.79	17.00	1.86	3.35	2.19	1.51	0.01	1.72	3.72	4.35	6.44	1.74
		2002–03	9.88	20.73	2.18	5.28	6.59	0.03	0.09	0.26	0.44	5.05	8.93	0.21
		2003–04	10.10	9.08	1.18	1.56	6.31	0.18	0.00	0.32	0.67	3.27	5.65	0.29
		2004–05	13.99	17.43	4.87	4.95	1.55	0.00	1.20	1.84	2.50	5.37	8.56	1.38
	Transition	2005–06	7.61	8.49	3.52	0.33	2.48	0.09	0.26	1.76	2.96	3.06	4.49	1.27
	Post-Basslink	2006–07	3.96	11.43	0.38	0.50	0.00	0.00	0.00	0.11	0.37	1.86	3.25	0.12
		2007–08	2.31	24.00	0.70	0.07	0.33	0.00	0.21	1.02	0.49	3.24	6.77	0.43
		2008–09	3.11	24.34	9.40	0.18	3.22	0.46	0.13	4.39	5.98	5.69	8.05	2.74
		2009–10	4.35	9.85	5.05	6.84	7.64	0.68	0.04	1.97	3.54	4.44	6.75	1.56
		2010–11	9.36	19.35	11.61	3.85	4.83	0.12	0.69	6.40	1.79	6.44	9.80	2.25
Moss	Pre-Basslink	2001–02	6.09	10.63	0.14	8.50	1.05	0.33	0.80	2.84	3.10	3.72	5.28	1.77
		2002–03	2.07	8.16	1.06	3.42	2.46	0.13	0.25	0.54	0.06	2.01	3.43	0.24
		2003–04	2.09	6.18	0.07	1.64	2.15	0.98	0.75	0.87	0.62	1.71	2.43	0.81
		2004–05	4.91	12.62	0.54	0.76	2.14	1.98	0.25	1.59	0.41	2.80	4.19	1.06
	Transition	2005–06	1.94	8.63	0.06	1.54	0.50	1.63	0.64	0.25	2.08	1.92	2.53	1.15
	Post-Basslink	2006–07	2.73	8.07	0.41	2.82	2.73	1.12	0.28	1.45	0.64	2.25	3.35	0.87
		2007–08	4.32	6.70	0.28	5.34	3.42	0.66	0.26	0.81	0.95	2.53	4.21	0.67
		2008–09	9.18	0.89	0.04	0.88	0.41	0.18	0.06	0.48	3.32	1.71	2.28	1.01
		2009–10	3.80	16.21	0.04	1.45	1.15	0.62	0.28	1.58	0.56	2.85	4.53	0.76
		2010–11	4.82	4.54	0.17	0.52	1.10	0.47	0.10	1.17	0.41	1.48	2.23	0.54

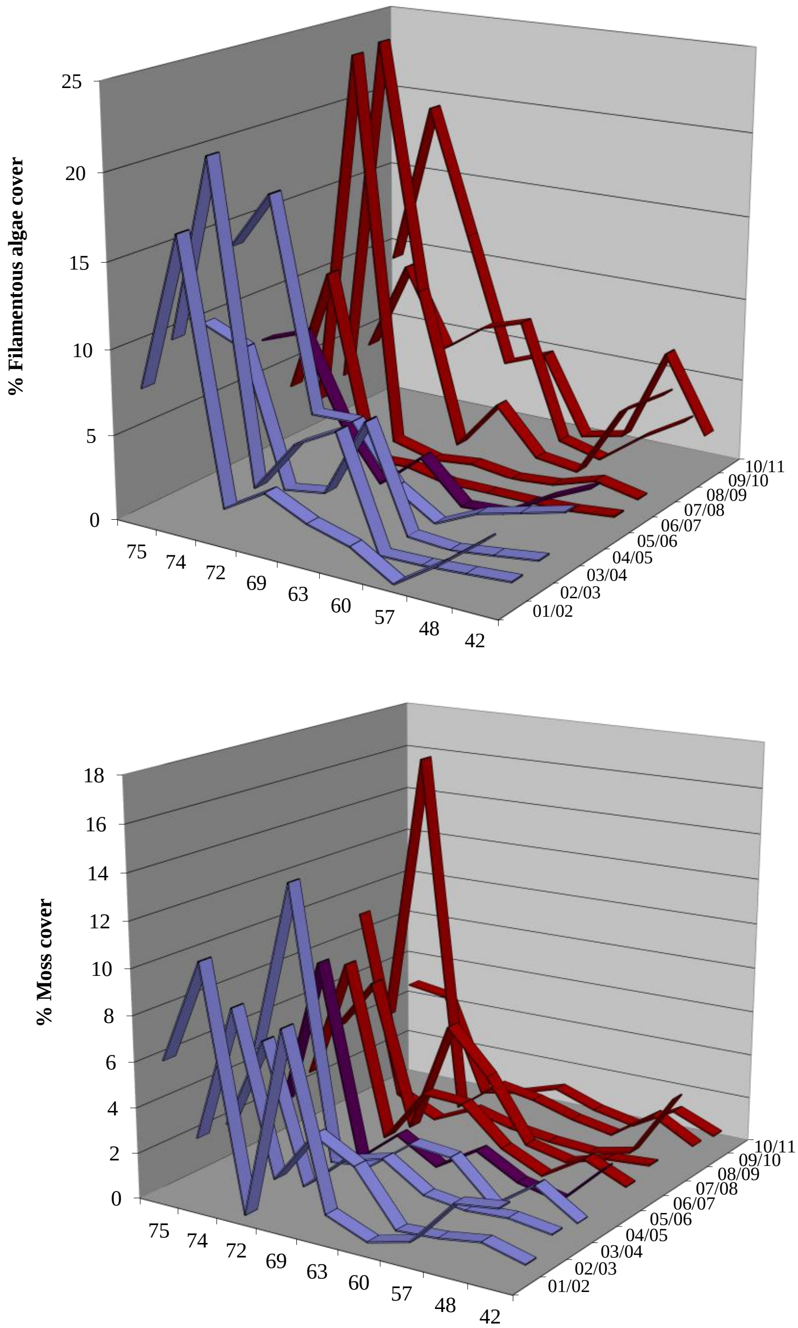


Figure 8-1 Downstream trends in mean per cent moss cover and mean per cent filamentous algal cover in the Gordon during the pre-Basslink period (2001–02 to 2004–05, blue lines), the transitional period (2005–06, deep purple) and the first five years of the post-Basslink period (2006–07 to 2010–11, orange)

8.4 Comparisons with triggers

8.4.1 Results

Two metrics have been identified for assessing the degree of any changes in benthic plants in the Gordon River due to Basslink operations:

- per cent cover of filamentous algae; and
- per cent cover of moss.

Trigger values (Appendix 10) for these metrics have been established based on the 95th percentile of pre-Basslink values. These trigger values are used in reporting on whether Limits of Acceptable Change (LOAC) have been exceeded or not post-Basslink. Upper and lower triggers have been determined. Triggers have been developed for each individual site in the Gordon, as well as for the entire river ('whole-of-river', WOR) and zones within the river. Seasonal differences are also taken into account for the whole-of-river case. Two zones have been described for algae and moss – zone 1 (upstream of the Denison confluence, incorporating sites 69 to 75) and zone 2 (downstream of the Denison confluence, incorporating sites 42 to 60).

Values of these metrics for 2010–11 are shown in Table 8-2 and Table 8-3.

Triggers have been established for one year of observations, and are compared against the data for 2010–11 (as in the 2006–07 to 2009–10 reports), in order to assess the post-Basslink effect for this year only.

Plots of the one-year trigger levels for each metric are compared with the value for the metric recorded in 2010–11, at individual site level (Figure 8-2) and at whole-of-river (WOR) and zone level (Figure 8-3).

8.4.2 Trigger status – one-year (2010–11)

The following section summarises and comments on the observations for 2010–11 in comparison with the one-year trigger values.

8.4.2.1 Filamentous algal cover

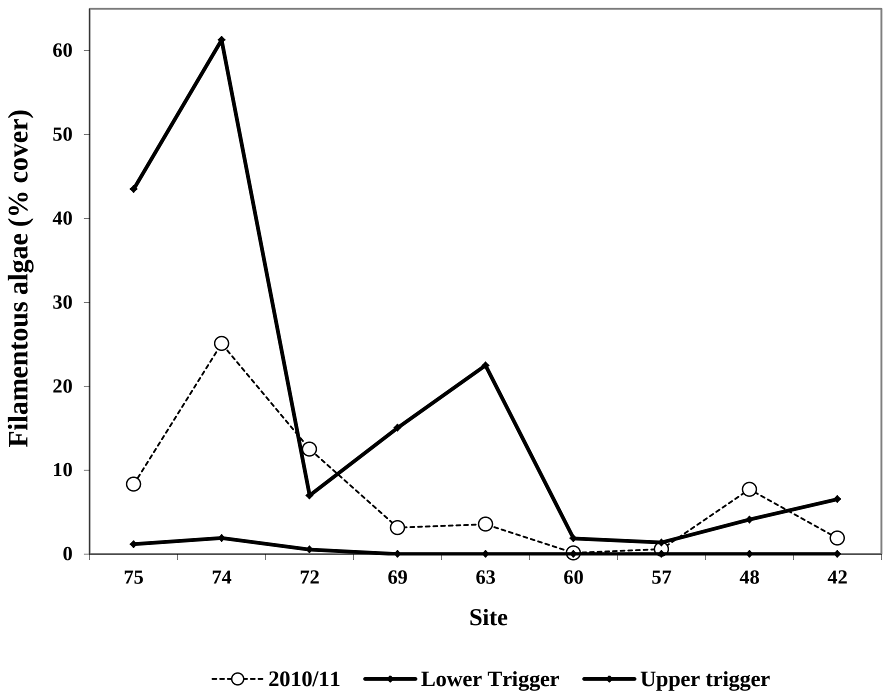
Cover values in 2010–11 fell within trigger bounds at all sites except for minor exceedances at sites 48 and 72. These resulted in minor exceedances for the whole-of-river, in spring and for zone 2 (Figure 8-2 and Figure 8-3), of 0.5 to 2 % above the upper trigger threshold.

Comment – generally consistent with pre-Basslink conditions, but with minor exceedances which are not deemed of ecological significance.

8.4.2.2 Moss cover

All site cover values fell within trigger bounds (Figure 8-2), as did whole-of-river and zone values (Figure 8-3).

Comment – Consistent with pre-Basslink conditions.



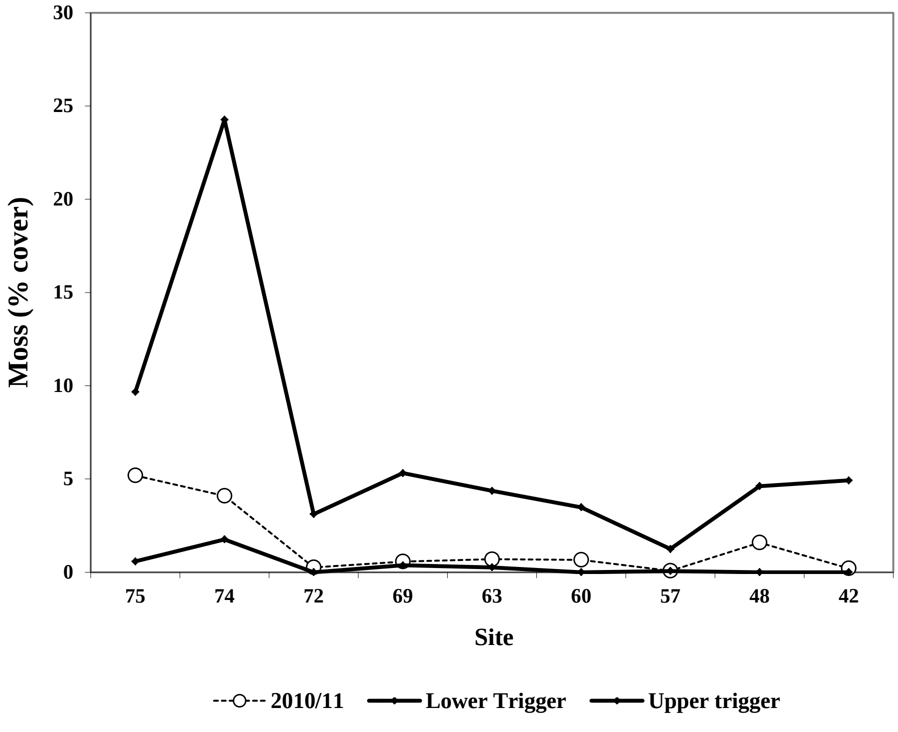
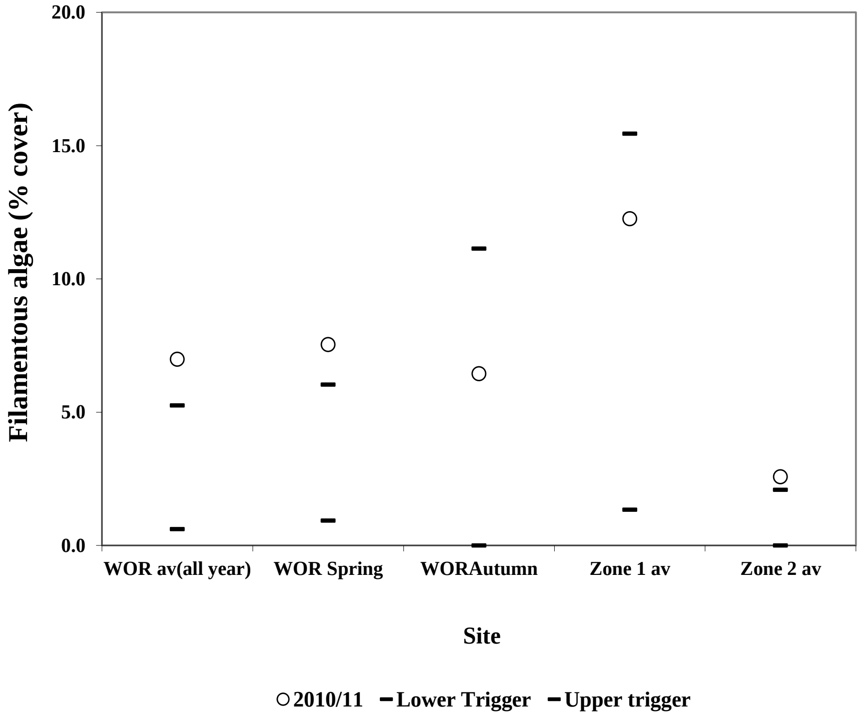


Figure 8-2 Per cent cover of benthic filamentous algae and moss for 2010–11 compared with upper and lower one-year LOAC trigger values for each site in the Gordon River. Trigger values based on the 95th percentile of pre-Basslink data



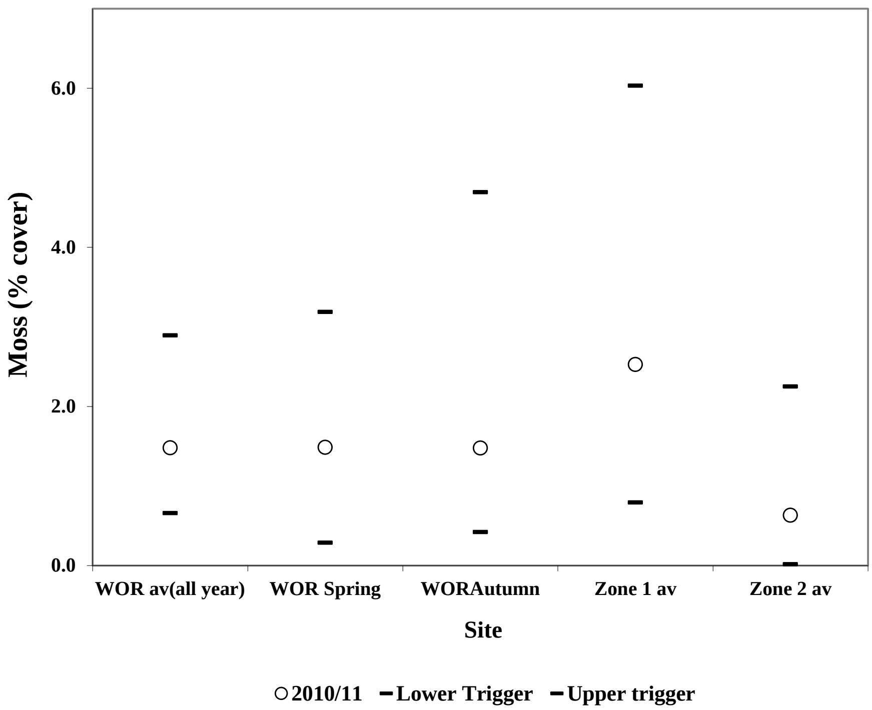


Figure 8-3 Per cent cover of benthic filamentous algae and moss for 2010–11 compared with upper and lower one-year LOAC trigger values in the Gordon River for the following cases: Whole-of-river (year = seasons combined, spring and autumn), zones 1 and 2 (year). Trigger values based on the 95th percentile of pre-Basslink data

8.4.3 Trigger status – five-year (2006–07 to 2010–11)

The following section summarises and comments on the mean observations for 2006–07 to 2010–11 in comparison with the five-year trigger values.

8.4.3.1 Filamentous algal cover

Cover values in 2006–07 to 2010–11 at all sites, for whole-of-river and both zones fall within their trigger bounds (Figure 8-4 and Figure 8-5) with the following exceptions:

- sites 48 and 72 have minor algal cover exceedances above the upper trigger; and
- whole-of-river (WOR) all year and in spring, as well as zone 2, also show minor exceedances.

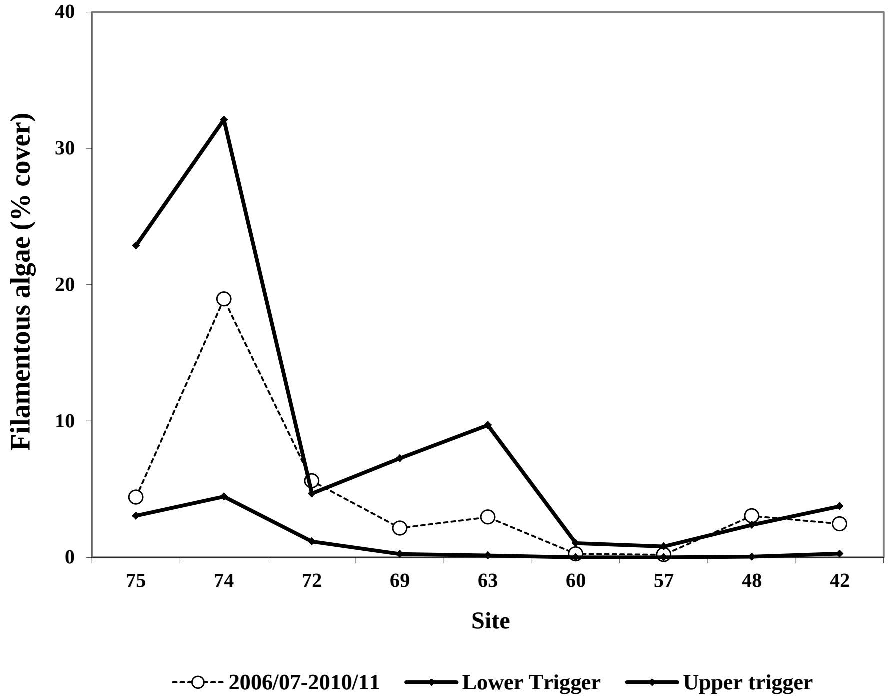
Mean cover appears to be trending upward over the five years post-Basslink in both zones and for the whole-of-river (Figure 8-6), now resulting in minor trigger exceedances (Figure 8-5). The trend is slow, and considerable inter-site variation still exists in cover values.

Comment – The pattern between sites and zones is consistent with pre-Basslink conditions. Site values have been broadly consistent with pre-Basslink ranges but now show minor exceedances for selected sites, and at WOR and zone 2 scales.

8.4.3.2 Moss cover

Cover values fall within or close to trigger bounds at all sites (Figure 8-4). The mean value for whole-of-river (all year) falls just below the upper trigger bound (Figure 8-5). Cover exceeds the upper trigger bound in spring for the whole-of-river mean, but not by an ecologically significant amount. There has been no significant long-term or post-Basslink trend in moss cover (Figure 8-6).

Comment – Generally consistent with pre-Basslink conditions, with minor exceedance in spring.



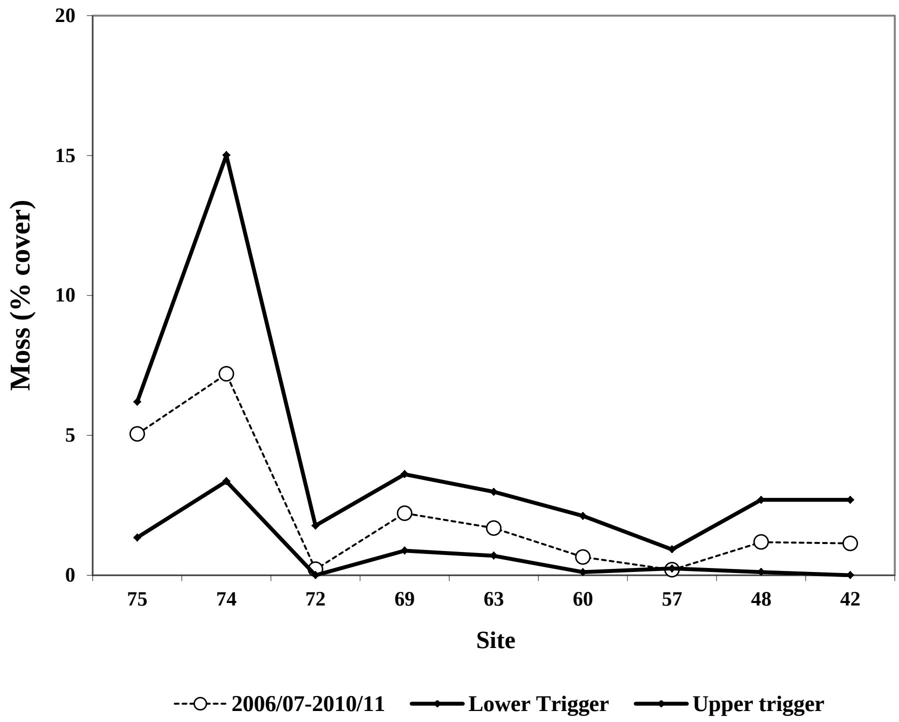
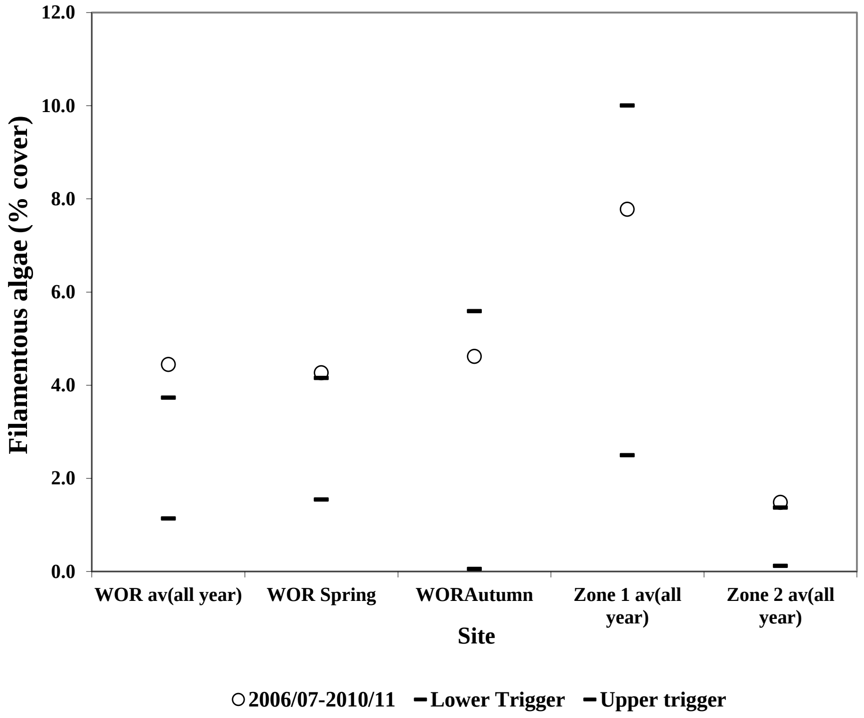


Figure 8-4 Mean per cent cover of benthic filamentous algae and moss for 2006–07 to 2010–11 compared with upper and lower five-year LOAC trigger values for each site in the Gordon River. Trigger values based on the 95th percentile of pre-Basslink data



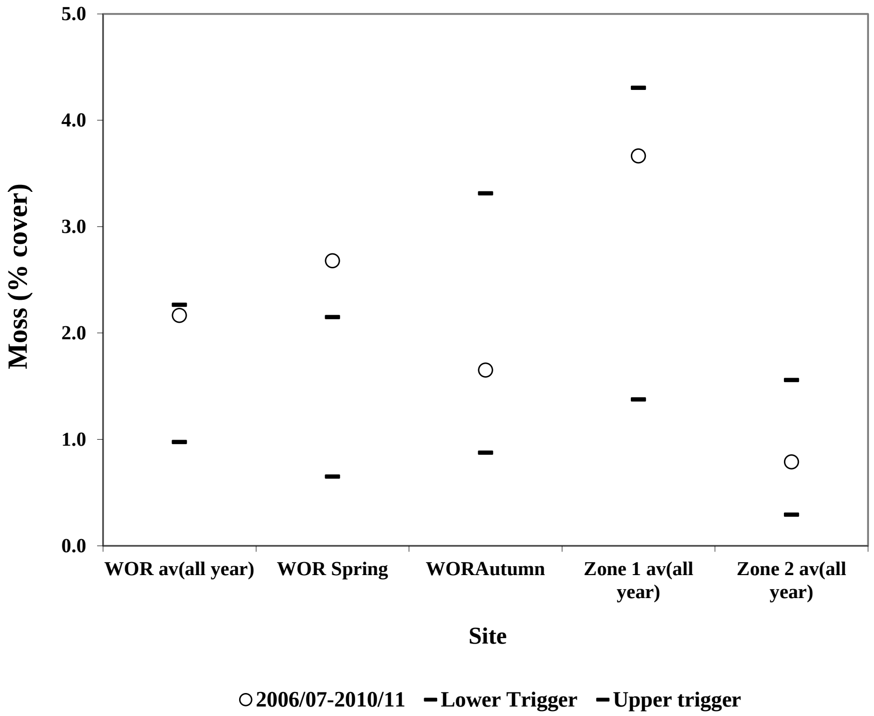


Figure 8-5 Mean per cent cover of benthic filamentous algae and moss for 2006–07 to 2010–11 compared with upper and lower five-year LOAC trigger values in the Gordon River for the following cases: Whole-of-river (year = seasons combined, spring and autumn), zones 1 and 2 (year). Trigger values based on the 95th percentile of pre-Basslink data

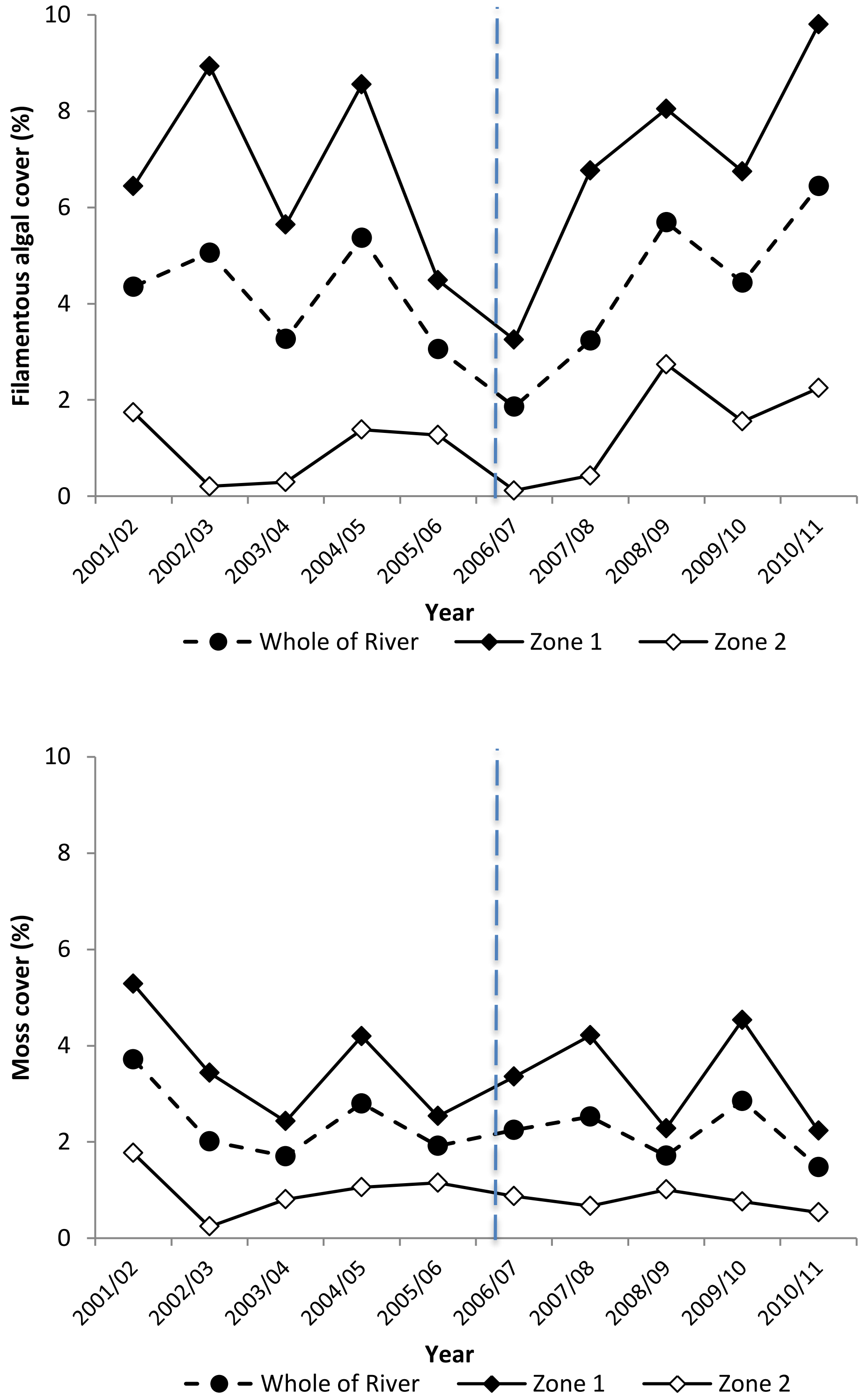


Figure 8-6 Long-term trends in per cent cover of benthic filamentous algae and moss in the two zones of the Gordon and for the whole-of-river from 2001–02 to 2010–11. Vertical dashed line indicates commencement of Basslink operations

8.5 Conclusions

Spring 2010 and autumn 2011 constitute the fifth full year of the post-Basslink monitoring period.

As in the pre-Basslink period, overall aquatic plant cover was low in the Gordon River.

Moss cover was very low downstream of the Denison confluence, as observed previously. Values fell within trigger level bounds and were consistent in overall magnitudes and trends of cover with pre-Basslink years.

Filamentous cover was generally low, peaking in the upper reaches of zone 1, and was very low downstream of the Denison confluence, as observed previously. A minor exceedance was noted at whole-of-river and zone 2, but were otherwise consistent in overall magnitudes and trends of cover with pre-Basslink years. The long-term (five-year) post-Basslink mean cover shows some minor exceedances for filamentous algae, and also for moss. The exceedances do not constitute a substantive ecological change.

9 Fish

9.1 Introduction

The aims of the fish monitoring program are to:

- monitor the relative abundance of fish in the middle Gordon River and assess whether there is a significant change due to Basslink-related alterations to hydrological conditions;
- assess potential changes in the longitudinal fish community structure of the Gordon River with the aim of identifying any changes in the zone of influence; and
- determine any changes to the fish populations of affected tributaries, particularly if recruitment success for juvenile galaxiids has changed under Basslink.

This report summarises the results of the 2010–11 Basslink fish monitoring surveys, which were undertaken in December 2010 and March 2011.

9.2 Methods

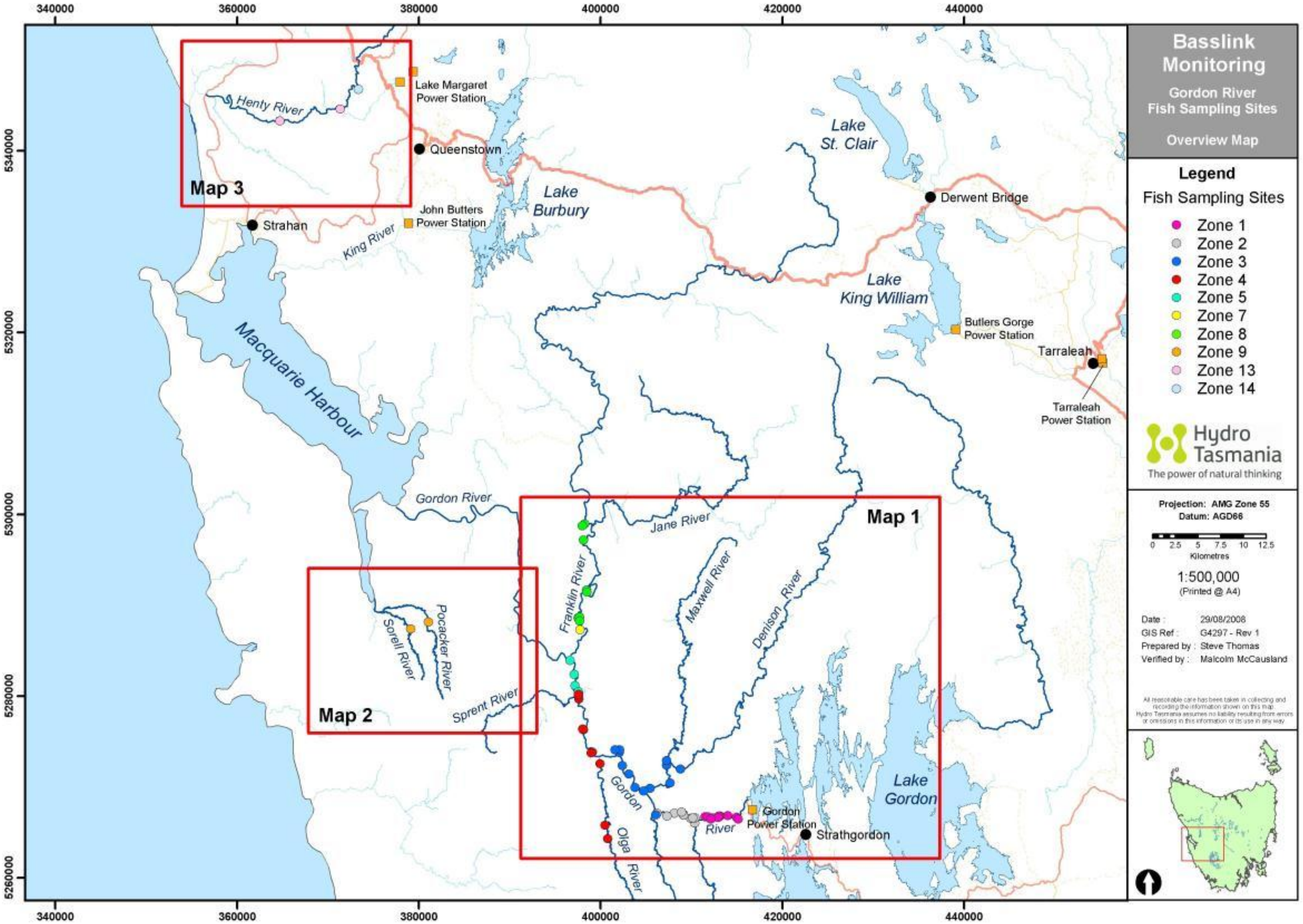
The summer 2010 monitoring surveys were conducted on 2–5 December. Autumn fish sampling was undertaken on 5–7 March and 11 March. The autumn sampling was spread over two trips to work around elevated flows in the Henty River and upper Franklin sites. The data for this year and all previous years is presented in Appendix 9.

Thirty-one monitoring sites in the Gordon catchment were scheduled for sampling on each monitoring trip. These sites are listed in Table 9-1 and are located in the main channel of the Gordon River or in tributaries of the Gordon River, with fish populations in these sites are either directly or indirectly affected by power station operation. The monitoring sites are distributed through a series of Gordon catchment monitoring zones: Map 9-1 and Map 9-2 show the location of these zones. The rationale behind the zone allocations is discussed in Howland *et al.* (2001). Seven river and four tributary reference sites were scheduled for sampling in conjunction with the monitoring sites, and these reference sites are listed in Table 9-2.

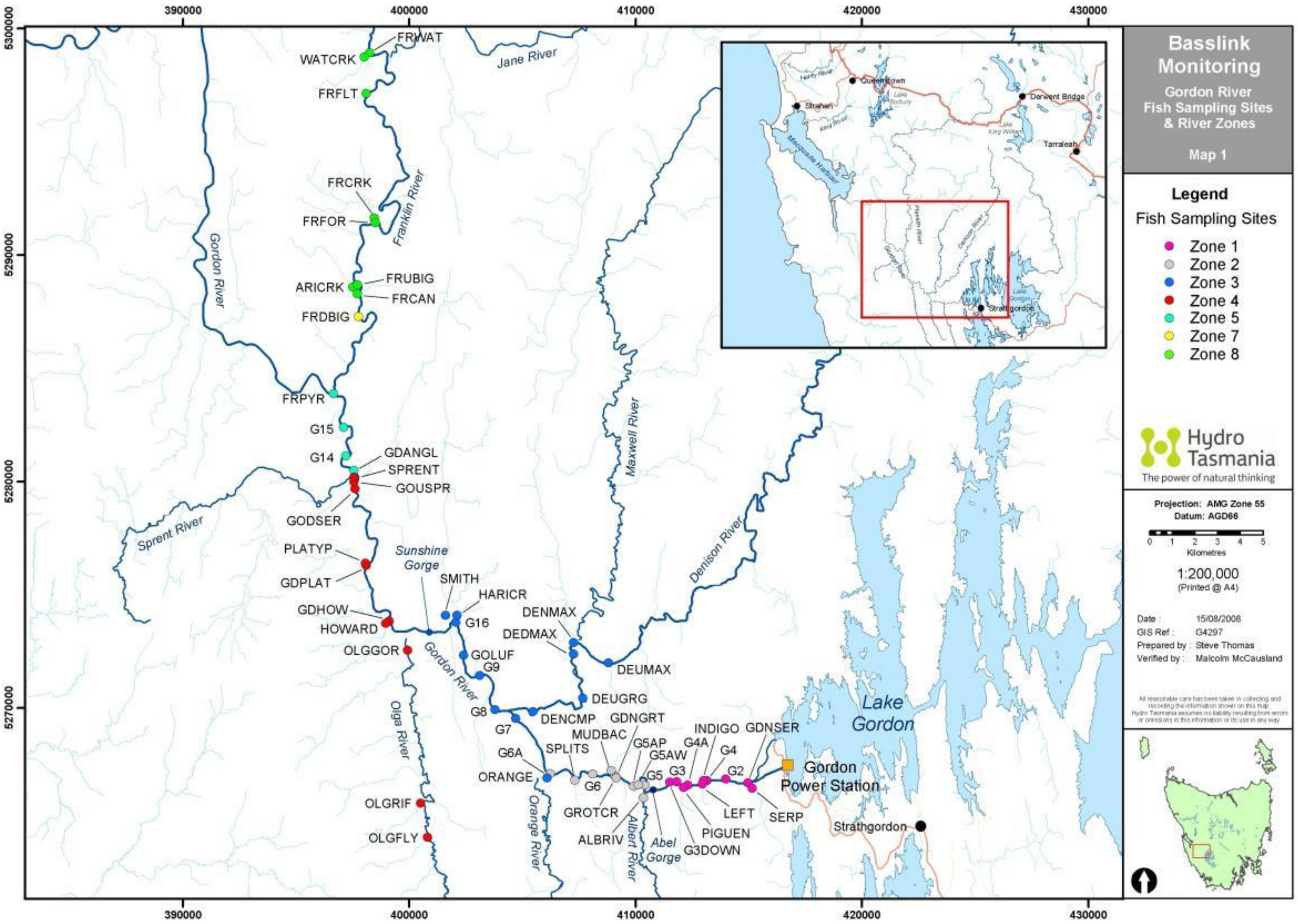
The fish monitoring zones are defined as follows:

- zone 1: Gordon River and tributaries from Gordon Dam downstream to, and inclusive of, Abel Gorge;
- zone 2: Gordon River and tributaries from Albert River downstream to, and inclusive of, the First Split;
- zone 3: Gordon River and tributaries from Orange River downstream to Sunshine Falls;
- zone 4: Gordon River and tributaries from Sunshine Falls to the Sprent River;

- zone 5: Gordon River from Angel Cliffs downstream to Big Eddy;
- zone 7: Franklin River between Pyramid Island and Big Fall;
- zone 8: Franklin River and tributaries upstream of Big Fall;
- zone 9: Birches Inlet catchment;
- zone 13: Henty River at and downstream of the Yolande River; and
- zone 14: Henty River upstream of the Yolande River.



Map 9-1 Fish monitoring sites and zones in the Gordon River (zones 1–5), Franklin River (zones 7–8), Birches Inlet (zone 9) and Henty River (zones 13–14)



Map 9-2 Gordon River fish sampling sites and river zones, zones 1–8

Table 9-1 Gordon catchment monitoring sites. Alternative site names are shown in parenthesis. * indicates a change to the original site list, see text for explanation

Zone	River sites	Tributary sites
1	75 (G4), 74 (G4a), 73 (G3 u/s and d/s)	Left Bank Creek @ site 75*, Indigo Creek, Piguenit Rivulet
2	72 (G5 upper and lower), 71 (G5a pipe and water meter) and 69 (G6)	Albert River, Splits Creek and Mudback Creek
3	68 (G6a), 63 (G7) and 57 (G16)	Smith River and Harrison Creek, Denison River u/s Gorge, Denison River @ Maxwell, Orange River*
4	54 (Howards Creek), 51 (Platypus Creek), 46 (Gordon u/s Sprent)	Howards Creek, Olga River, Platypus Creek and Sprent River
5	45 (Gordon d/s Sprent), 44 (G14), 42 (G15)	Franklin @ Pyramid Island

Table 9-2 Reference sites

Zone (catchment)	River sites	Tributary sites
7 (Franklin)	Franklin d/s Big Fall	none
8 (Franklin)	Franklin u/s Big Fall Franklin @ Canoe Bar	Forester Creek, Ari Creek, Wattle Camp Creek
9 (Birches Inlet)	Sorell River	Pocacker River
13 (Henty)	Henty u/s Bottle Creek Henty @ Yolande River	None recommended
14 (Henty)	Henty @ Sisters	None recommended

‘Optional’ sites, listed in Table 9-3, are included in the monitoring program design and consist of 11 monitoring and four reference sites that are located in both Gordon River tributaries and out-of-catchment rivers. These sites were included to provide additional data for the monitoring program in the event of failure to sample some of the core/essential sites. ‘Optional’ sites are sampled if time and logistics permit, however essential sites take priority in the sampling regime.

The majority of the essential monitoring sites were sampled in 2010–11. High water levels meant that Gordon at G6 could not be sampled in December. Access to the Olga at Gordon site had previously been blocked by a tree fall, but the site was successfully accessed in both summer and autumn. High flows limited the number of optional sites that could be sampled in summer to five; however, favourable conditions in autumn allowed 10 optional sites to be sampled.

Several changes have been made to the monitoring site classifications since the inception of the monitoring program in 2001. The Orange River monitoring site was originally classified as optional but was reclassified as essential to replace the Denison u/s Maxwell site, which had to be abandoned due to ongoing access difficulties. The Serpentine River site was removed from the sampling program and replaced by Left Bank Creek @ G4 due to ongoing safety concerns.

Franklin @ Flat Island was added in March 2011 due to ongoing access difficulties at Franklin @ Wattle Camp Creek, as the small size of the cobble bar at this site makes it susceptible to inundation at moderate flows.

Table 9-3 Optional survey sites. * indicates a change to the original site list, see text for explanation Alternative site names are shown in parenthesis

	Zone	River sites	Tributary sites
Monitoring	1	76 (G2)	none
	2	Gordon @ Grotto Creek	Grotto Creek
	3	site 60 (G9), Gordon @ G8, Gordon @ Fluffies	*Denison @ Denison Camp
	4	none	Howards Creek inundation, Olga @ Riffles
	5	Gordon @ Angel Cliffs	none
Reference	8 (Franklin)	Franklin @ Forester Creek, Franklin @ Wattle Camp Creek, *Franklin @ Flat Island	none
	14 (Henty)	Henty @ West Sister	none

Fish surveys were undertaken by backpack electrofishing, following the methods detailed in Howland *et al.* (2001). Surveys of the Gordon monitoring sites were conducted by three two-person teams, with a target electrofishing effort of 1200 seconds shocking time for each site. Gordon catchment tributary sites situated outside the power station zone of influence were sampled by two teams, and a single team sampled the out-of-catchment reference sites. Teams were comprised of Entura, Hydro Tasmania and Inland Fisheries Service personnel.

Fish teams sampled a range of representative habitats at each site. After capture, fish were anaesthetised, identified and counted, and fork lengths were recorded to the nearest millimetre. Fish were then released to a suitable backwater area to recover from anaesthesia. Qualitative assessments of general aquatic habitat descriptors were recorded for each site.

9.3 Results and discussion

9.3.1 Exotic species

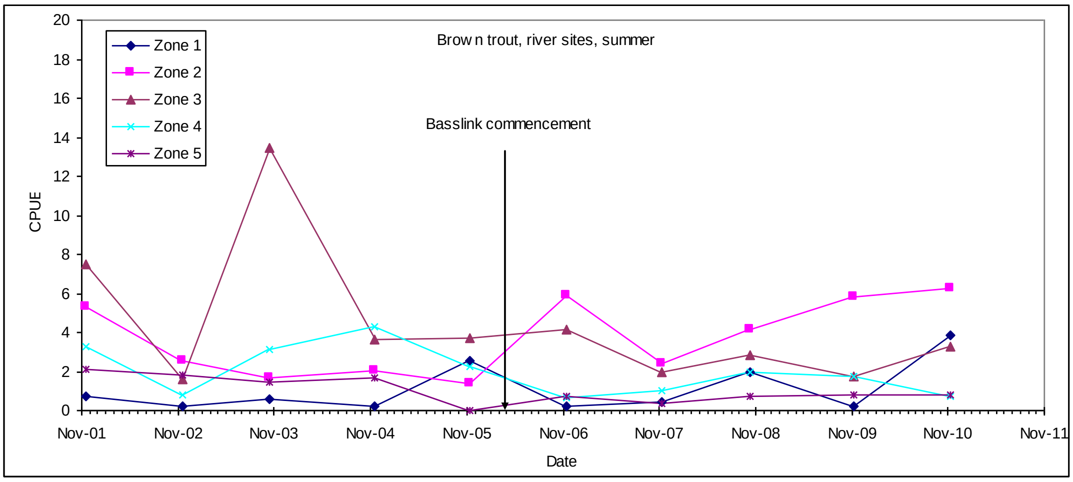
9.3.1.1 Brown trout (Salmoniidae)

Figure 9-1 shows brown trout catches in the Gordon River between the start of the monitoring program in December 2001 and March 2011. Brown trout summer abundances in the zone 1 and zone 2 river sites continue to be above mean pre-Basslink levels, and zone 1 and to a marginal extent zone 5 autumn abundances also continued to be above mean pre-Basslink levels.

Tributary monitoring zone catches are shown in Figure 9-2. Zone 2 catches were above the pre-Basslink average in both the summer and autumn samples. Zone 3 tributary catches have consistently been the highest of all zones for the duration of the monitoring program in both summer and autumn catches, however post-Basslink catches in 2010–11 did not appear to be significantly different to the pre-Basslink mean.

Data from the reference sites is shown in Figure 9-3. Catches were generally similar to historical levels in most zones. Trout are usually absent from the Birches Inlet sites (zone 9), however in the last two years zone 9 trout catches have been well above pre-Basslink means.

In summary, brown trout abundances in the upper Gordon River and tributary zones have increased post-Basslink, and have not changed notably in the reference rivers, which may reflect improved instream habitat due to the environmental flow releases. The nature of the data makes this difficult to test statistically. The increases have not been consistent across all zones and so have not resulted in upper exceedences of any exotic species trigger categories (refer to section 9.5.2 for further discussion).



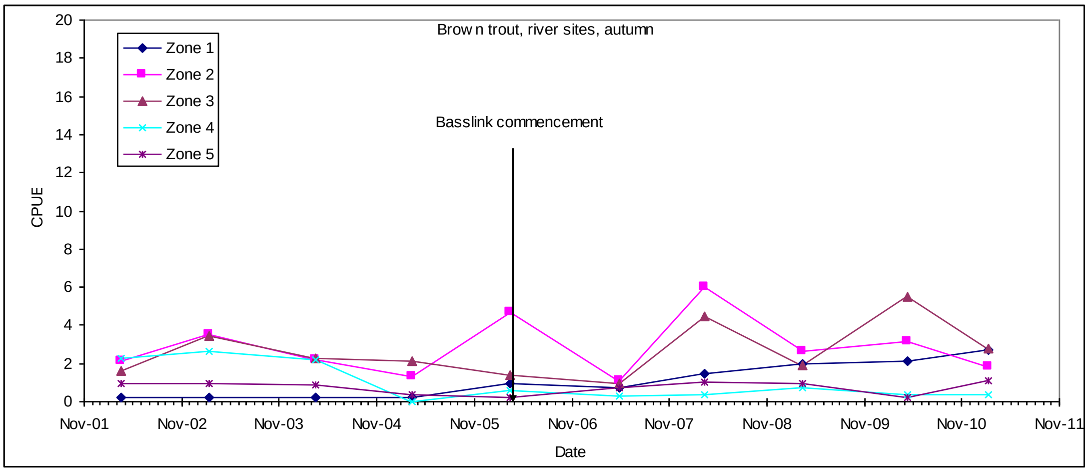
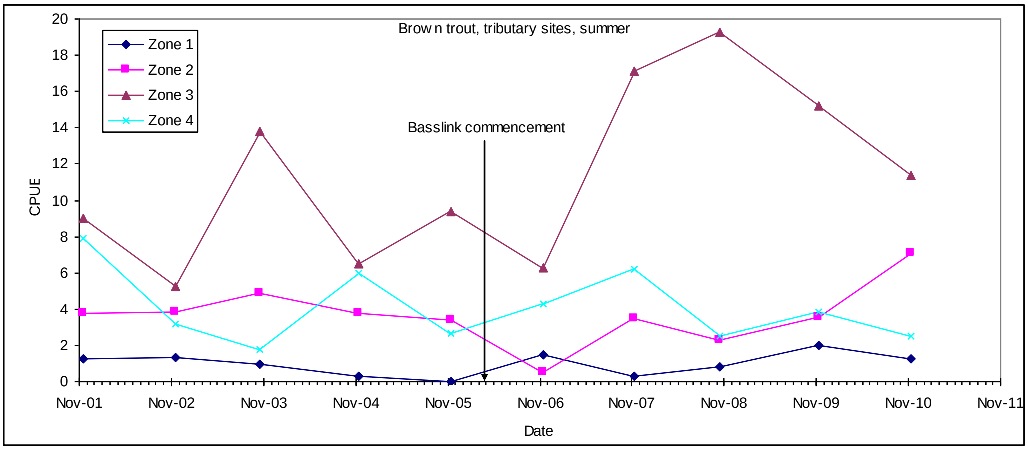


Figure 9-1 Seasonal (summer and autumn) CPUE for brown trout caught in the Gordon River monitoring zones between December 2001 and March 2011



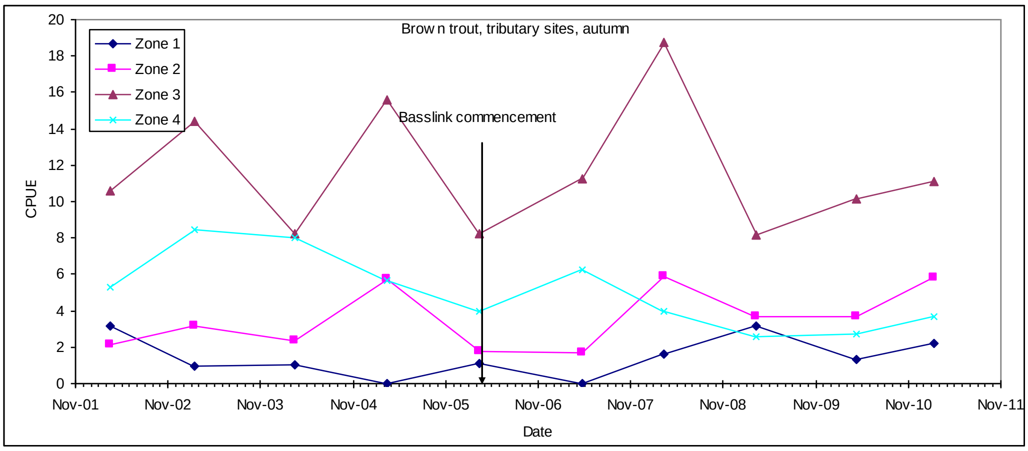


Figure 9-2 Seasonal (summer and autumn) CPUE for brown trout caught in the Gordon tributary monitoring zones between December 2001 and March 2011

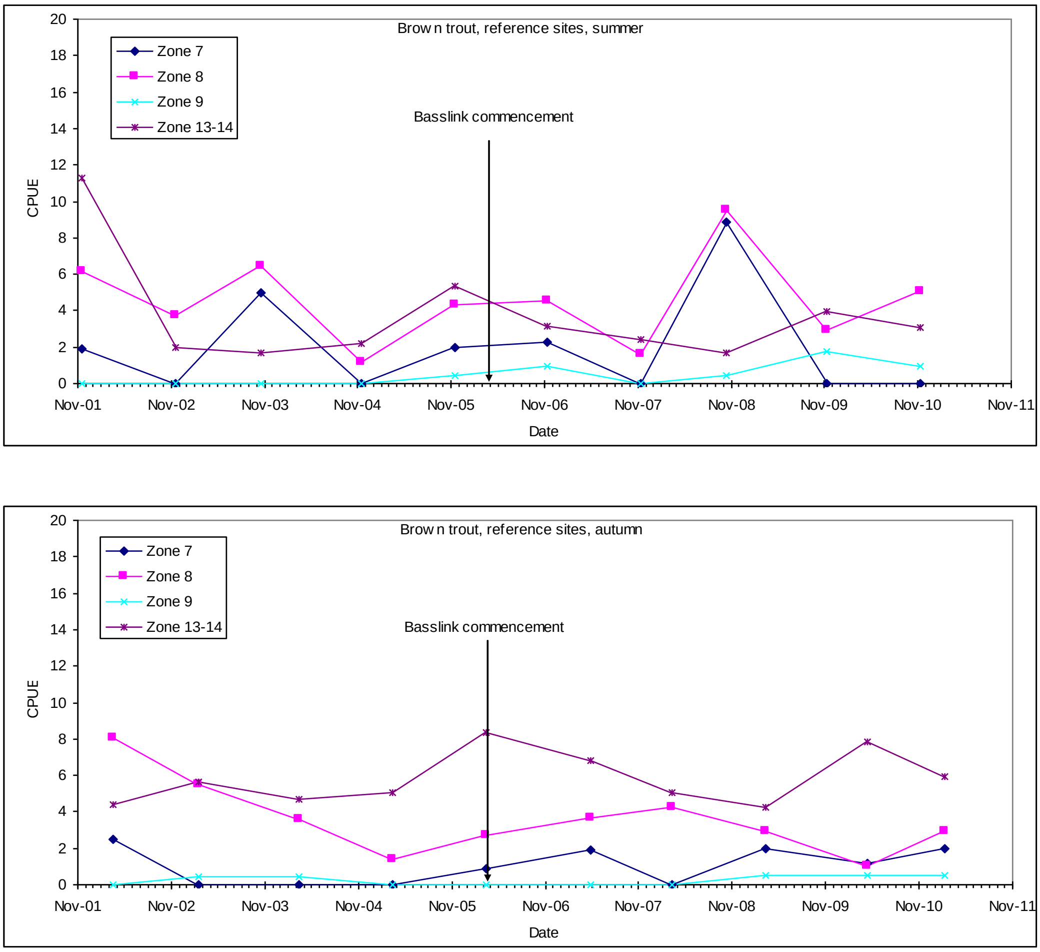


Figure 9-3 Seasonal (summer and autumn) CPUE for brown trout caught in the Reference zones between December 2001 and March 2011

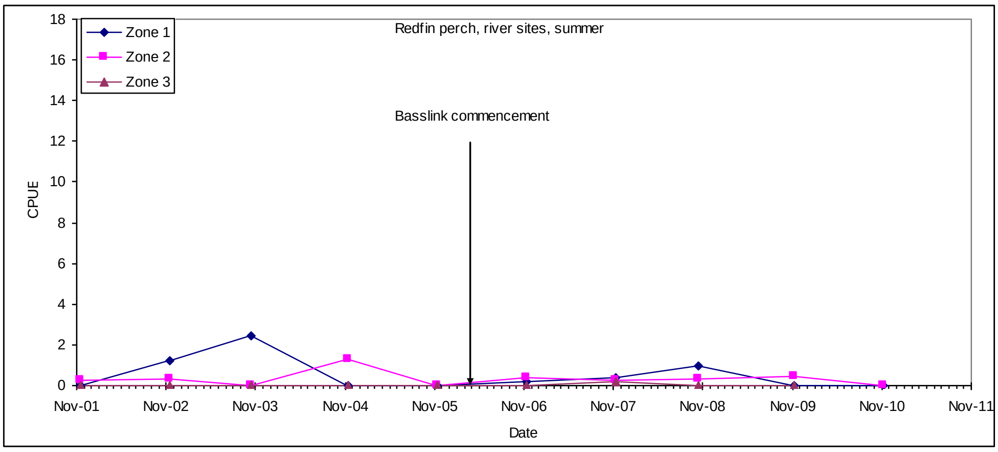
9.3.1.2 Rainbow trout and Atlantic salmon (Salmoniidae)

Rainbow trout or Atlantic salmon were not captured during the summer or autumn sampling trips. These species are rarely caught and are not common at any of the monitoring sites.

9.3.1.3 Perch (Percidae)

Figure 9-4 shows the relative abundance of redfin perch in the Gordon River between the start of the monitoring program and the latest monitoring trip in March 2011. No redfin were observed or captured during the 2010–11. This is the first time that this has occurred since the start of the monitoring program.

Catch data to date, particularly from the post-Basslink period, suggests that although redfin are present in the reaches below Gordon Dam, hydrological and/or habitat conditions are not conducive to the establishment of large populations of this species in the middle Gordon River. The monitoring program may also be having a limited 'fish down' effect on the population, particularly if the population is small and recruitment success and immigration from Lake Gordon is limited, as all redfin that are captured are euthanised in accordance with statutory permit requirements. This theory may partially account for the general decrease in redfin captures over the duration of the program.



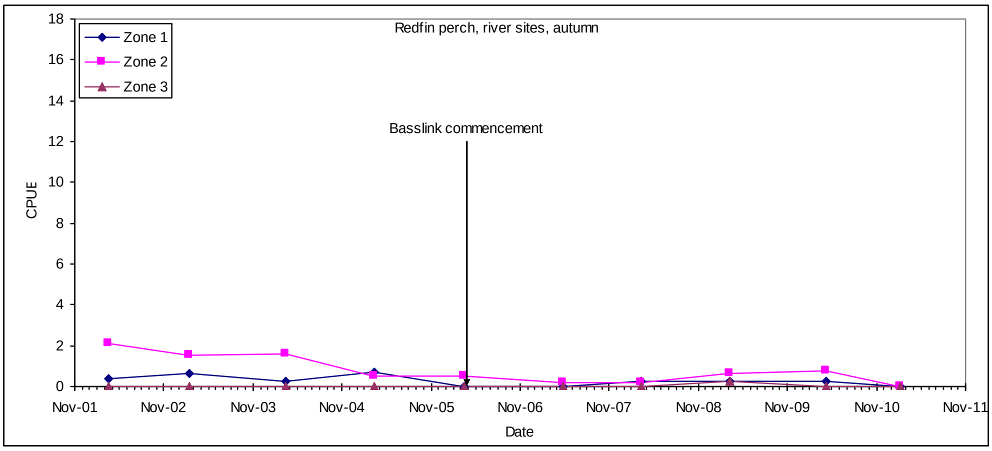


Figure 9-4 Seasonal (summer and autumn) CPUE for redfin perch caught in the Gordon River monitoring zones 1, 2 and 3 between December 2001 and March 2011

9.3.2 Native species

9.3.2.1 Lampreys (Mordaciidae and Geotriidae)

Short headed lamprey (*Mordacia mordax*)

No short headed lampreys were captured during the summer 2010 samples and one fish was electrofished from the Olga @ Riffles site during the autumn sample. As previously reported, short headed lampreys are generally uncommon in the river, and this result is within their expected abundance levels and distribution range derived from baseline data.

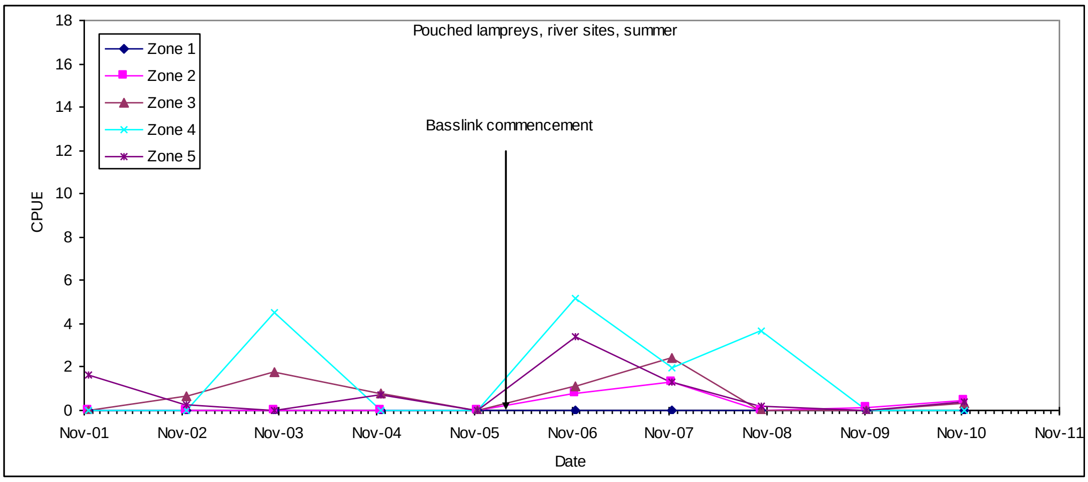
Pouched lamprey (*Geotria australis*)

Figure 9-5 shows the relative abundance of pouched lampreys in the Gordon River zones, and Figure 9-6 shows relative abundance data from the reference sites.

Autumn pouched lamprey catches were low across the middle and lower Gordon River monitoring sites. Low autumn catches were also apparent across the majority of reference sites. While summer catches were relatively low across both the Gordon River and reference sites, they did not deviate significantly from the pre-Basslink mean.

The 2009–10 annual report flagged low lamprey catches in the Gordon River sites, and recommended that the catch data be further assessed in 2010–11 to determine whether a consistent and significant decrease in lamprey abundance is evident, and whether this is linked to a Basslink operating regime. Potter *et al.* (1986) stated that linear models showed larval lamprey density variations can be attributed to the effects of a combination of between five and nine environmental variables, including amount of organic matter and chlorophyll-*a* in the substrate, presence of macrophytes roots, degree of low angle shading, water depth, water velocity, substrate depth, substrate profile, light intensity, sand particle size, and localised hydrological characteristics. Consequently hydropeaked operation has the potential to affect several of these variables.

While low lamprey abundances persisted in the autumn Gordon catches, catches from the reference sites were also low, indicating a seasonal catchment trend rather than a Basslink effect confined to the Gordon River.



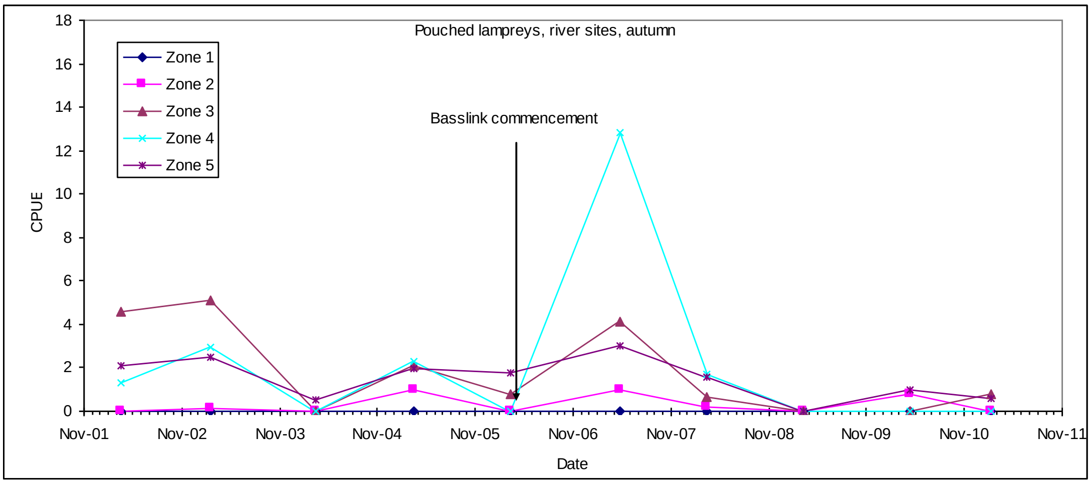
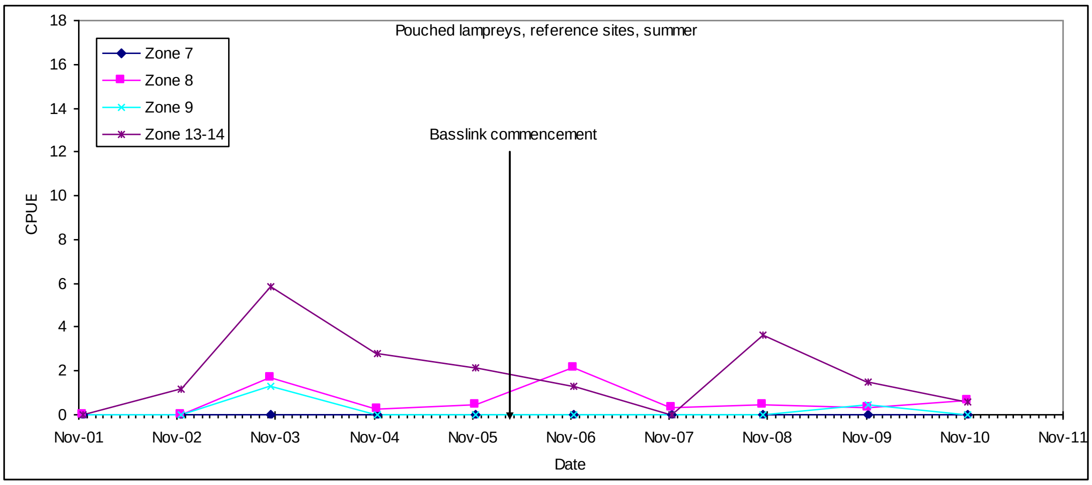


Figure 9-5 Seasonal (summer and autumn) CPUE for pouched lampreys caught in the Gordon River zones between December 2001 and March 2011



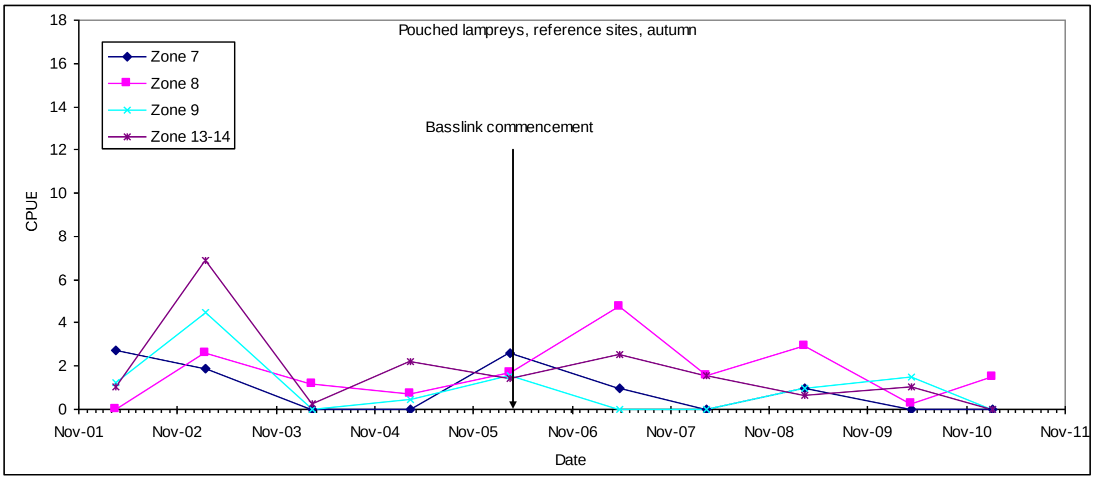


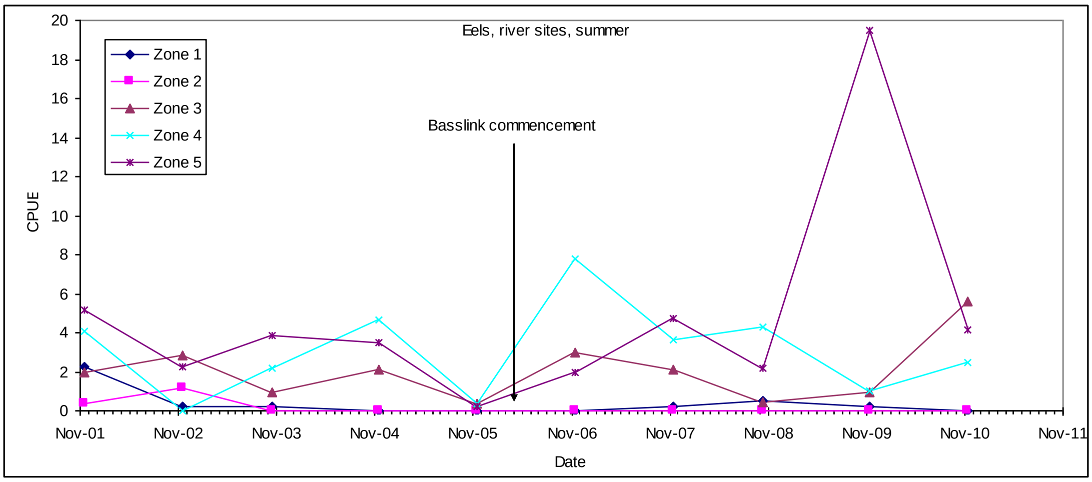
Figure 9-6 Seasonal (summer and autumn) CPUE for pouched lampreys caught in the Gordon River zones between December 2001 and March 2011

9.3.2.2 Eels (Anguillidae)

Short-finned eels (*Anguilla australis)*

The relative abundance of short-finned eels over the duration of the monitoring period is shown in Figure 9-7. Summer and autumn catches were similar to pre-Basslink means however there were several exceptions. Summer catches in zone 3 were above, zone 1 autumn abundances and summer catches at some of the reference sites (zone 13–14) were below pre-Basslink means. Temporary migration bottlenecking due high flows at hydrological barriers (Sprent confluence) did not occur during the 2010–11 sampling program.

Figure 9-8 shows the population structure of short-finned eels captured from the Gordon River and tributary monitoring zones during summer and autumn 2010–11. The results from summer 2009 sample are shown in Figure 9-9 for comparison. The 2009–10 annual report (Hydro Tasmania 2010) reported that strong recruitment had occurred in summer 2009, a feature that was highlighted by hydrological bottlenecking at the Sprent confluence. Figure 9-8 shows that, while catch numbers were reduced in comparison to the unusually high numbers in 2009–10, the population structure of eels in the Gordon River and tributaries is comparable, and that reasonable juvenile recruitment occurred in 2010–11.



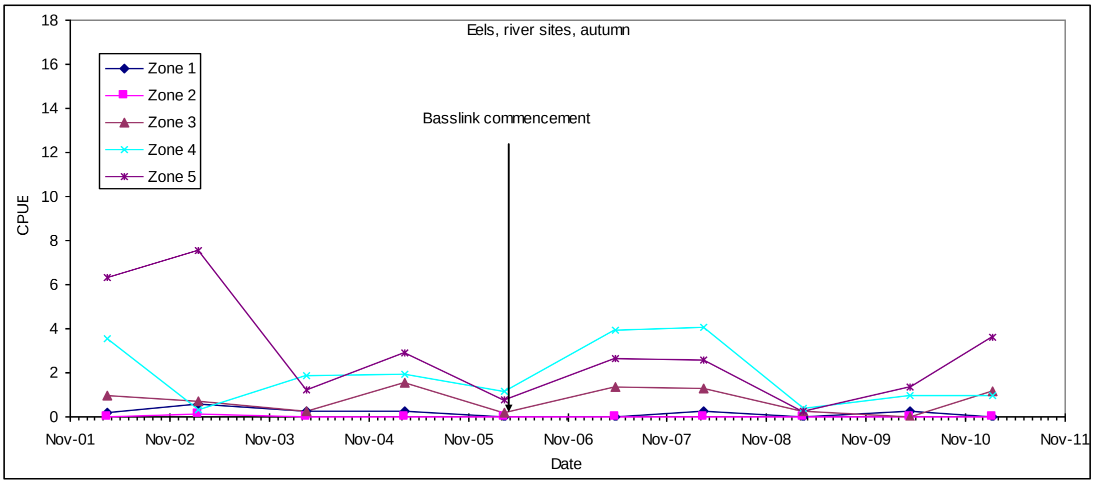


Figure 9-7 Seasonal (summer and autumn) CPUE for short-finned eels caught in the Gordon River monitorng zones between December 2001 and March 2011

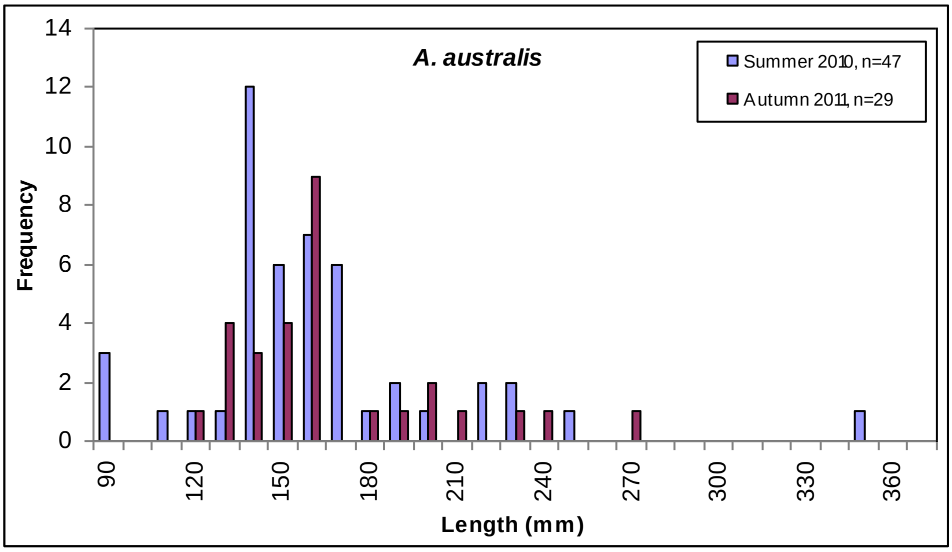


Figure 9-8 Population structure of *A. australis* captured from the Gordon River and tributaries during summer 2010 and autumn 2011

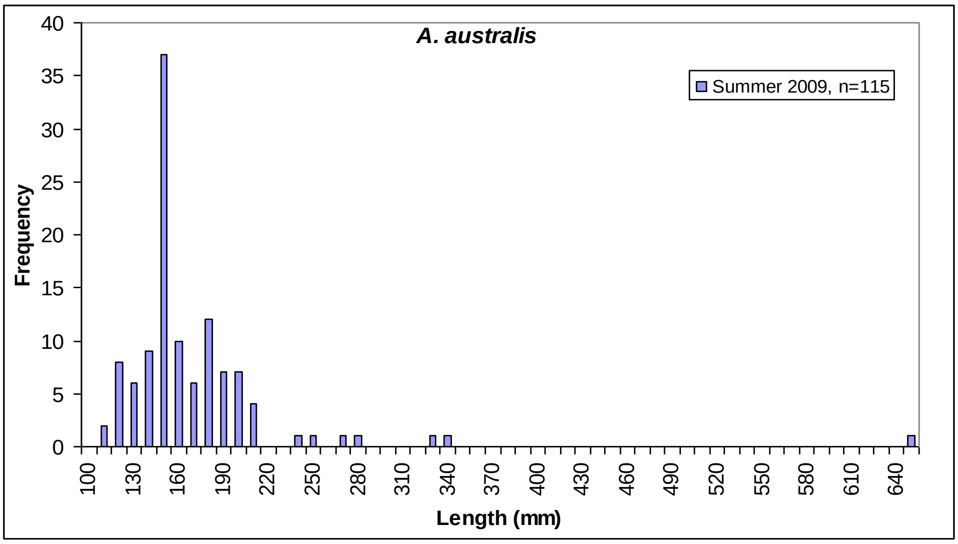


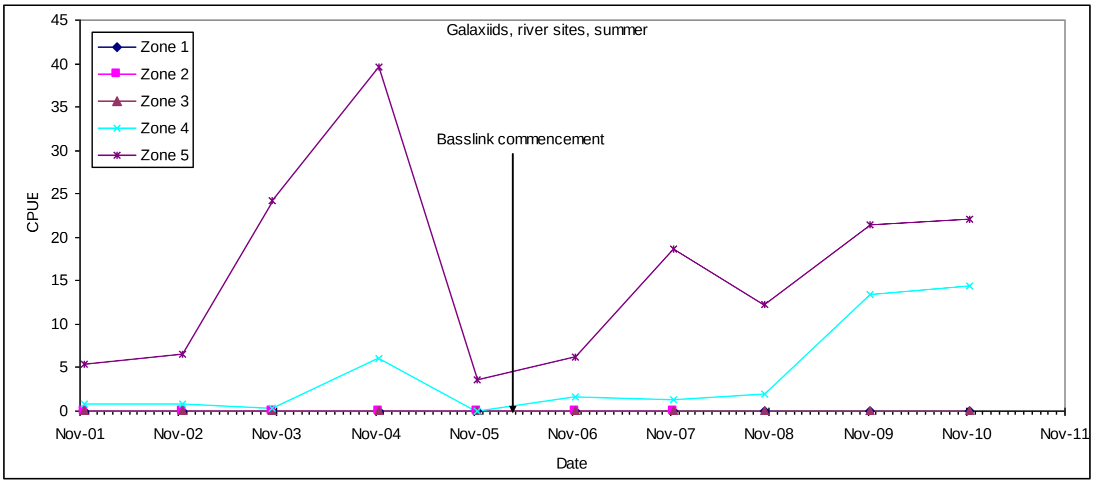
Figure 9-9 Population structure of *A. australis* captured from the Gordon River and tributaries during summer 2009

9.3.2.3 Galaxiids (Galaxiidae)

Figure 9-10 and Figure 9-11 show the relative abundance of galaxiids in the Gordon River and tributary sites over the monitoring program. Relative abundance data for *G. truttaceus*, *G. brevipinnis*, *G. maculatus* and *N. cleaveri* have been used to derive these plots. Survey data from 2009–10 monitoring year indicated *G. truttaceus* was the most abundant fish in the Gordon River and tributaries during the summer, and was second only to brown trout in relative abundance during the autumn. This pattern of results was repeated in 2010–11, again reflecting strong *G. truttaceus* recruitment in spring/summer 2010.

Figure 9-12 shows population structure of *G. truttaceus* collected from the Gordon River monitoring zones during summer and autumn 2009–10 and 2010–11. Strong juvenile recruitment is clearly evident in both years, and the autumn 2010 mode (75 mm) appears to have progressed through with strong representation in summer 2010 data as indicated by a mode in the 85 mm size class.

With the exception of the 2006–07 data, summer and autumn galaxiid catches from zone 4 tributaries continue to be above pre-Basslink means, a result which is driven by consistently high *G. truttaceus* catches. The reasons for this are unclear, however, power station discharge during the spring migration period leading up to sampling in December appeared to be higher in 2006–07, and may have inhibited upstream migration during this period. In contrast, power station discharge leading up to the December 2010 trip was relatively low, with a three-week outage in October and early November followed by an extended period of discharge that was generally between 25 and 50 cumecs, which may have facilitated upstream migration.



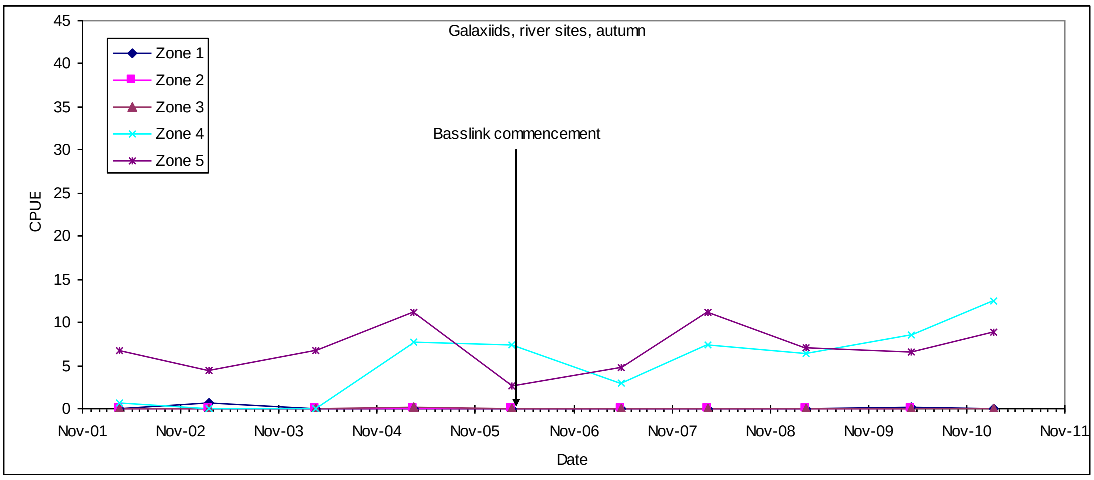
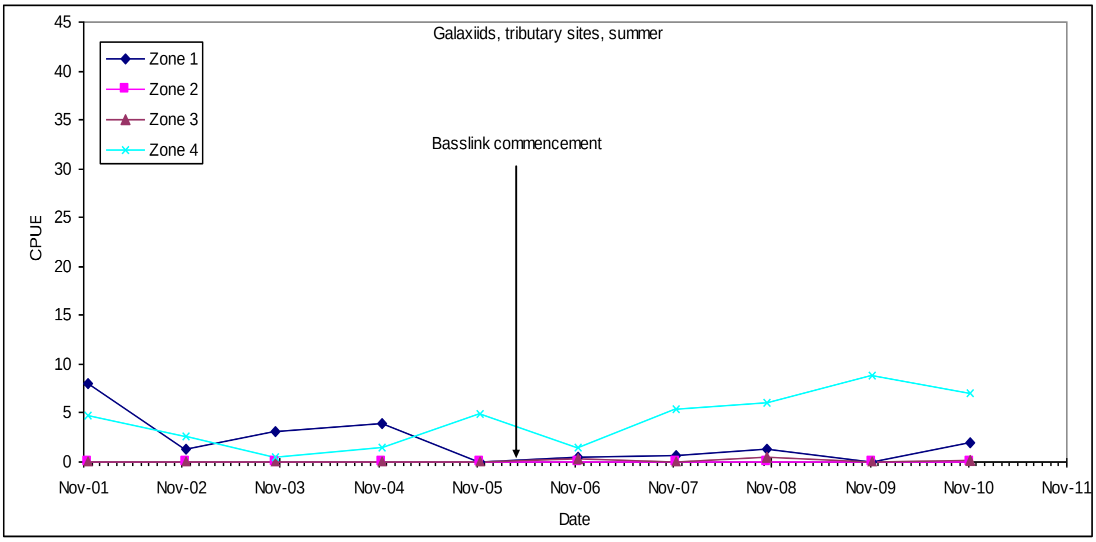


Figure 9-10 Seasonal (summer and autumn) CPUE for galaxiids caught in the Gordon River zones between December 2001 and March 2011

Jollytails and climbing galaxias were captured in small numbers during the 2010–11 monitoring year. Juvenile climbing galaxias were present in low abundances in summer catches from zones 4 and 5, but recruitment appears to have been limited in 2010–11. There was no evidence of juvenile recruitment to zone 1 in either season; however adults were captured in both samples. Catches of jollytails in the Gordon River were relatively low, with small numbers caught in zone 5, which is consistent with previous results.



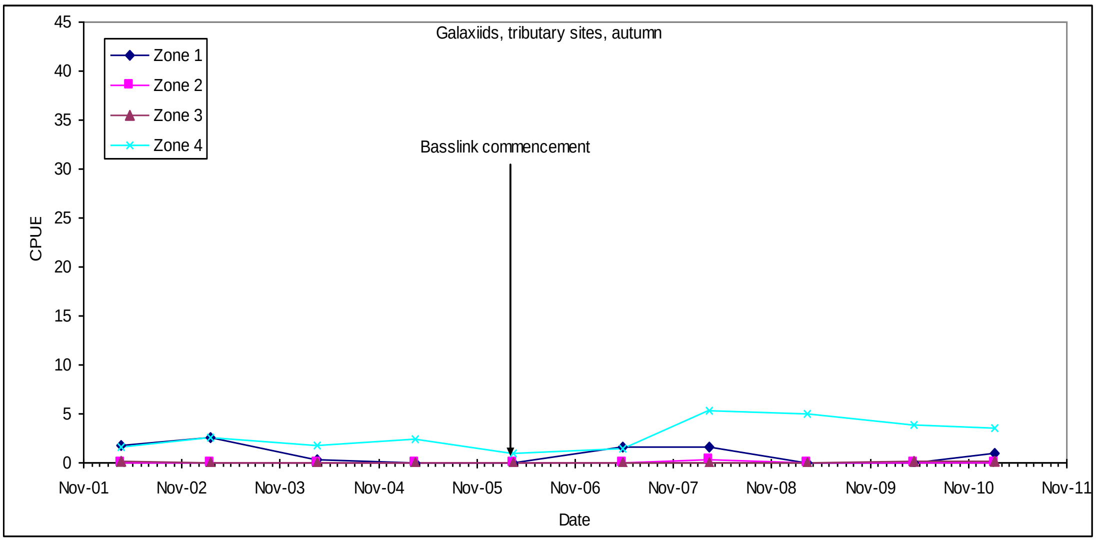
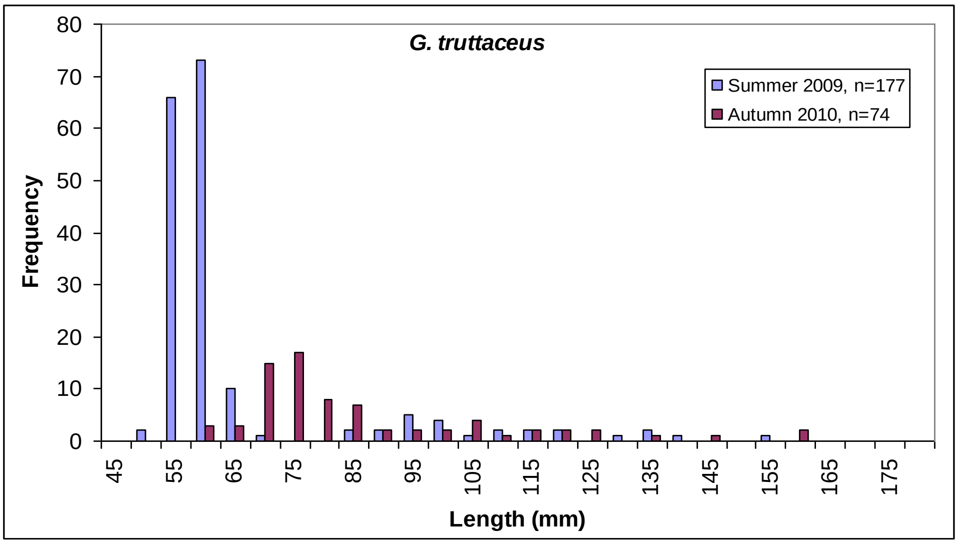


Figure 9-11 Seasonal (summer and autumn) CPUE for galaxiids caught in the Gordon tributary zones between December 2001 and March 2011



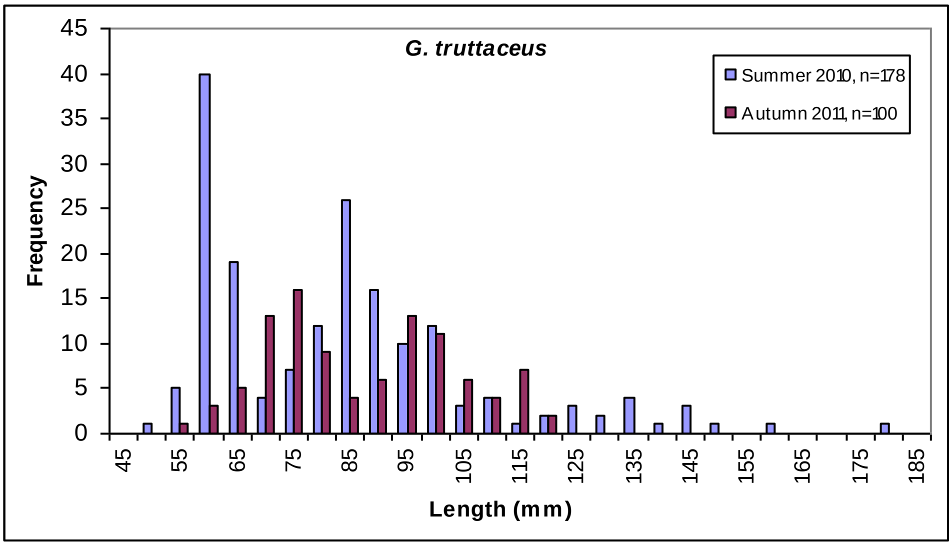
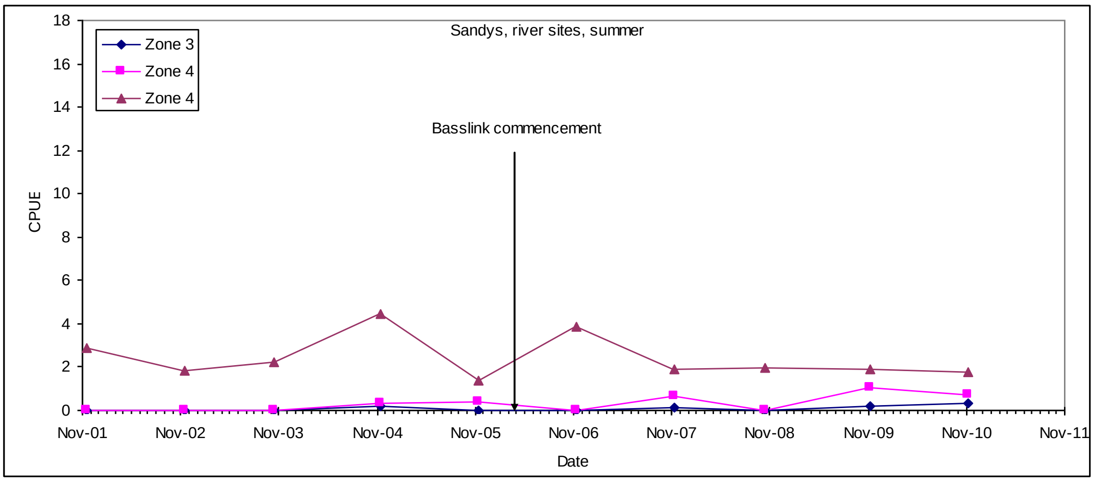


Figure 9-12 Population structure of *G. truttaceus* captured from the Gordon River and tributaries during summer and autumn 2009–11

9.3.2.4 Bovichthyidae

Sandys (*Pseudaphritis urvillii*)

Figure 9-13 shows the relative abundance of sandys in zones 3 to 5 during 2001–11. As per previous annual reports, zones 1 and 2 are not included in this figure as the distribution of this species appears to be restricted to sites downstream of the Splits (zone 3). Sandy catches were generally similar to or greater than pre-Basslink means. However, autumn catches from the lower Franklin and Birches Inlet reference sites were significantly below pre-Basslink means.



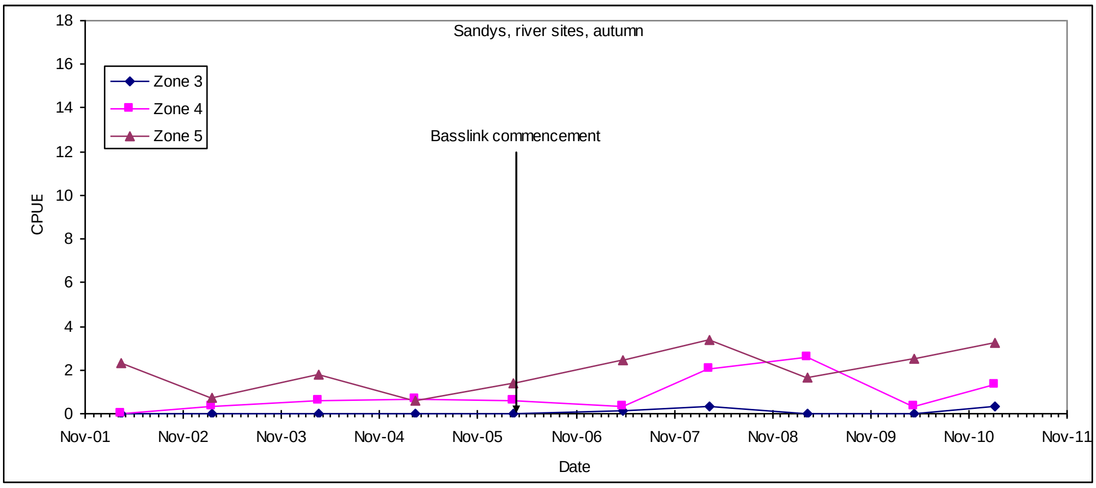


Figure 9-13 Seasonal (summer and autumn) CPUE for sandys caught in the Gordon river zones between December 2001 and March 2011

9.3.2.5 Prototroctidae

Australian grayling (*Prototroctes maraena*)

Australian grayling were not caught from the Gordon River or from tributary or reference sites during the 2010–11 surveys, which is consistent with the majority of previous monitoring years. Grayling have previously been caught only on one occasion during the monitoring program: one fish was caught at the Henty u/s Bottle Creek reference site in December 2004.

9.4 Fish stranding

There were no stranded fish recorded during the 2010–11 monitoring period.

9.5 Trigger levels

Ten trigger levels have been developed for the Basslink fish monitoring program. Data was pooled from river and tributary sites and zones for assessment against trigger levels. Five triggers have been derived using autumn data and the remaining five triggers were derived using annual data. Triggers are calculated for individual years, and there are also cumulative triggers based on pooled data over multiple post-Basslink years. Each trigger category has both upper and lower bounds. Exceedence of the lower bound may indicate a deterioration of the rivers fish community relative to the Basslink period. With the exception of the exotic fish trigger, exceedence of the upper bound may indicate an improvement in the status of the river's fish community. However potential exceedences, regardless of direction, should be used as an indicative tool and, where appropriate, further investigation conducted to determine whether they are likely to be linked to a Basslink effect.

Performance against these triggers during the 2010–11 monitoring year and cumulative 2006–11 monitoring years is shown in Figure 9-14 to Figure 9-17.

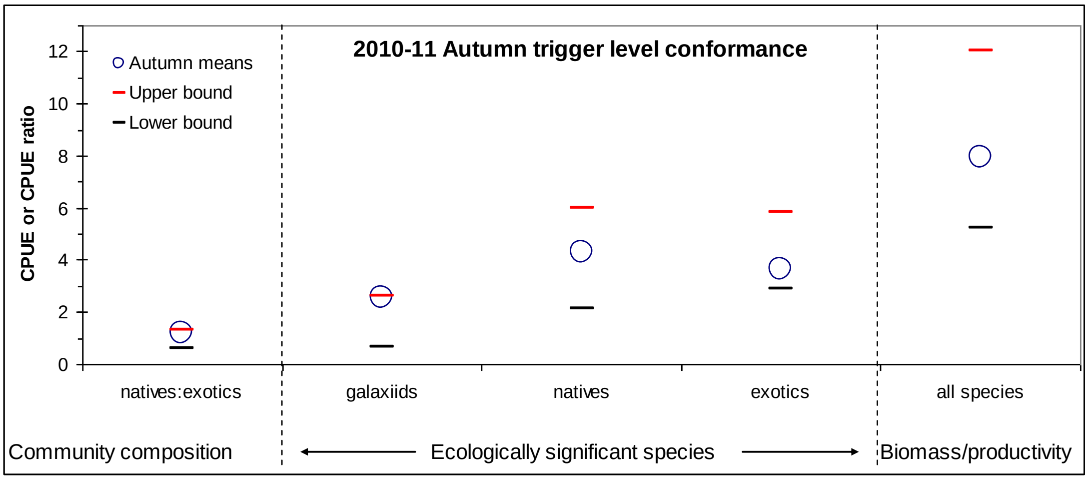


Figure 9-14 Summary of 2010–11 autumn trigger level conformance

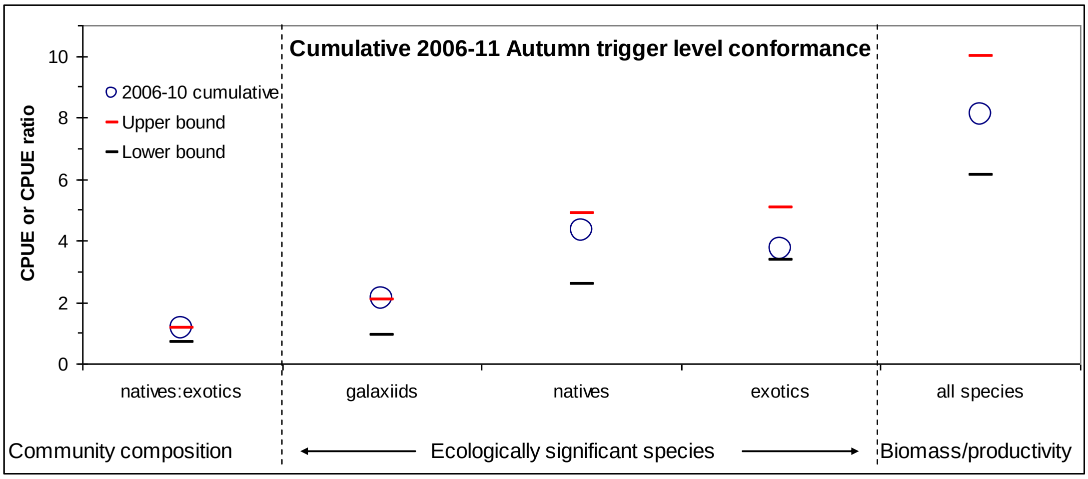


Figure 9-15 Summary of cumulative (pooled) 2006–11 autumn data trigger level conformance

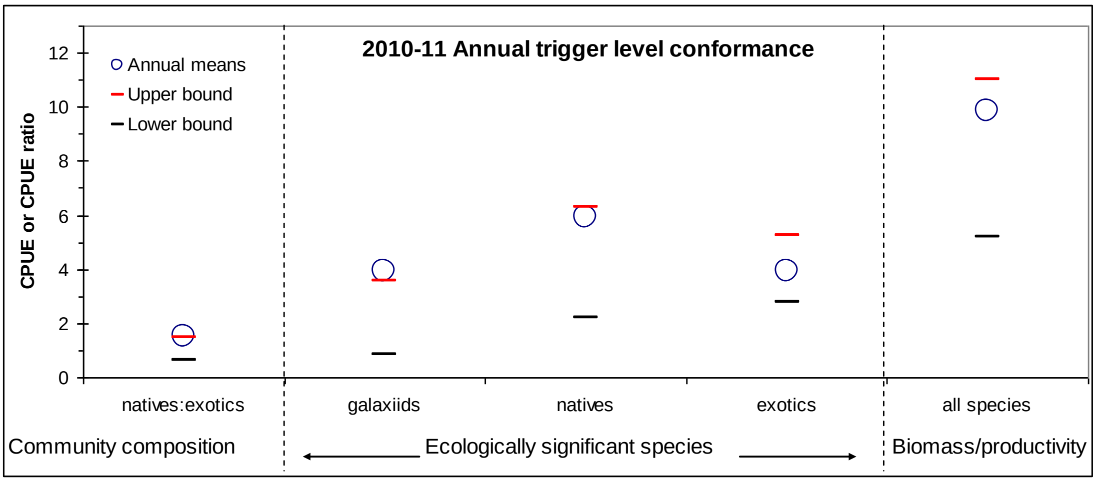


Figure 9-16 Summary of 2010–11 annual trigger level conformance

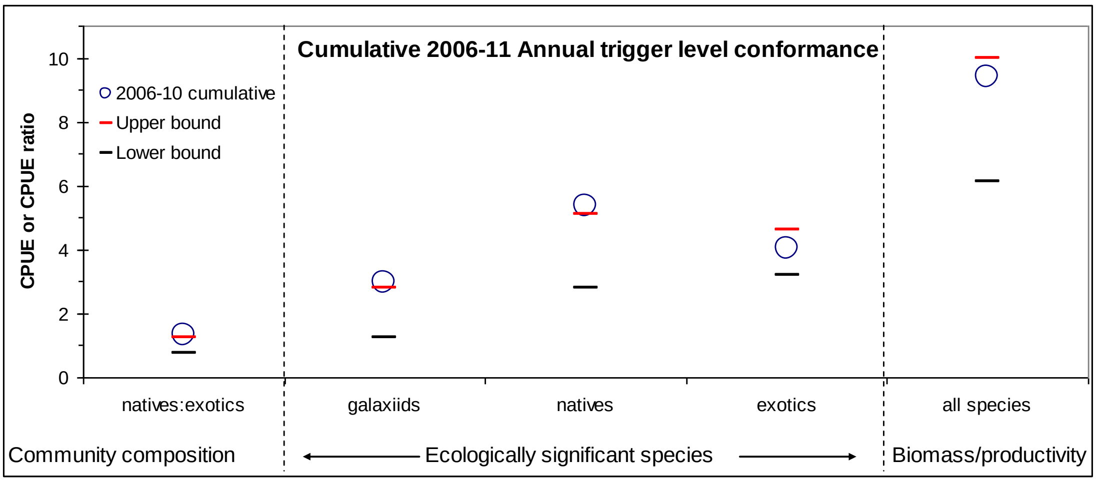


Figure 9-17 Summary of cumulative (pooled) 2006–11 annual data trigger level conformance

9.5.1 Community composition

Two trigger levels, derived from the ratio of native to exotic fish, have been developed to assess potential changes to community composition following the commencement of Basslink operations. Single season (autumn) and annual (summer and autumn) trigger values are shown in Appendix 10.5 (Table A10-13). Figure 9-14 and Figure 9-15 show a graphical representation of the 2010–11 and cumulative 2006–11 autumn means in comparison to their respective triggers levels. Figure 9-16 and Figure 9-17 show the 2010–11 and cumulative 2006–11 annual means in comparison to their trigger levels.

The 2010–11 autumn and annual community composition indicators were within or above bounds of their respective triggers. The CPUE ratio in the autumn 2010 data was within the range of previous post-Basslink monitoring years. The 2010–11 annual community composition indicator was marginally in excess of the trigger level (1.50), as were the cumulative 2006–11 autumn (1.16) and cumulative 2006–11 annual (1.34) results. These result are similar to 2009–10 trigger results and were again driven by elevated native fish abundances relative to exotic (trout) abundance. Trout abundances were generally comparable to pre-Basslink levels across the Gordon monitoring sites, however, redfin perch were absent from catches. This result indicates that the river's native fish abundance has increased relative to pre-Basslink levels, which may be linked to low power station discharge in recent years during the spring migration period. Environmental flow releases from the Gordon Power Station may also have contributed to strong galaxiid recruitment.

9.5.2 Ecologically significant species

Six trigger levels have been developed to assess the potential impact of Basslink operations on ecologically significant species. Seasonal trigger levels derived for native fish relative abundance, exotic species relative abundance and galaxiid relative abundance are shown in Appendix 10.5, Table A10-14 to Table A10-16. Figure 9-14 and Figure 9-16 show performance against the triggers during 2010–11. Performance against the cumulative autumn 2006–11 triggers and annual 2006–11 triggers is shown in Figure 9-15 and Figure 9-17.

All of the ecologically significant species categories were above their respective lower trigger bounds. Galaxiid relative abundance approached the upper 2010–11 autumn trigger level, and exceeded the 2010–11 annual, cumulative 2006–11 autumn, and cumulative 2006–11 annual trigger levels.

High galaxiid relative abundance was accompanied by native fish relative abundances that were, for the most part, relatively high in comparison to pre-Basslink levels. The 2010–11 autumn, cumulative 2006–11 autumn and 2010–11 annual native fish abundances were within the trigger bounds, while the cumulative 2010–11 annual trigger for these categories was in excess of the trigger bounds. These results reflect good post-Basslink native fish abundances, particularly in the later years of the monitoring program, which are primarily driven by strong spotted galaxias and short-finned eel recruitment.

The exotic fish category was within the pre-Basslink bounds of the 2010–11 autumn, 2010–11 annual and both cumulative 2006–11 trigger levels, and as such has remained within the trigger bounds during the post-Basslink period to date, indicating that there has not been a significant change relative to the pre-Basslink period.

9.5.3 Biomass/productivity

Two trigger levels have been developed to assess potential changes to biomass or productivity due to changed hydrological conditions following the commencement of Basslink operation. Trigger levels for this category were derived from autumn and annual relative abundance data for all fish species present in the Gordon River monitoring zones. Appendix 10.5, Table A10-17 lists the trigger bounds for the biomass/productivity triggers. Results for the 'all species' biomass/productivity trigger has been calculated for the 2010–11 monitoring year and the pooled 2006–11 monitoring years. The 2010–11 results are shown in Figure 9-14 and Figure 9-16. The cumulative 2006–11 results are shown in Figure 9-15 and Figure 9-17.

All species relative abundance was above the lower bound for the 2010–11 autumn and 2010–11 annual triggers levels, and has remained above the lower bound throughout the post-Basslink monitoring period. The cumulative 2006–11 annual result was well above its lower trigger bound, as was the cumulative 2006–11 autumn trigger. These results indicate that the relative abundance/biomass of the Gordon River's fish assemblage is comparable to the pre-Basslink period, and is buoyed by strong native fish abundance.

9.6 Conclusions

This report summarises the results of the 2010–11 fish monitoring surveys. Summer monitoring was conducted in early December without issue. Elevated flows during the autumn sample meant that sampling of reference sites with marginal cobble bar landing areas had to be completed on a follow-up trip.

Spotted galaxias were the most abundant fish in the river over summer, second only to brown trout in autumn as per previous years, reflecting strong recruitment in spring/summer 2010. Climbing galaxias and jollytails were caught in relatively small numbers, which is consistent with previous years.

Brown trout were the only exotic species captured in the river during 2010–11. While rainbow trout and Atlantic salmon have occasionally been captured, redfin perch are usually present in small numbers in the upper zones. This is the first year that redfin perch have not been captured from the river since the start of the monitoring program, and reflects the species low abundance in the Gordon River.

Brown trout catches in the upper Gordon River appear to have increased in the post-Basslink period, and may be related to improved habitat due to the environmental flow. However, increases at the zone level are difficult to verify statistically due to the nature of the data. These increases have not resulted in exceedences of the upper exotic trigger, which is calculated across pooled zones.

Pouched lampreys abundances were relatively low in the autumn sample, however low abundances were also noted from the reference sites, indicating a seasonal catchment trend rather than a Basslink effect. Short headed lampreys are uncommon in the river, and the 2010–11 catches were characteristically low.

Short-finned eel abundances were generally similar to pre-Basslink means, with no evidence of hydrological bottle necking as per the 2009–10 survey.

Out of the 10 triggers for 2010–11, exceedences occurred in the ratio of natives to exotics (community composition) and annual galaxiid relative abundance (ecologically significant species). Within the cumulative year triggers, exceedences of the upper bound occurred across the community composition and ecologically significant species groups (five of 10 triggers). These exceedences were driven by elevated *G. truttaceus* abundance and reflect strong recruitment of this species in the Gordon River over the post-Basslink period. All trigger exceedences are considered to be positive changes. The trigger exceedences in 2010–11 are considered to be a positive change and are indicative of an improvement in the community composition and in ecologically significant species.

10 Discussion of trigger results

10.1 Introduction

The decision tree framework developed in 2007–08 (Hydro Tasmania, 2008), and revised as part of the three-year review (Hydro Tasmania 2010a), has been used to assess trigger exceedances for individual disciplines and to identify linkages between disciplines. The updated decision tree, shown in Figure 10-1, provides a broad framework for the interpretation of results. It should be considered a guide for interpreting results only, as scenarios may arise that fall outside of the framework.

10.2 Application of decision tree to individual disciplines

The decision tree technique is applied to the disciplines of fluvial geology, macroinvertebrates, algae and moss, riparian vegetation and fish. Hydrology, water quality and karst geomorphology are not assessed as these disciplines are not associated with any formal triggers.
Results for the 2010–11 monitoring year have been assessed against triggers derived for a single year comparison as well as for the 2006–11 period.

The following discussion for individual disciplines focuses, for the most part, on results and trigger exceedances for the 2010–11 monitoring year. This discussion provides short synopses relating the trigger value results to the decision tree. 'Steps' mentioned in the discussions refer to the decision tree in Figure 10-1. Additional discussions of trigger results are contained in the individual discipline sections.

10.2.1 Fluvial geomorphology

Using the Basslink decision tree to evaluate the Gordon River geomorphology results is difficult because the decision tree is based on the interpretation of trigger value results, and the geomorphology trigger values, in isolation, have been found to be an unsatisfactory way to identify post-Basslink changes. The Basslink Review Report 2006–09 (Hydro Tasmania, 2010a) recommended, and the Gordon River Scientific Reference Committee agreed, that a multiple-lines-of-evidence approach should be used to evaluate the geomorphology results, with the triggers constituting one of the lines of evidence. Other information to be considered includes field observations, photo-monitoring, piezometer results and the analysis of hydrologic parameters. In line with this approach, the following analysis uses all results to evaluate the 2010–11 findings with respect to the conceptual model, rather than limiting the analysis to the trigger values alone.

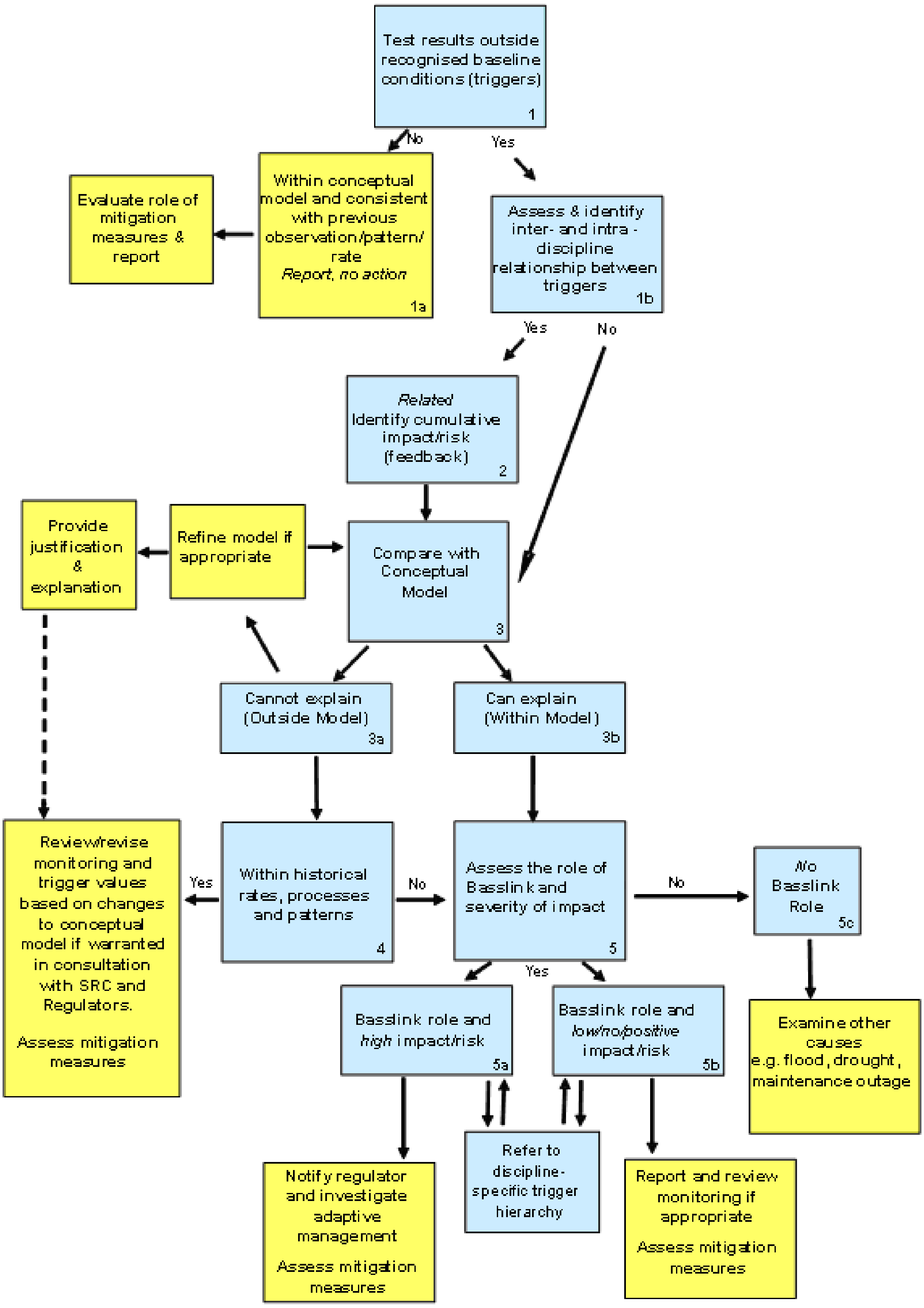


Figure 10-1 Decision tree for interpreting Basslink trigger results. Yellow boxes show outcomes and actions, numbers refer to ‘streams’ referred to in discussion

At a broad scale, equivalent to ‘step 1’ in the decision tree, the 2010–11 results are outside of the pre-Basslink baseline condition, but consistent with the conceptual model and previous observations and patterns (step 1b). In 2010–11, the hydrology of the river differed considerably from the pre-Basslink monitoring years due to the low total volume of flow discharged from the power station, and the generally short-duration events associated with power station operation. These hydrologic characteristics are similar to those which occurred in 2009–10, and the monitoring results from the two periods are similar, and consistent with the conceptual model.

As described in sections 4.5.1 and 4.5.2 of the fluvial geomorphology chapter, characteristics common to both the 2010–11 results and the 2009–10 results are:

- the continued presence of vegetation in the 1–2 and 2–3 turbine bank levels;
- unsaturated banks in the 2–3 turbine bank levels, with no evidence of seepage induced erosion in the 2–3 turbine bank level;
- recent scouring of denuded bank faces in the 1–2 turbine bank level consistent with peaking operations leading to the frequent passage of the water surface over the bank face; and
- evidence of seepage derived sediment deposits in the <1-turbine bank level on banks which continue to support root mats and tea tree, which are likely associated with the drawdowns following peaking events, with the deposited material derived from the 1–2 turbine level.

These characteristics were not common during the pre-Basslink monitoring period, but are consistent with the conceptual model and understanding of the relationship between power station operation, bank saturation, seepage erosion and scour. During the 2010–11 monitoring year, the understanding (and hence conceptual model) of how peaking operations affect bank saturation has increased through additional investigations aimed at revising the ramp-rule (see Appendix 5). Observations of drawdowns completed under a range of bank saturation levels, combined with piezometer results have better refined the understanding of the timescales required for banks to 'fill' and 'drain' under different levels of saturation, and most of the 2010–11 results are consistent with processes associated with (generally) low-bank saturation.

The trigger values for geomorphology remain outside of the pre-Basslink predictions due to a combination of an extreme flood event in August 2007, which led to widespread alterations to the river, combined with little change over the past few years. The low rates of change observed in the Gordon River over the past three years are likely associated with the very low flow volumes released by the power station over this period, combined with the lack of major flooding.

Overall the monitoring results for the 2010–11 monitoring year are consistent with the understanding of the river and conceptual model. The deviation of the results from the derived trigger values owes more to the assumptions that are the basis of trigger values (i.e. that erosion rates will remain uniform over time), rather than post-Basslink changes.

The impact of the mitigation measures on the geomorphology results is assessed as follows:

- **minimum flow:** the minimum flow has minimal direct effect on the banks of the Gordon River. In one location in zone 2 the bank toe may have steepened since the introduction of the environmental flow due to the hydraulic effects of logs near the bank toe, but otherwise few changes have been observed. The higher minimum water level following a decrease in power station discharge may reduce scour rates, as scour is related to the surface slope of the river, and a higher minimum level will reduce the surface slope of the river following power station shutdown, but there is no evidence to support this; and
- **ramp-down rule:** similar to 2009–10, seepage erosion in the 2–3 turbine level was generally avoided due to the low level of bank saturation throughout most of the year. Towards the end of the monitoring year, when peaking operations and bank saturation increased, ramping was frequently implemented and would have promoted draining of the banks at reduced in-bank water slopes. The implementation of the rule prevented periods of 'high risk' with respect to seepage erosion even though water levels in the banks were above 2.75 m on several occasions. Of note is that during this peaking period, discharge was not frequently reduced from (up to) full-gate to 150 $m^3 s^{-1}$ as permitted under the present rule, with most flow reductions ramped. The lack of seepage flows observed in the 2–3 turbine bank level during the February monitoring is likely attributable to implementation of the rule combined with a low number of flow fluctuations between full-gate and 150 $m^3 s^{-1}$ when bank saturation was elevated.

10.2.2 Riparian vegetation

The analysis of the trigger values for riparian vegetation showed that 15 of the 37 vegetation values were outside trigger bands (Table 10-1). Trigger responses are grouped into two main ecological variables that can be used to assess the health, or otherwise, of riparian vegetation:

- community composition, assessed at the zone level; and
- plant abundance by life form, assessed at the whole-of-river scale.

Where triggers for the whole-of-river have shown deviations outside trigger bands, data has been explored at the zone scale to determine if the response is occurring in all areas, if particular areas are driving the changes, or indeed if other areas are masking real effects (step 1).

The community composition triggers which include measures of similarity of the vegetation pre- and post-Basslink, species richness and species evenness are all highly correlated. Therefore if there is a change in abundance or loss of species occurring in plots then this is likely to affect all of these measures to different degrees.

A number of community composition trigger values were marginally outside the trigger ranges, predominantly species similarity, but also in one instance species evenness. Higher quadrats ‘above’ and ‘high’ were generally remaining stable (either within trigger ranges or above) while 'low' in two zones were becoming less similar. The change in similarity in 'low' quadrats is likely to be the result of past recruitment in 'low' quadrats in low flows over the past years but with recent high flows selectively removing various species, resulting in a divergence in similarity indices. Stableness of higher quadrats is likely to be the result of less turnover in species in the more stable environment of the upper banks.

Changes in the trigger values for comparison of 'above'/'high' and 'above'/'low' variables (bare ground, total vegetation, bryophytes, ferns and shrubs) can be explained by the impact of high flows immediately prior to the monitoring event. These high flows impacted proportionally more on 'low' and 'high' quadrats than 'above' quadrats, resulting in increased ratios of 'above'/'high' and 'above'/'low' for the variables of total vegetation, bryophytes, ferns and shrubs and decreased ratios for bare ground. These measures, particularly of ferns and total vegetation, were highly influenced by sites in zone 2 where increases in ferns in upper quadrats, and loss of fern and vegetation cover of 'low' resulted in very high ratio scores.

When assessed within the decision tree framework, these deviations from trigger values proved to be outside baseline conditions (hence the triggers being exceeded) but did not show interdisciplinary relationships (step 1b). Increased bare ground and decrease vegetation cover in some quadrat types was not reflected in the geomorphological studies which did not record a significant increase in erosion. It is possible that the impact on the vegetation will take time to be evidenced in erosion studies.

Following the decision tree process, these results are within conceptual model processes (step 3 to 3b). The model identifies the recovery of vegetation during periods of low flow and for the removal of bank vegetation as part of an ongoing process 'linked to the regulated water levels'. The role of Basslink in this process (step 5) is considered to be minimal (5b) because the establishment and subsequent loss of vegetation from the river banks is part of a response to disturbances caused by higher discharges from January to April 2011. Therefore, the navigation through the decision tree for the values outside triggers ends with a combination of a low Basslink impact and no Basslink effect.

These results reflect the relationship between the vegetation and flow patterns on the river identified in pre-Basslink monitoring and in the conceptual model, with the shorter periods of inundation in 2008–09 and 2009–10 and the subsequent recovery of vegetation continuing in to 2011 but high flows prior to monitoring selectively removing some species particularly from lower quadrat types. Linkages to geomorphological processes are summarised in section 10.3.

10.2.3 Macroinvertebrates

Nine measures (incorporating 126 individual triggers; see Appendix 8.3) were assessed for macroinvertebrates under the five following components:

- community structure — Bray Curtis (abundance) and O/Erk;

- community composition — Bray Curtis (presence/absence) and O/Epa;
- taxonomic richness — N taxa (family) and N EPT species;
- ecologically significant species — Abundance EPT and Proportional abundance EPT; and
- biomass/productivity — total abundance.

Performance against triggers is assessed for each site for the 2010–11 monitoring year. Results are also combined and assessed at the whole-of-river (WOR) scale for the whole year and both seasons (spring and autumn), as well as at the zone scale (zone 1 and 2).

Three of the nine measures, O/Epa and O/Erk and total abundance, did not have any significant trigger exceedances when analysed across all sites, both zones and whole-of-river year and seasons (spring/autumn) scales (Table 10-1). These results are consistent with the pre-Basslink conceptual models, as well as with previous observations and patterns (step 1 and 1a).

Seven indicators exhibited local exceedances when reported at site level as well as recording exceedances at the whole-of-river or zone level. These were as follows:

- **Bray Curtis (presence/absence)**: exhibited minor exceedance of the upper bound for all year zone 2 case;
- **Bray Curtis (abundance)**: sites 57 (zone 2) recorded minor exceedances above the upper trigger bound; also exceeded upper trigger bounds for whole-of-river, all year;
- **N Taxa (family)**: exhibited an exceedance for the whole-of-river autumn season, but no exceedance for any individual site;
- **proportional abundance EPT**: All values above or at upper trigger levels for sites 69–75 in zone 1 (otherwise compliant at all sites in zone 2, for WOR and whole of zone 1); and
- **abundance EPT**: exceeding or falling on upper trigger bound at sites 63, 72, and 74 (zone 1) and 42–57 (zone 2); exceeds for WOR (all year and both seasons) and zone 1, and falls at upper bound for zone 2.

None of these trigger bound exceedances constitute a negative Basslink effect (i.e. a decline in biodiversity or community structure relative to reference streams). All represent improvements in biological condition – which, though small are statistically and, for zone 1, ecologically significant.

Raised aquatic insect abundances, especially snowflake caddis (*Asmicridea*), Gripopterygid stoneflies and Hydrobiosid caddis, especially at sites above the vicinity of the Denison confluence, are (again) the primary cause of the trigger bound exceedances recorded in 2010–11. This phenomenon is consistent with the conceptual model (step 1a) as these abundances are expected to be highly responsive to changes in (minimum) flow stability as well as in tributary inputs in food resources.

Introduction of the minimum environmental flow was expected to promote the abundance of filter feeding EPT species, especially *Asmicridea*, as this flow provides protection from bed dewatering and/or extreme low water velocities at low flows and between power station releases (absent under pre-Basslink conditions). This is not seen as a negative ecosystem response, although it is sensitive to the post-Basslink flow regime in combination with natural catchment inputs.

A rise in overall diversity and abundance of aquatic insects, especially in zone 1, is driving an increase in community compositional similarity towards that recorded in reference rivers. This change is reflected in changes in Bray Curtis index values. Bray Curtis values are also high in zone 2, though still mainly below upper trigger bounds.

None of the trigger exceedances were inconsistent with the conceptual model.

The primary mitigation measure affecting macroinvertebrates is the minimum environmental flow. Consistent results for indicators within or above the upper trigger bounds at a range of scales indicates that this measure is protecting the fauna from post-Basslink changes in the flow regime that might otherwise cause declines in abundance and/or diversity. The minimum environmental flow is also leading to abundances of key flow-obligate species, such as *Asmicridea*, exceeding those observed pre-Basslink and thus exceeding the upper trigger bounds (step 6). Community compositional similarity to reference rivers has therefore risen slightly, indicating an overall improvement in ecological condition, especially in zone 1 above the Denison River.

With regard to the decision tree (Figure 10-1), the macroinvertebrate indicators are either consistent with the conceptual model and within pre-Basslink ranges (step 1a) or are experiencing small changes driven by Basslink flow changes, but with a neutral or positive impact (step 5b). No changes to mitigation actions are required at this stage.

10.2.4 Algae and moss

The following is a description of the trigger behaviour within the context of the decision tree framework, for the algae and moss triggers (see Appendix 10) for 2010–11. Two measures were examined for algae and moss, with performance against a total of 28 triggers assessed at the site, zone (1 and 2) and whole-of-river (WOR) scales (all year, spring and autumn):

- **filamentous algae cover:** values in 2010–11 fell within trigger bounds at all sites except for minor exceedances at sites 48 and 72. These resulted in minor exceedances for the whole-of-river, in spring and for zone 2, of 0.5 to 2 % above the upper trigger threshold. Despite these minor exceedances, these observations are consistent with pre-Basslink conditions and the conceptual model (step 1a); and
- **moss cover:** values in 2010–11 fell within trigger bounds for all sites, as did whole-of-river and zone values (step 1). Despite this minor exceedance, the observations are still consistent with the conceptual model (step 1a).

The algal and benthic moss cover indicators are consistent with the conceptual model and within or very close to pre-Basslink ranges (step 1a, Figure 10-1). No changes to mitigation actions are required at this stage.

10.2.5 Fish

The fish 2010–11 trigger levels results were within or above trigger bounds (Appendix 10).

Trigger levels are grouped into three principal categories — community composition, ecologically significant species and biomass/productivity — and five indicator variables are nested within these groups. The derivation of these categories is discussed in Hydro Tasmania (2006).

No lower trigger level exceedances were reported (step 1) with galaxiid, native fish, exotic, native to exotic ratio, and all species relative abundances above lower indicator levels. However, the 2010–11 annual community composition indicator was marginally in excess of the trigger level, as were the cumulative 2006–11 autumn and annual results. This result was driven by the elevated ratio of native fish abundance to exotic species abundance. Upper trigger levels were also exceeded for the annual, cumulative autumn, and cumulative annual galaxiid abundance. The cumulative annual native fish abundance was also in excess of the trigger bounds. These upper trigger level exceedances do not represent a negative Basslink effect, but reflect robust post-Basslink native fish abundances, particularly in the later years of the monitoring program.

The results were consistent with the conceptual model, as proposed in the Basslink Baseline Report (Hydro Tasmania 2005), and were generally consistent with previous observations however there were several upper trigger exceedences. It is difficult to determine whether these small, positive exceedences are linked to the effect of the environmental flow (5b), natural processes (5c) or a combination of both. No follow-up actions or changes to mitigation measures are recommended, as there is a low risk of negative Basslink impact.

10.3 Links between disciplines

Various disciplines and their exceedances in 2010–11 were largely influenced by hydrology. Links between disciplines currently appear to be limited to links between geomorphology and riparian vegetation. A summary of the links between disciplines, and the influence of hydrology is as follows:

- lower bank scour erosion rates were related to the limited high flows, while low seepage erosion rates in the 2–3 turbine bank range were the result of short-duration high flows resulting in low saturation of the banks;

- geomorphological field observations noted scour in the 1–2 turbine bank level, and seepage-induced deposition of sands in some areas. While not widely reflected in the statistical analysis of the erosion pins it is consistent with the results of the vegetation quadrat analysis;

- combined geomorphological/vegetation monitoring showed minor changes in the position of ground cover variables (litter, riparian species, CWD, seedlings, bare ground and root mat) on the banks and was consistent with the results of the fluvial geomorphological studies which showed little change in the geomorphology of the river during the 2010–11 year as compared to other years;
- exceedances in the trigger values for comparison of 'above'/'high' and 'above'/'low' variables (bare ground, total vegetation, bryophytes, ferns and shrubs) can be explained by the impact of high flows immediately prior to the monitoring event;
- the continued positive exceedances seen in macroinvertebrates are linked to the presence of the environmental flow and its influence on maintaining habitat availability and more constant hydrological conditions; and
- there are no clear links that can currently be drawn between positive fish trigger exceedances and other disciplines.

Table 10-1 Summary of trigger value exceedances across all disciplines for 2010–11

Discipline	Trigger	Zone/Site/Season	Trigger exceeded	No. and proportion of triggers of exceeded (2010–11)	Trigger response
Geomorphology 5 trigger values	*4 triggers exceeded out of total 5 (80 %)*				
	Erosion pins	Zone 1	-	0 out of 1	-
	Erosion pins	Zone 2	Below trigger bands	1 out of 1	Note and explain with multiple lines of evidence
	Erosion pins	Zone 3	Below trigger bands	1 out of 1	Note and explain with multiple lines of evidence
	Erosion pins	Zone 4	Below trigger bands	1 out of 1	Note and explain with multiple lines of evidence
	Erosion pins	Zone 5	Above trigger bands	1 out of 1	Note and explain with multiple lines of evidence
Macroinvertebrates 126 trigger values	*22 triggers exceeded out of total 126 (17 %)*				
Community structure	Bray Curtis (abundance)	site 57, WOR (all year)	Above trigger bands	2 out of 14	Note and explain
	O/Erk	-	-	0 out of 14	-
Community composition	Bray Curtis (pres/abs)	zone 2 (all year)	Above trigger bands	1 out of 14	Note and explain
	O/Epa	-	-	0 out of 14	-
Taxonomic richness	N taxa (families)	WOR (autumn)	Above trigger bands	1 out of 14	Note and explain
	N EPT taxa	-	-	0 out of 14	-
Ecologically significant species	Proportion abundance EPT	zone 1 – sites 69, 72, 74 & 75 WOR (all year)	Above trigger bands	6 out of 14	Note and explain
	Abundance EPT	zones 1 and 2 – sites 42, 48, 57, 63, 72 & 74 WOR (all year, autumn, spring)	Above trigger bands	11 out of 14	Note and explain
Biomass/productivity	Total abundance	-	-	0 out of 14	-

Table 10-1 continued next page

Discipline	Trigger	Zone/Site/Season	Trigger exceeded	No. and proportion of triggers of exceeded (2010–11)	Trigger response
Benthic algae and moss cover 28 trigger values	*5 triggers exceeded out of total 28 (18 %)*				
	% filamentous algae cover	zone 2 – sites 48 and 72 WOR (spring)	Above trigger band	5 out of 14	Note and explain
	% moss cover	-	-	0 out of 14	-
Riparian vegetation 37 trigger values	*15 triggers exceeded out of total 37 (41 %)*				
Community composition	Bray Curtis similarity	Zone 3 – ‘High’ (below), ‘Low’ (below) Zone 4 – ‘Above’ (above), ’High’ (above) Zone 5 – ’High’ (below), ‘Low’ (below)	Above and below trigger bands	6 out of 9	Note and explain
	Species/taxa richness	-	-	0 out of 9	-
	Species/taxa evenness	Zone 4 – ‘High’	Below trigger band	1 out of 9	Note and explain
Plant abundance by life form	Bare ground cover	‘Above’/’High’	Below trigger band	1 out of 2	Note and explain
	Total vegetation cover	‘Above’/’High’ and ‘Above’/’Low’	Above trigger bands	2 out of 2	Note and explain
	% non-vascular (bryophytes)	‘Above’/’Low’	Above trigger bands	1 out of 2	Note and explain
	% ferns	‘Above’/’High and ‘Above’/’Low’	Above trigger bands	2 out of 2	Note and explain
	% shrubs	‘Above’/’High and ‘Above’/’Low’	Above trigger bands -	2 out of 2	Note and explain

Table 10-1 continued next page

Discipline	**Trigger**	**Zone/Site/Season**	**Trigger exceeded**	**No. and proportion of triggers of exceeded (2010–11)**	**Trigger response**
Fish 10 trigger values	*2 triggers exceeded out of total 10 (20 %)*				
Community composition	native:exotics	Annual	Above trigger band	1 out of 2	Note and explain
Ecologically significant species	native fish relative abundance	-	-	0 out of 2	-
	exotic species relative abundance	-	-	0 out of 2	-
	galaxiid relative abundance	Annual	Above trigger band	1 out of 2	Note and explain
Biomass/productivity	All species	-	-	0 out of 2	
			TOTAL	**48 out of 206 (23 %)**	

Table 10-1 continued

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