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Mount Lyell Remediation Research and Demonstration Program

a Tasmanian and Commonwealth Government initiative *supervising scientist report* **118**

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A joint program between the Supervising Scientist and the Department of Environment and Land Management, Tasmania.

This report describes research that is part of the Mt Lyell Remediation Research and Demonstration Program, a joint program between the Supervising Scientist and the Department of Environment and Land Management, Tasmania.

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Tourism House, Blackall Street, Barton ACT 2600 Australia

ISSN 1325-1554

ISBN 0 642 24317 4

Printed in Tasmania by Australian Government Printing Services.

Executive summary

Mount Lyell, western Tasmania, a 100 year old copper mining operation in which large quantities of sulphide rich ore rock have been both exposed to weathering and discharged as tailings into the Queen and King Rivers, is the subject of a research program evaluating environmental impacts of resulting acid mine drainage (AMD) and remediation options. A survey of biological and water quality conditions of streams in the Mount Lyell region was conducted and a long-term biological and water quality monitoring program was designed based on the survey results and related data.

In order to identify ecological targets for long-term remediation of the Mount Lyell mine lease, a total of 32 reference ('least disturbed') and monitoring sites were established in streams in major catchments of the region. Riffle macroinvertebrates at all sites were sampled in four seasons in 1995/96 (winter and spring 1995, summer and autumn 1996) using the National River Health Program (NRHP) rapid assessment protocol (RAP). A suite of environmental variables was also measured at each site including water quality variables. A number of sites were also sampled for macroinvertebrates quantitatively. A survey of stream fish populations was conducted in summer-autumn 1996, by backpack electrofishing.

The macroinvertebrate communities of reference sites were diverse and characterised by a high abundance of stonefly, mayfly, caddisfly and beetle larvae. Despite a history of severe stream sedimentation and poor water quality (with low pH and high metal concentrations), all AMD-polluted sites supported a macroinvertebrate fauna, characterised by low abundances of chironomid and scirtid beetle larvae and oligochaetes (worms). Relationships between biological and water quality variables were examined and highlighted the complex nature of habitat alteration in AMD-affected sites typified by substrate concretion and sedimentation. Ordination and classification of the RAP sample data revealed four primary groups of reference sites in the region. A RIVPACS (River Invertebrate Prediction and Classification Scheme) model (MLRIVPACS I) was developed to identify a faunal community suitable as a remediation target for each AMD-affected stream site. Assessment of sites in the Queen and lower King Rivers using the MLRIVPACS I model indicated that they were all highly or extremely impacted. A single site in the King River upstream of the Queen River junction was assessed as mildly impacted by hydroelectric power station operations.

A variety of quality assurance aspects of the RAP and quantitative sampling protocols were also examined. Relationships between data derived from live-picked RAP samples and their reconstituted residues were evaluated, as well as the influence of inter-operator and inter-riffle variability on the classification of river sites. Relationships between estimates of the mean, as well as the power to detect differences, and the number of quantitative sample units were also examined as a basis for the design of the long-term monitoring program.

A few streams in the Queen River catchment supported populations of introduced brown and rainbow trout. Tributaries of the lower King River were found to support three native fish species whose abundance and presence decreased with distance from Macquarie Harbour. These data, combined with data on fish ages, indicated that recruitment of native fish into streams of the Macquarie Harbour catchment occurs on an annual basis; that recruitment into the King River has occurred previously but has recently ceased, possibly due to changes in flow regime related to HEC operations; and that the galaxiid species only occur in tributaries within 5 km of the King River mouth. Thus water in the King River has occasionally been of sufficiently high quality to allow episodic migration of juvenile galaxiids and eels into the lower King River during the last 10 years.

A boat-mounted electrofishing survey was conducted. No fish were captured in the lower King River, in contrast to a high abundance and diversity of species found in the lower Henty River with similar sampling effort. Thus there appear to be no resident fish in the lower King River.

Water quality data for the Queen and King River catchments were reviewed. Strong correlations between AMD-sourced pollutants were observed (copper, manganese, iron, sulphate and pH). Relationships of analyte means, medians and standard deviations and sampling frequency were examined. These indicated that, for both the lower King and Queen Rivers, sampling frequencies greater than four hourly would significantly distort estimates from 'true' values. A water monitoring program based on high frequency recording of conductivity was recommended, coupled by a stratified water analysis program to derive relationships between conductivity and pollutant concentrations under a range of flow conditions. A minimal water quality and biological monitoring program is described, aimed at detecting long-term recovery of the Mount Lyell region streams from AMD pollution resulting from remediation activity and the distance from specified targets.

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Acknowledgments

We wish to acknowledge:

- the hard work of Dr Jean Jackson, Mr Will Elvey and Ms Claire McKenny in what was a highly cooperative team effort in sampling and sample processing; Mr Paul Lewis also assisted with sample processing
- Mr John Johnston, Department of Environment and Land Management, for general and friendly assistance to the project
- Messrs Rob Dineen and Mike Johnson Department of Environment and Land Management, and Mr Harry Cox, State Government Analytical Laboratories, for assistance with water sample analyses
- Mrs Karen Johnston who helped us greatly with the key components of tea and cakes, secretarial support and, most of all, the dreaded formatting
- Dr Lois Koehnken for helpful discussion
- Mr Tim Smith and Kerry Hay for assistance in the field and for their considerable local knowledge
- Mr Leo Deakin and other members of the Queenstown and Strahan community for anecdotal information on fish and the streams
- Copper Mines of Tasmania for allowing access to key sites on the lease
- Mr Mark Johnson, HEC, and Mr Alan Hayter, RGC, for provision of flow and water quality data was greatly appreciated
- Dr Richard Norris, CRC for Freshwater Ecology, for kindly supplying SAS macros, modified for RIVPACS model development
- staff of the Inland Fisheries Commission for kindly assisting with the use of their electrofishing boat

1 Introduction and aims

Mining and its associated impacts have been a major feature of the Mount Lyell region of western Tasmania since the late 1800s. Though the history of mining at Mount Lyell has been described (Blainey 1967, McQuade et al 1995) and the gross nature of its environmental impacts publicly recognised for many decades, no detailed quantitative description of the environmental condition of streams of the area has been published, other than in relation to sediment deposition and transport in the lower King River (Locher 1995) and water quality in Comstock and Linda Creeks (Mounter 1993). The project detailed in this report describes the water quality and biological condition of streams in the Mount Lyell area, compares streams affected and unaffected by mining, and sets ecological goals for remediation.

The history of mining operations at Mount Lyell and its environmental impacts is summarised by McQuade et al (1995). Extraction, processing and exposure of large quantities of sulphide-rich (principally pyritic) ores between 1893 and 1995 resulted in disposal of 97 and 1.4 million tonnes of tailings and slag, respectively, into the Queen and King Rivers (Locher 1995, Taylor et al 1996), as well as a major acid-mine drainage (AMD) problem (McQuade et al 1995). The Mount Lyell Mining and Railway Company (MLMRCL), the sole mining company in the region since 1903, ceased operations on 15 December 1994, ending the release of tailings and slag into the Queen River. The primary focus of its operations in recent years was on the Prince Lyell orebody, initially mined in the West Lyell open cut and then worked underground. The sustained release of AMD from diffuse (slag heaps, tailings, exposed country rock and waste rock dumps) and point sources (pumped drainage from the Prince Lyell mine, drainage from old workings and adits) has continued essentially unaltered.

Prior to closure of MLMRCL operations, the Queen and lower King Rivers were typified by high and variable levels of suspended sediment, turbidity and metals (McQuade et al 1995, Locher 1995). Following closure, suspended solids loads have dropped markedly but metal concentrations and pH have increased and decreased, respectively (when compared under similar flow conditions). Significant changes in the flow regime of the King River have occurred due to the construction by the Hydro Electric Commission of the Crotty Dam and the operations of the John Butters Power station, which essentially controls the discharge of the lower King River. The power station is operated partially on a 'frequency control' (also known as hydropeaking) basis, with highly fluctuating discharges at hourly and daily time scales (see Discussion). This affects the water quality in the lower King River by altering both the pH and the relative dilution of Queen River water (Koehnken 1996).

The variety of AMD sources at Mount Lyell dictates a variable relationship between rainfall and the quantity and chemical composition of AMD, and hence water quality in the Queen River. Rain and groundwaters percolate relatively freely through fractured material within the West Lyell drainage and thence into the lower levels of the Prince Lyell mine, leaching acid-metal rich material from the exposed and fractured rock. These waters are pumped to dewater the mine and are discharged untreated into Haulage Creek and thence into the Queen River at Queenstown. A range of AMD-generating waste rock, slag and tailings materials are exposed to the atmosphere on the surface and also permit percolation of rainfall. Thus, while individual storm events dictate major changes in the amount of metals and acid draining from surface-exposed materials, the AMD pumped from the Prince Lyell mine and draining from other adits (eg Comstock, Tharsis) may remain relatively unchanged. This varies, however, depending on the duration, intensity and seasonality of rainfall.

The AMD effluents have pH values ranging from 2.5 to 3.5 with elevated concentrations of toxic metals, particularly copper and aluminium (McQuade at al 1995). Metals in the AMD effluents are almost entirely in dissolved form (Mounter 1993, Koehnken pers comm). Currently (under post-mine conditions) transport down the Queen and King Rivers is accompanied by a limited 'chemical recovery' process (Kimmel et al 1981), typified by increasing pH in a downstream direction (to 3–3.5 in the Queen River at Lynchford and 3.5–4.5 in the lower King River at Cutten Creek). This rise in pH is accompanied by precipitation of hydroxides of iron ('yellow boy'), aluminium and manganese. These colloidal and flocculated hydroxides are known to adsorb free ions of other metals (such as copper), and thus reduce their concentration in solution. Some deposition of these hydroxides has occurred over time, resulting in haematite concretion of stream bed material. However, the current velocities in the Queen and lower King Rivers do not allow significant deposition of these hydroxides under existing conditions (Davies pers obs, Koehnken pers comm).

The only continuous water quality monitoring reported to date for the Mount Lyell region is that described by Mounter (1992, 1993) for Linda and Comstock Creeks, which drain Mount Lyell to the east. This work was aimed at determining metal loads entering the upper King River (and ultimately the new HEC storage formed by the Crotty dam, Lake Burbury) as a prelude to transferring part of that load to the Queen River catchment by diversion works from the Comstock valley into the East Queen River (still in operation). Continuous conductivity and flow records were obtained at three sites in each of Idaho, Linda (above Idaho), and Comstock Creeks over the period 1986–1993. Relationships between conductivity and metal concentrations were explored in order to estimate loads, and were statistically and predictively significant for copper, zinc, manganese and iron over a wide range of concentrations. Copper concentrations at the Linda and Comstock Creek stations were measured over ranges between 0.6 and 5.2 and 0.02 to 0.45 mg/L respectively, with most concentrations falling in the range 0.6 to 2 and 0.1 to 0.2 mg/L respectively

Several recommendations have been made for remediation of the Mount Lyell lease site (Miedecke 1996), and the potential for remediation of AMD at Mount Lyell is a major theme of the Mount Lyell Remediation Research and Development Program (MLRRDP), of which the project described here forms a component. This project also aims to recommend a monitoring program to assess changes in water quality and ecological health associated with management of the Mount Lyell area.

This project therefore has two major components:

1 a biological and water quality survey of streams associated with the current and past operations at Mount Lyell, and an assessment of their biological health; and

2 a design of a long-term, integrated water quality and biological monitoring program for streams in the Mount Lyell area.

The definition of ecological health used in this study is that adopted by the National River Health Program (Davies 1994): 'the ability to support and maintain ecological processes and a community of organisms having a species composition, diversity and functional organisation as comparable to that of the natural habitat as possible'.

This project addresses the assessment of ecological health by using comparative measures of community composition (of macroinvertebrates and fish). This reflects currently nationally accepted practice for the assessment of the ambient ecological condition of surface waters (Davies & Schofield 1996).

The specific aims of the present project are to:

1 conduct a biological sampling program that would:

- characterise the biota (fish and invertebrate communities) of all major streams in the Queen and King River catchments affected by the direct and indirect effects of mining activities at Mount Lyell and of appropriate 'control' or reference streams unaffected by these impacts;
- determine the factors (environmental and anthropogenic) which cause differences between stream biotic communities in terms of presence/absence, abundance and diversity (defined as the number of taxa);
- relate water chemistry to biological community composition with an emphasis on the effects of low pH, high sulphate, high copper and sediment concentrations;
- assess the effects of season and discharge events (floods, low flows, mine and hydro dam discharges) on biological communities in these streams;
- assess the effects of change in habitat structure on stream biological communities that are related to past activities at Mount Lyell (eg changes in benthic substrate composition).

2 design a long-term, integrated water quality and biological monitoring program that would take all the above factors into consideration as well as the following:

- the frequency and intensity of sampling required to achieve desired levels of power for the detection of changes associated with the effects of remediation and other human activities on stream biota and water quality;
- the form of statistical analysis required for detecting trends in biological community composition and water quality and which environmental variables are required to be monitored to increase the power of detecting trends (eg stream flow).

The biological sampling component of the project has three main sections:

1 A seasonal (quarterly) survey of macroinvertebrate communities at 28–32 sites in streams in the Queen and King River catchments and in appropriate reference streams. This survey uses the rapid assessment protocol (RAP) sampling and sample processing techniques used in the current National River Health Program (NRHP) Bioassessment Protocol (Davies 1994), similar to that described by Chessman (1995) and Growns et al (1995), for sampling macroinvertebrate communities.

   Data derived from this sampling are then used to develop a locally-derived predictive river health assessment tool (the River Invertebrate Prediction and Classification System or RIVPACS; Wright et al 1989, Wright 1995). RIVPACS allows prediction of the invertebrate community composition of a site based on habitat variables and the objective comparison of the predicted 'undisturbed' fauna with that actually found at the site (Furse et al 1984, Moss et al 1987, Wright 1995). The intention of the seasonal rapid assessment macroinvertebrate sampling is, therefore, to:

   - develop a specific 'Mount Lyell region RIVPACS' (MLRIVPACS) model and to assess stream sites affected by acid mine drainage from Mount Lyell using that model. This will then allow long-term ecological targets for the Queen and King Rivers to be developed, against which the success of any remediation of water and/or habitat quality can be assessed.

- sample stream sites across a gradient of acid mine drainage (AMD) impacts so that relationships between the levels of AMD (specifically copper, pH and sulphate concentrations) and the departure from RIVPACS predictions can be examined.
- sample control sites impacted and unimpacted by HEC operations that are comparable to the King River above Queen so that suitable long term targets for this river can be set. This will be done primarily using rapid assessment samples collected from the Franklin-Gordon river catchment for a parallel project (also using the NRHP sampling protocol and sampling streams on the West Coast), which commenced in August 1995.

2 Collection of quantitative samples of macroinvertebrates from riffle habitats in a subset of those sites selected for RAP sampling on a seasonal basis. These samples would be archived for use in future monitoring. Several of these sites would be sampled more intensively to collect data for performing power analyses with the intention of:

   - identifying the appropriate sample sizes for different levels of discrimination of differences between sites; and
   - detecting changes in abundance and diversity of known magnitudes.

   The results of these analyses would then be incorporated into the long-term monitoring program design.

3 Sampling of streams to identify the species of fish present and the relationship between the characteristics of any fish communities found and the impact of Mount Lyell and HEC operations in the King and Queen river catchments.

The water quality component of the project aims to:

1 perform an extensive, low intensity survey of water quality from a range of AMD-affected and unaffected sites;

2 examine selected historical water quality data from the Queen and King Rivers in order to assess relationships between variables and with river discharge, and to determine appropriate sampling frequencies for assessing water quality conditions in relation to the objectives of future remediation management strategies.

2 Background review: Mining impacts on the aquatic environment

2.1 General impacts

The discharge of waters from active and abandoned mines is one of several mechanisms by which mining adversely affects the environment (Pentreath 1994). Mining may impact on surface waters in several ways:

- *Changing water quality* Declines in water quality due to increases in concentrations of metals, associated anions and particulates as well as decreases in pH are frequently reported for both open cut and underground mining operations with poor environmental controls (Moore & Luoma 1990, Pentreath 1994). Both surface and ground water quality may decline resulting in a combination of chronic (ground-water controlled) contamination under low flows and acute (storm-flow controlled) declines in water quality with high suspended solid loads.

- *Changing surface hydrology* Changes in surface stream flows may result from a combination of use and re-routing of ground waters, transfers of surface and ground water flows across drainage boundaries, changes to the physical drainage network and changes in surface landform. Secondary hydrological impacts also result from loss of terrestrial vegetation in areas surrounding mines associated with large-scale surface disturbance or localised atmospheric pollution (eg from smelting operations with little or no environmental controls). Under such conditions streams become 'flashier' with higher flood peaks, more rapid responses to rain events and significant channel adjustment associated with higher stream energy during floods. Low flows during dry periods may also decline due to the loss of soil and vegetation (Cornish 1993). The hydrological changes associated with deforestation are well documented both internationally and in Australia (Jayasuria et al 1993, McCulloch & Robinson 1993).
- *Changing physical structure of surface drainage* This may result from mechanical re-routing or infilling of surface drainage channels; enhanced suspended sediment transport causing sediment deposition within and marginal to the channel and sediment infiltration into the stream bed; enhanced high and flood flows causing changes to a stream's plan as well as its profile (Gregory & Walling 1973). At a smaller spatial scale, within-channel habitat quality for biota may decline due to: infilling from coarse or fine sediments, cementation of the stream bed from physico-chemical processes such as iron hydroxide flocculation and enhanced metal loads adsorbed onto interstitial or hyporheic material.

Acid mine drainage is typified by release of highly acidic ground and/or surface waters containing relatively high concentrations and/or loads of metals and associated anions (typically sulphate, eg Ficklin & Smith 1994). These conditions are more generally associated with mines which work metalliferous ores of high sulphur content or particular types of coal deposits. Where such mines allow active contact of the exposed deposit to surface or ground waters in combination with atmospheric oxygen and/or there is a high level of activity of certain types of bacteria, then release of acidic waters may occur (Singer & Stumm 1970, Moore & Luoma 1990, Bhole 1994, Smith 1994). These waters are also able to release ionic forms of metals present within the deposits into the water draining them.

These AMD-generating conditions generally pose higher ecological risks in areas where contamination of surface (eg stream) waters is possible in sufficient quantity and for a sufficient duration to cause either lethal or chronic toxic effects in stream biota. Impacts from toxic forms of dissolved metals are significantly greater in streams with low buffering capacity, which is normally dictated by the abundance and hydrogeologic orientation of carbonate-bearing rock in the watershed. Where carbonate or other buffering mechanisms effectively neutralise the increased hydronium ion concentrations, ferrous iron (FeII) will be oxidised to ferric (FeIII) iron. This results in the precipitation of ferric hydroxide ($FeOH_3$). Other precipitates may also form (eg $CaSO_4$). Thus, under neutralising conditions or as AMD waters pass downstream through a stream drainage network, soluble ferrous iron is oxidised to the ferric form which flocculates and precipitates from solution (Kimmel et al 1981). In soft waters this 'chemical recovery' may occur over a considerable distance downstream from the AMD source. Metal hydroxide flocs are themselves physically detrimental in a stream environment Thus, while dissolved metals and low pH may cause toxic impacts on stream life, stream habitat may be altered by precipitation and cementation of the stream bed.

The primary impacts of mining and associated AMD may be manifest on:

- aquatic biota and ecosystem processes;
- aesthetic and recreational values;
- other human water uses (eg drinking, industrial use).

Until recently, traditional environmental assessment of mine and AMD impacts on surface waters depended on responding to changes in water chemistry and managing to improve chemical quality (Cohen & Gorma 1991). This focus has shifted significantly in the social, management and regulatory arenas as impacts of industry and land use on biodiversity are deemed critical. A recent assessment of environmental issues most relevant to the mining industry (Buckley 1992) cited biodiversity as one of the three highest priorities, and one of the primary recommendations of a Federal government Working Group on ESD in the mining industry was 'maintaining biodiversity and ecological systems' (ESD 1991). Management of surface waters is now focussed more and more on the achievement of specific ecological endpoints. Accordingly, assessments of success in environmental management are increasingly relying on ecological monitoring rather than solely upon more traditional physico-chemical monitoring.

Only a small number of studies have been conducted on the impact of large scale metalliferous mining operations on stream water quality or biota in Australia. These include early investigations of the impact of current or past mining activity on the Molonglo River in NSW (Weatherley et al, 1967, Norris 1986), the King River (Lake et al 1977, Roberts & Watson 1979, Swain et al 1981, Koehnken 1996) and South Esk River (Thorpe & Lake 1973, Tyler & Buckney 1973, Norris et al 1980, 1981, 1982, Norris & Lake 1984) in Tasmania and, more recently, on Rockhole Mine Creek (Faith et al 1995, Dostine et al 1993) and the Finniss River (AAEC 1975, ANSTO 1992, 1993, Ferris et al 1995) in the Northern Territory. These studies assessed the impact of operations of the Lake George copper-lead-zinc mine, the Comstock and Lyell copper mines, the Storys Creek and Aberfoyle tin and tungsten mines and the Rockhole and Rum Jungle uranium mines, respectively. Major studies have also been conducted on the Fly River, PNG, associated with the Ok Tedi copper mine in New Guinea (Smith & Hortle 1989 and references therein, Smith & Morris 1992). All of these operations caused stream contamination with metals, while the Ok Tedi, Rum Jungle and Lake George operations were also associated with elevated suspended sediment loads. Only those studies on the King River, Rockhole Mine Creek and the Finniss River assessed the impact of acid mine drainage on streams. In all three cases, elevated iron and sulphate levels were combined with low pH and elevated concentrations of other metals, particularly copper, manganese and zinc.

2.2 Aquatic ecological impacts of AMD

All of the changes detailed above (see 2.1) may result in loss of, or decline in the amount and in the physico-chemical quality of, instream habitat for algae, invertebrates, fish and other vertebrates such as platypus. High suspended solid loads, often contaminated with adsorbed metals, when combined with high discharge events may also lead to substantial deterioration of the quality of riparian (stream-bank and flood plain) habitats (Feminella et al 1989, Smith & Hortle 1989) with consequent secondary impacts on instream habitat quality.

The following section discusses the impact of declines in pH and raised metal and sediment levels on stream biota, accompanied by a general assessment of the effects of AMD.

2.2.1 Effects of low pH on stream biota

Stream biota are acutely and chronically affected by the decline of stream pH below 4–5 due to:

- disruptions to ion-exchange mechanisms and respiratory metabolism in gills and related structures (fish and invertebrates);

- declines in levels of stream inorganic carbon necessary for growth (plants and algae).
- changes in speciation, and hence physical and toxicological behaviour of metals.

Many studies of the effect of decreased pH on natural streams and lakes have been conducted, partly as a response to the phenomenon of acid-rain the northern hemisphere (examples include: Neville 1979, Hall et al 1980, Harriman & Morrison 1982, Rahel & Magnuson 1983, Watt et al 1983, Mackay & Kersey 1985, Mulholland et al 1986, Collier et al 1989, Bergman & Mattice 1991, Reader et al 1991, Rosemond et al 1992).

Naturally acidic streams (pH < 5), in New Zealand, have been observed to support a less diverse and less numerically abundant invertebrate fauna than neutral streams draining native forests (Collier et al 1989). Colonisation following land disturbance was also observed to be inhibited due to the low faunal abundance in the acid brown water streams. Though some taxa were acidophilic and some were pH generalists, most taxa were sensitive to low pHs. pH 4.5 was observed as a threshold in stream faunal responses. Similarly, anthropogenically-induced stream pH declines (from around 6.5 to 4) due to planting of Sitka spruce plantations in Scotland, were observed to cause major declines in invertebrate abundances and diversity (particularly of mayflies and stoneflies) and to inhibit fish recruitment (Harriman & Morrison 1982).

Mackay & Kersey (1985) in a study of headwater streams in Ontario found strong relationships between faunal abundance and diversity and pH. Streams with pH values between 4.3 and 4.5 had no mayflies and few stoneflies. When pH values were between 5 and 6.3, these groups were present, accompanied by caddisflies but the chironomid subfamilies Chironominae and Tanypodinae were dominant. Those streams whose pH ranged between 5.3 and 6.7 had similar faunas to the latter but with a lower dominance of chironomids.

Acidification of streams to pH < 5 has been observed to reduce inorganic carbon and raise aluminium levels to a point where they limit algal productivity (Mulholland et al 1986). Sites with higher pH values were the least phosphate limited, possibly as phosphate and aluminium co-precipitate at higher pH. However, greater algal biomass and primary productivity were observed at pH values < 5.7, primarily due to the reduced numbers of scraping and grazing macroinvertebrates.

The most well known and intensive study of stream acidification effects on a stream ecosystem was that conducted at Hubbard Brook in New Hampshire, USA (Hall et al 1980). This study was coupled with long-term (> 10 year) observations of the impact of declining stream pH values associated with acid-rain. Stream water pH was decreased by addition of sulphuric acid to pH 4 from natural values of 6–7 over a six month period. Benthic densities of all invertebrates declined associated with declines in the emergence of mayflies and stoneflies. A decrease in invertebrate drift (a behavioural downstream movement of invertebrates in the water column) was observed for the entire period following an initial increase during the first week of low pH. Periphytic (attached) algal biomass increased and no stress was observed in brook trout resident in the stream. Overall, the stream ecosystem suffered from a decline in species diversity, respiration and food web complexity. The biological evidence suggested the dominance of physiological responses to low pH rather than declines in stream energy or food supply.

Experimental stream acidification studies support the above general observations. Decreasing stream pH values from 6.3–6.9 to 4 over 85 days lead to declines in abundances of all invertebrate groups, with mayflies almost disappearing (Allard & Moreau 1987). Differential responses were observed for some groups. In the dipteran family Chironomidae (midges), members of the sub-family Orthocladiinae were highly sensitive to the low pH while the

Chironominae and Tanypodinae were much less so. The Tanytarsinae were intermediate in response. Oligochaetes (freshwater worms) and nematodes showed varying responses.

Controlled experimental and laboratory toxicology studies of stream faunal and algal responses to low pH are too numerous to review in detail, ranging from individual single species toxicity tests (Neville 1979, Alabaster & Lloyd 1982–refs therein, Goss & Wood 1988, Reader & Dalziel 1991, Buckler et al 1995, Waring & Brown 1995) to integrated studies such as the North American lake acidification and fisheries project (LAF) in which responses of trout to low pH, from the biochemical and physiological to the population level, were evaluated (Bergman & Mattice 1991). Overall, the following observations apply:

- declines in pH to between 4 and 5 can cause a range of sub-lethal physiological effects on fish and invertebrates including elevations in plasma cortisol and moderate ionoregulatory disturbance, and result in reduced egg hatching and larval growth;
- acute effects of pH are demonstrable for most species below pH 4, with most species suffering complete mortality at pH values less than 3;
- acute lethal effects and sub-lethal effects are observed at pH 5 when Al is present in the range 25–50 µg/L, and 10–25 µg/L respectively.

2.2.2 Effects of metals associated with AMD

Two major sources of metals in AMD affected streams are noted:

- those emanating from the acid source rock or ore deposits—typically including those metals for which the mineral exploitation has been conducted; and
- those emanating from the surrounding 'country rock' due to the actions of the acid stream water (including rocks of the drainage channel)—particularly aluminium.

Field and laboratory studies of heavy metal effects (and AMD) on stream fish and invertebrates abound (eg Mance 1987, Consultants 1990). ANZECC (1992) reviews some of the literature for key metals associated with AMD—notably copper, zinc, iron, arsenic and aluminium. Guideline levels for these metals for protection of aquatic ecosystems in soft waters (and provided FeII is absent) are 2, 5, 1000, 50, and < 5 (for pH $\leq$ 6.5) µg/L, respectively.

Clements et al (1988) compared field observational and experimental stream studies of the effects of metals emanating from mine operations on invertebrates in the Clinch River, Virginia. Copper at 12 µg/L (all dissolved) reduced the number of taxa, the overall abundance and the abundance of the dominant taxa within four days of commencement of exposure. At ten days exposure, control streams were dominated by mayflies and tanytarsine chironomids, while copper exposed streams were dominated by orthocladine chironomids and hydropsychid caddis. These experimental observations were confirmed in the field. In further experimental trials, Clements et al (1992) assessed the relative sensitivities of invertebrates to metals including copper. Exposure to 25 µg/L copper eliminated four species of mayflies from experimental streams and caused severe reductions in the abundance of tanytarsine and chironomine larvae. Moderate to minor reductions in abundance were observed for three species of caddis and tanypodine chironomids. Orthocladine chironomids increased in abundance relative to controls. Again, these relative sensitivities were consistent with observations of contaminated river sites in the field. Similar relative sensitivities are described by Smith & Cranston (1995) at Rockhole Mine Creek, NT, Australia.

In another experimental stream study, Leland et al (1989) observed invertebrate responses in a naturally oligotrophic stream dosed with copper (to total and soluble copper concentration ranges of 12–75 and 2.5–15 µg/L respectively). All invertebrate orders declined in abundance at 5 and 10 µg/L total copper. Herbivores and detritivores were more sensitive than predatory species, with only two species increasing in abundance relative to controls. The results suggested that the primary route of copper uptake was by ingestion (eg by grazing of periphytic algae which accumulated copper by factors of 10^4–10^5) rather than by solute transport. This may reflect the relatively low soluble proportion of the copper load in this study. The number of taxa and measures of community similarity were sensitive to copper, while diversity indices were not, confirming the well recognised poor performance of such indices (Washington 1984).

Perrin et al (1992) evaluated the effect of lime-treated AMD from the Equity Silver Mine, British Columbia, on benthic algae and macroinvertebrates in artificial streams. Despite high statistical power in the analyses of variance, no effects were detected on abundance or diversity. This study illustrated the value of using on-site continuous-flow artificial stream mesocosms in assessing the effects of mine discharges in interactive or adaptive management.

Crossey & La Point (1988) described responses of periphyton community composition and metabolism to mixed mine metal discharges including cadmium, copper, lead and zinc, observing declines in diversity and metabolic rates for all metals, with little synergism in mixed metal exposures.

A large number of field studies have been published describing the impacts on mine or metal enriched discharges on stream biota (see review by Clements 1991), including a number of Australian examples, discussed here. None of the Australian studies are based on truly balanced or replicated (in time and space) designs (see Faith et al 1995 and references therein), since no comparable longitudinal trend in macroinvertebrate communities is evaluated in an unimpacted 'control' river, nor is there any evaluation of a mine impact pre-discharge. This is a common feature of most published studies of mine impacts on stream biota, due at least in part to the relatively recent awareness of the ecological nature of the impact of mine discharges compared with the age of most major mining operations. A single exception to this occurs in Australia, with the current long-term biomonitoring program being conducted at the Ranger Uranium Mine, Jabiru, Australia (Humphrey et al 1990, 1995) which is in its 'pre-impact' phase.

Two studies of the effect of past mining operations on the upper King River were conducted by Lake et al (1977) and Swain et al (1981). While both studies focussed on the effects of the AMD emanating from the Linda and Comstock Creek valleys on stream biota, no studies have been published of the impacts of the much larger Mount Lyell mining operations on the adjacent Queen River catchment. Both studies reported no fauna or fish in the two creeks, while impacts of their discharge on the upper King River caused declines in macroinvertebrate abundance and diversity in the reaches downstream of the confluences over a distance of at least 20 kilometres, with mayflies (*Atalophlebioides*) and the dipteran *Austrosimulium* particularly sensitive. Fish (primarily brown trout) were completely absent in the King River downstream of the AMD inputs. These discharges were associated with enhanced copper, zinc, manganese, sulphate and iron levels and decreased pH (Roberts & Watson 1979), all characteristic of AMD.

A number of studies have been published on the effects of drainage from the Storys Creek and Aberfoyle mines in northeastern Tasmania on water quality and ecology of Storys Creek and the larger, receiving South Esk River (Tyler & Buckney 1973, Thorpe & Lake 1973, Norris et al 1980, 1981, 1982). Although none of these published studies provides a detailed elucidation of the impact on stream water quality from these mines, the impacts on macroinvertebrate communities of the South Esk are more clearly evaluated. Sites upstream and downstream of the input of Storys Creek were compared by both Thorpe & Lake (1973) and by Norris et al (1981). Thorpe & Lake (1973) observed that the cadmium and zinc contamination from Storys Creek was associated with a decline in abundance and diversity of all invertebrates downstream of the input, with crustaceans (especially the shrimp *Paratya*), molluscs and worms being highly sensitive, while leptocerid caddis and Hemiptera (bugs) were highly tolerant. Norris et al (1982) confirmed these observations, noting that two mollusc species, four leptophlebiid mayflies and five caddis species were highly sensitive to the discharge, while orthocladine chironomids, and four species of caddis were tolerant. It should be noted that the impact of Storys Creek on the water quality of the South Esk was a mild enhancement of zinc, copper and cadmium with no significant change in pH or suspended solids load (Tyler & Buckney 1973, Norris et al 1981).

The Molonglo River, NSW, experiences zinc contamination from the Lake George Mine at Captains Flat (Weatherly et al 1967, Norris 1986), associated with overall declines in abundance and diversity of macroinvertebrates and fish. Tubificid worms were found to be tolerant of the zinc contamination while naidid worms were highly sensitive. Leptocerid caddis were also found to be abundant at zinc contaminated sites, suggesting tolerance.

The AMD discharge into Rockhole Mine Creek was characterised by low pH and elevated levels of metals including Cu, Zn, and Al (which exceeded the ANZECC (1992) guideline values). Survey and experimental evaluation of the biological impact demonstrated a marked change in the downstream macroinvertebrate community (Dostine et al 1993, Faith et al 1995, Smith & Cranston 1995). Upstream sites were dominated by mayflies (of the families Leptophlebiidae and Baetidae), helodid caddis, palaemonids and flatworms. A polluted downstream site had lower abundances and diversities of all macroinvertebrates, no leptophlebiid mayflies, and was dominated by leptocerid caddis, gyrinids and notonectids.

A number of technical reports on the impact of the Rum Jungle Mine on the Finniss River have been published (AAEC 1975, ANSTO 1992, 1993, Ferris et al 1995), both pre- and post-site rehabilitation. This major source of AMD has caused declines in abundance and diversity of fish, macroinvertebrates and algae, accompanied by fish kills under low flows, in the East Finniss and Finniss Rivers.

Smith & Hortle (1989) in a study of the relationship between river fish populations (assessed as catch rates) and pollutants emanating from the Ok Tedi mine, observed negative relationships with the total river copper load but not suspended solid load. Predictions were then made about river fish populations under a variety of copper loads.

A number of studies of the impact of AMD from mining operations in the USA bear out the general conclusions from the above Australian studies, that declines in pH and elevated metal levels cause major declines in fish, macroinvertebrate abundance (eg Kimmel et al 1981, Cannon & Kimmel 1992).

The overall results of field studies of mine discharge associated with enhanced metal and suspended solids loads and declines in pH are:

- a decline in the abundance and diversity of most stream fish, macroinvertebrates and algae;
- a decline in the rate of stream processes such as respiration;
- a downstream recovery in abundance and diversity of most stream biota, the degree of which is determined by the balance between the recovery in water quality, flow and biological colonisation due to tributary inputs and instream processes and the magnitude of mining-derived inputs.

Most studies of mine impacts report declines in stream biotic abundance for many kilometres downstream, with extensive loss of biodiversity.

Few studies of the effectiveness of mine remediation on stream biological values have been published (Chadwick & Canton 1986). Two examples exist in Australia, on the Molonglo and Finniss Rivers. Norris (1986) reported no recovery in stream biota associated with remediation works at the Lake George mine at Captains Flat on the Molonglo River, NSW. Some improvement in ecological condition of the Finniss River drainage has been reported (ANSTO 1993), associated with the rehabilitation works, but significant impacts are still occurring.

An extremely large range of toxicity studies has been published on metals (see Alabaster & Lloyd 1982, Mance 1987, ANZECC 1992). Key metals associated with AMD impacts in surface waters are copper, zinc, arsenic, aluminium and occasionally cadmium, lead and mercury. The first four metals have direct toxic effects in the low mg/L to high µg/L range, with frequent sublethal effects (eg on reproduction, physiological functioning and growth) in the mid to low µg/L range. Copper is particularly toxic in soft waters with low pH values and in the absence of natural organic acids, with 96 hr LC50 values (the concentration that kills 50% of a test population in 4 days) to fish in the 10–100 µg/L range. Sub-lethal effects of copper have been demonstrated at 2–10 µg/L in soft water (Knittel 1980) and avoidance responses reported in the same range (Giattina et al 1982).

Metal toxicity is often higher at low pH, especially in soft waters. The mitigating effects of high calcium levels (often reported as hardness in mg/L $CaCO_3$) on the toxic responses of fish to metals such as copper are well recognised (Alabaster & Lloyd 1982, Sadler & Lynam 1988, Sayer & Reader 1989, with strong inverse correlations reported between sub-lethal and lethal (eg LC50) responses for fish and hardness (Mance 1987). Reader & Everall (1989) observed that at pH 4.5, brown trout fry had impaired ion regulation and skeletal calcification but only low mortality (10% in 30 days). However, on addition of copper at 5 µg/L, calcium uptake and calcification were grossly impaired and mortality was high (97%).

The mitigating effects of organic acids, frequently measured as dissolved organic carbon (DOC), on metal toxicity to aquatic biota are also important in the interpreting the environmental effects of metal discharges to surface waters (Brezonik et al 1991, Winner 1985). Winner et al (1990) observed marked seasonal variability in the sensitivity of pond invertebrate fauna to copper and found that periods of high vulnerability were those during which DOC levels were low. Winner (1995) observed that each 0.5 mg/L increase in DOC (as humic acid) caused an increase in the chronic no-effect concentration of copper to *Daphnia magna* (water flea) by 20 µg/L.

It should also be noted that although most impact assessment is based on considerations of dissolved metals, the load of metals in stream sediments is also a key factor in interpreting mine impacts on surface waters (Eyres & Pugh-Thomas 1978, Burrows & Whitton 1983), the ecotoxicology of which is not well researched. Eyres & Pugh-Thomas (1978) observed the effects of copper, lead and zinc sediment contamination in the River Irwell, Lancashire UK, on invertebrates and fish even when water column concentrations were low and pH was neutral.

Elevated aluminium is a feature typical of surface waters affected by atmospheric or non-mining induced acidification (Dillon et al 1984). Though the environmental impact of acid rain on poorly buffered lakes and streams has frequently been linked to elevated aluminium levels, the relative environmental significance of lowered pH and raised aluminium concentrations is not always simple (Driscoll et al 1980, Campbell & Stokes 1985). Goss & Wood (1988) found that rainbow trout exposed to pH 4.8 in the laboratory showed only minor physiological stresses with no mortality. Addition of aluminium to 112 µg/L caused major blood chemistry dysfunction and 100% mortality. Reader & Dalziel (1991) also observed enhanced effects of episodic exposure to lowered pH on brown trout when co-exposed to aluminium. The toxicity of aluminium in acid waters peaks in the pH range 4.4–5.4 (Dillon et al 1984).

2.2.3 Sediments

There is widespread recognition of the detrimental effects of enhanced sediment inputs into streams on stream biota (Cordone & Kelly 1961, Campbell & Doeg 1989, Newcombe & MacDonald 1991). The direct effects of high suspended sediment loads on stream fauna are primarily those associated with clogging and abrasion of gills and reductions in visibility affecting feeding. Suspended sediment loads must be very high for prolonged periods to cause sublethal (2–3 g/L) or lethal (≥ 100 g/L) effects on fish (Alabaster & Lloyd 1982, Redding & Schreck 1987). These levels are much higher than those at which stream ecosystems become severely degraded.

The indirect effects of enhanced sediment loads in streams on biota has been well documented. Enhanced transport of fine sediment in streams has been associated with a range of negative impacts on fishes and macroinvertebrates (Cordone & Kelly 1961, Newcombe & MacDonald 1991, Ryan 1991), including impacts on the reproductive potential of stream fishes (Koski 1966, Kondolf 1988), reduction in macroinvertebrate abundance and diversity (Lenat et al 1981, Murphy et al 1981, Lemly 1982, Culp et al 1986, Doeg et al 1987) and enhanced invertebrate drift (Rosenberg & Wiens 1978, Culp et al 1986, Doeg & Milledge 1991). Increases in stream sediment due to road construction and drainage appear ubiquitous (Burns 1972, Cline et al 1982, Richardson 1985, Fahey & Coker 1992) and such increases have been associated with declines in abundance of invertebrates and fish (Cline et al 1982, Richardson 1985).

Enhanced movement of fine sediment may be associated with changes to catchment hydrographs following land clearing. Such changes typically take the form of more rapidly peaking floods of higher magnitude, reverting to a more damped flood hydrograph with revegetation in the long term (Gregory & Walling 1973).

2.3 Impacts on streams of mining in the Mount Lyell area

2.3.1 Water quality

It is apparent that principal current sources of AMD to surface waters in the Mount Lyell area have caused a major decline in water quality in a number of streams in the Queen and King River catchments (McQuade et al 1995, Koehnken 1996). These waters are typified by low pH, and high concentrations of sulphate, copper, aluminium, iron, manganese and other trace metals. Suspended solid concentrations are also elevated in some streams during storm events.

Historically, the MLMRCL was responsible for the discharge of large quantities of mine tailings and smelter wastes into the Queen River. Discharges resulting from MLMRCL operations were also chemically complex, resulting in deposition of iron hydroxide flocculates and other metals adsorbed to suspended sediment on the stream bed and in the riparian zone. Koehnken (1996), assessing the results of high intensity water quality monitoring in the King River, described complex interactions between water quality, river flow and the nature of AMD and mine tailing discharges. Precipitation and adsorption were two mechanisms which caused sequestering of metals from the water column to bottom sediments. The closure of the MLMRCL Prince Lyell mine at the end of 1994, accompanied by the cessation of tailings discharge, was observed to cause significant increases in the concentrations of dissolved metals in the King River due to the lack of adsorption by suspended sediment.

2.3.2 Hydrology

The impact of mining operations on river hydrology in the Mount Lyell area has not been evaluated in any detail. Changes to the surface structure of the Mount Lyell-Mount Owen region due to mine workings has certainly caused local changes in stream flows and re-routing of ground waters. Release to the surface through adits and other tunnel structures has altered base flows, particularly in the upper Linda, Comstock and East Queen sub-catchments (A Livingston, HEC, pers comm).

Significant deforestation occurred between the 1890s to 1920s (Blainey 1967, Wood 1991), much of which is still apparent in 1995. This extended from the western side of the Queen River valley to the eastern end of the Linda valley, southward over the slopes of Mount Owen and on the northwestern slopes of Mount Lyell. Such deforestation was certain to have caused significant changes to the hydrology of streams draining these steep slopes, some of which is suggested by anecdote (Blainey 1967), but which has not been assessed scientifically to date.

2.3.3 Drainage structure

As noted above, several smaller stream tributaries were re-directed during and as a result of mining operations in the immediate area of workings. Larger scale changes to the drainage structure (in plan) are thought to be slight (Helen Locher, MLRRDP, pers comm 1995). Changes to instream habitat structure have been significant, however (Davies pers obs, Locher 1995), and include:

- cementation of the natural stream bed armour layer in the Queen River;
- overlaying of stream beds with deposited sediment in the lower King River;
- deposition of large masses of metal contaminated sediments in the riparian zone and in bars on the inside of bends and tributary mouths.

3 Methodology

3.1 Biological monitoring

3.1.1 Sampling

Sites

The topography, geology and climate of the Mount Lyell region are described by McQuade et al (1995), along with locations of major AMD sources. These data were used to select sampling sites.

Sites were selected as either:

- **reference sites**: 'least disturbed' sites representing an essentially natural condition undisturbed by human activity, to be used to describe the condition of streams unaffected by human activity and to establish a RIVPACS model; or

- **monitoring sites**: sites known or believed to be affected by human impacts, to be assessed relative to the reference sites (eg using the RIVPACS model).

A suite of impacted monitoring sites was selected in the East Queen, Queen and King Rivers as well as in Linda and Comstock Creeks to represent sites affected by previous mining activities at Mount Lyell. A suite of reference sites was then selected using the criteria established by Davies (1994) for the NRHP, ie 'least disturbed' stream sites with similar geomorphological, channel and catchment characteristics to the monitoring sites. All sites sampled are indicated in table 1 and shown in fig 1. Figure 2 shows a detailed map of the Mount Lyell mine area, indicating rapid assessment protocol (RAP) sampling sites and major AMD sources.

RAP macroinvertebrate sampling

RAP (rapid assessment protocol) sampling for macroinvertebrates was conducted in the Mount Lyell region on four occasions: July 1995 (winter), October 1995 (spring), January 1996 (summer) and April 1996 (autumn). Twenty-eight sites were sampled in the first, winter, sampling (table 1). These sites were also sampled on the following three sampling events, but with the addition of 5 more reference sites and the subtraction of one (Queen R 3). An additional seven reference sites were sampled in the Franklin, Jane and Gordon Rivers in spring only (access in autumn was prevented by bad weather). These sites were selected as potential unregulated reference sites for the King River, and were accessed by helicopter. All other sites were accessible by vehicle and/or foot, with the exception of the Eldon, South Eldon and Governor Rivers and Comstock Ck site 4 which were accessed by boat via Lake Burbury.

All RAP sampling was conducted in accordance with the National River Health Program (NRHP) Bioassessment Protocol (Davies 1994). Thus, a 10 m kick sample was collected from a single riffle habitat at each site, using a 250 µm mesh standard kick net (dimensions 25 x 35 x 70 cm, height x width x depth). All samples were picked live. Thus, the contents of the kick net were emptied into a sorting tray and the sample picked for a total of 30 min using forceps and a pipette into a vial of 100% ethanol, attempting obtain samples with as full a list of taxa as possible and with representative rank abundances. The preserved picked material was identified and counted in the laboratory.

Only riffle habitats were sampled with the exception of autumn 1996, when edge habitats were also sampled. All identification was performed to 'family' level (all groups identified to family, excepting water mites and oligochaetes which were not further identified, and chironomids which were identified to sub-family), with the exception of the winter samples which were also identified to the lowest taxonomic or 'species' level (excepting water mites, coleoptera, chironomids and oligochaetes). Residues from spring kick samples were preserved after live-picking. Keys for identification were as listed in Hawking (1994).

A set of environmental and water quality variables was selected from those recommended in the NRHP Bioassessment protocol as well as several known to be relevant to sites in the Mount Lyell region. A set of environmental variables was measured on each site visit. An additional set of variables was derived for each site from 1:100,000 maps. In addition, a single water sample was taken on each site visit and analysed for several analytes. The environmental and water quality variables are indicated in table 2. Water analyses were performed by one or more of the following laboratories: Department of Environment and Land Management Laboratory, State Government Analytical Laboratory, Department of Mines (Minerals and Energy) Laboratory.

Quality assurance-Quality control (QA/QC)

Four aspects of QA/QC were explored:

a) Representativeness of live-picking Residues were kept for all RAP samples collected in spring 1995. Thus, all 37 samples were picked and the picked sample and the residue preserved separately in >75% ethanol. Picked samples were processed as described above. Residues were then floated using a saturated calcium chloride solution (with rapid sorting of the remaining material) and the floated material sub-sampled to 20% using a box sub-sampler as described by Marchant (1989). Invertebrates in the 20% sub-sample were then identified to 'family' level, as for the live-picked sample, and counted.

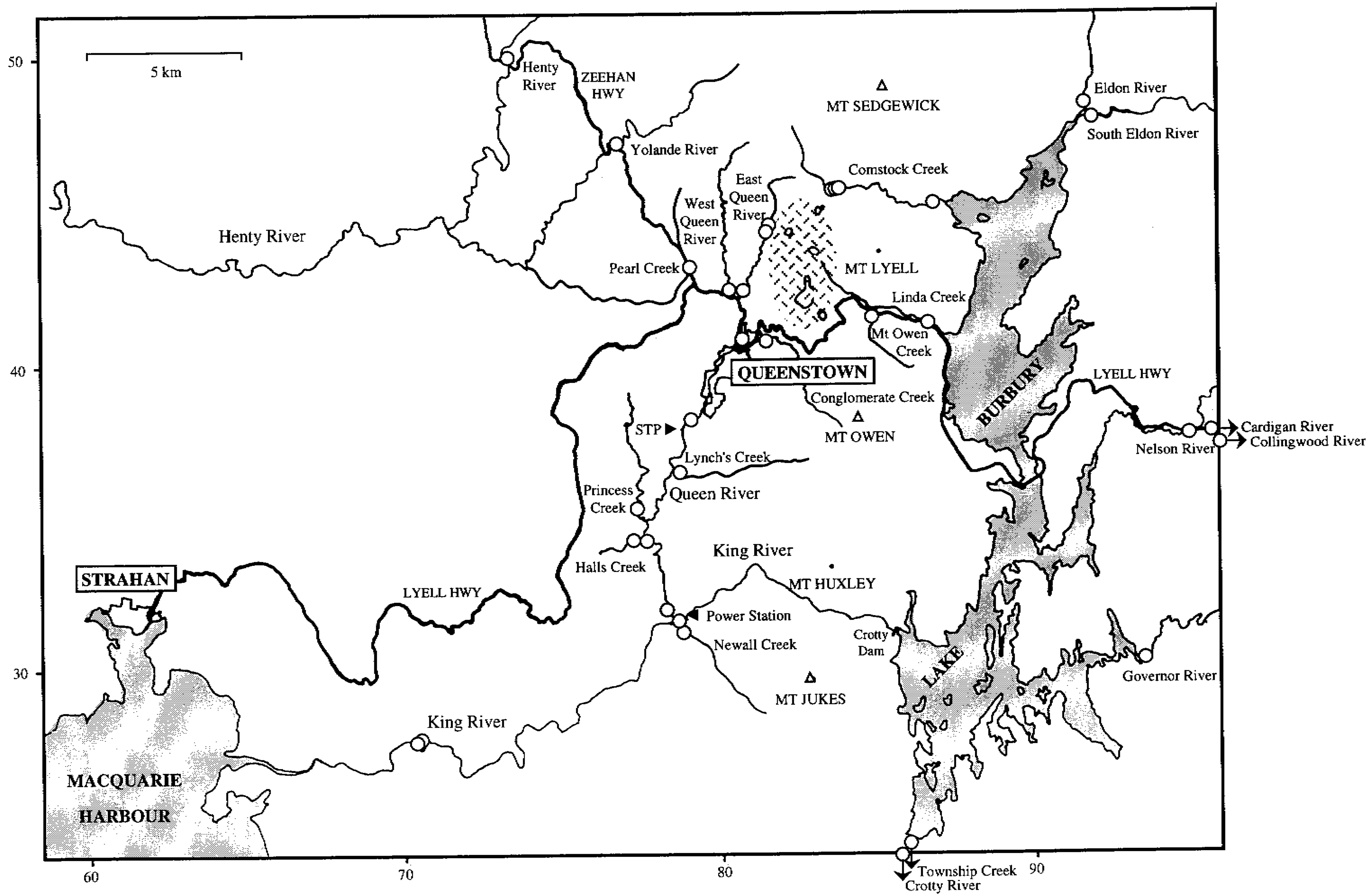


Figure 1 Map of the King and Queen River catchments indicating the location of sampling sites (O) and the Mount Lyell Copper Mine (hatched area)

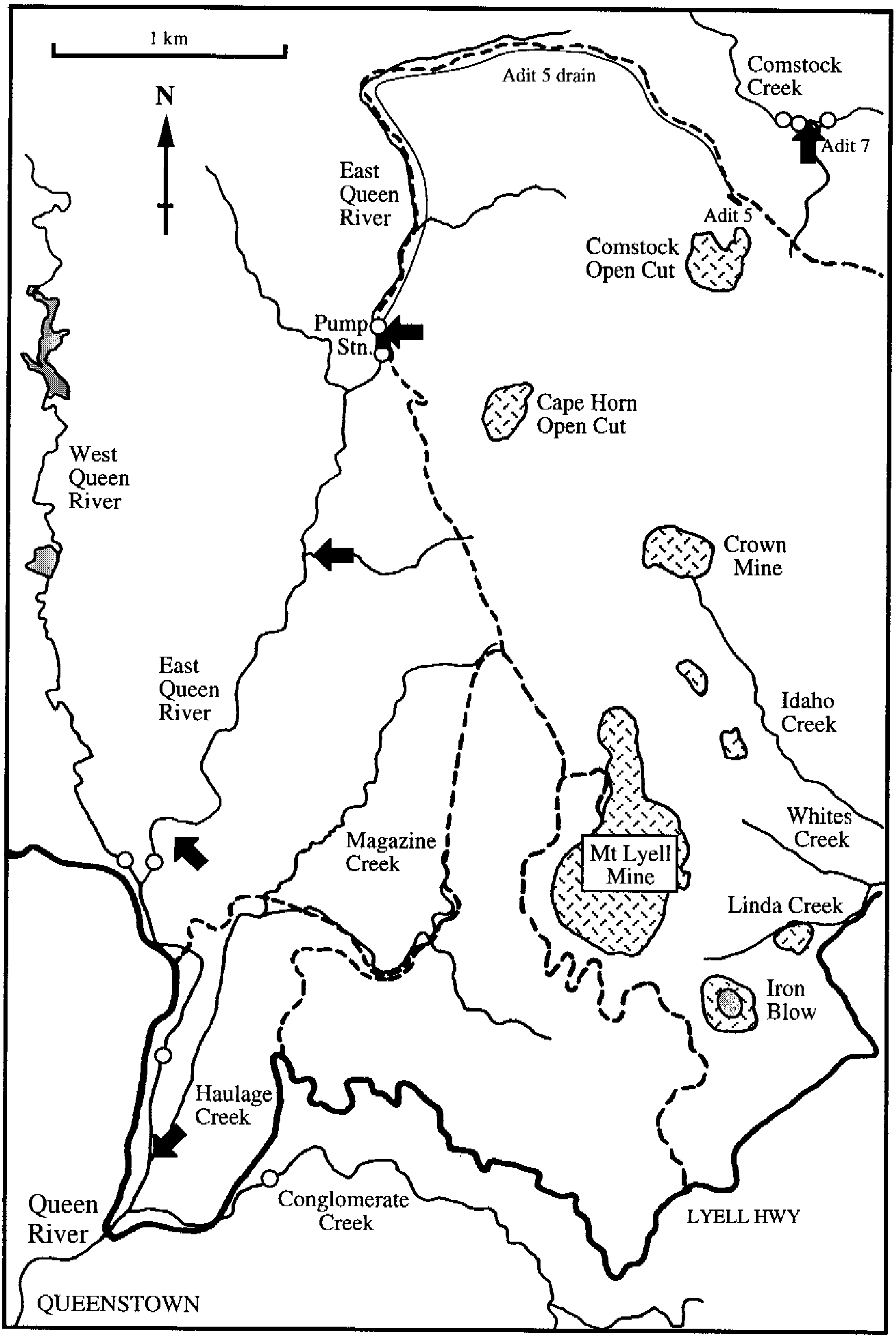


Figure 2 Streams of the Mount Lyell area showing principal areas of mining activity (hatched), major sources of acid mine drainage (arrows) and biological sampling sites (O)

Table 1 List of all stream sites sampled by RAP and Surber in the Mount Lyell region during 1995/1996. All sites sample at riffle habitats. Edge/backwater habitats also sampled at all sites in Autumn 1996.

Site name	Grid reference	Site type	RAP sampled	Surber sampled
Queen River 1	380700 5341800	M	W, Sp, Su, A	W
Queen River 2	379200 5338200	M	W, Sp, Su, A	W
Queen River 3	377500 5334200	M	W	
Queen River 4	378300 5332200	M	W, Sp, Su, A	
West Queen River	380500 5342200	R	W, Sp*, Su, A	
East Queen River 1	381800 5344800	R	W, Sp, Su, A	
East Queen River 2	381700 5344500	M	W, Sp, Su, A	
East Queen River 3	380700 5342100	M	W, Sp, Su, A	W
Comstock Creek 1	383500 5345500	R	W, Sp, Su, A	
Comstock Creek 2	383500 5345500	M/R	W, Sp, Su, A	
Comstock Creek 3	383600 5345500	M	W, Sp, Su, A	
Comstock Creek 4	387400 5345100	M	W, Sp, Su, A	W, Sp, Su, A
Linda Creek	386700 5341200	M	W, Sp, Su, A	
Mt Owen Creek	384900 5341600	R	W, Sp, Su, A	
Conglomerate Creek	381300 5340800	R	W, Sp*, Su, A	W, Sp, Su, A
King River 1	378600 5331500	M/R	W, Sp, Su, A	
King River 2	370600 5327700	M	W, Sp, Su, A	
King River 3	370200 5327800	M	W, Sp, Su, A	
Crotty River	386000 5321400	R	Sp, Su, A	
Township Creek	385800 5323100	R	Sp, Su, A	
Newall Creek	378700 5331500	R	W, Sp*, Su, A	
Hall's Creek	377300 5334300	R	W, Sp, Su, A	
Princess Creek	377400 5335300	R	W, Sp, Su, A	W
Lynch's Creek	378600 5336700	R	Sp, Su, A	
Pearl Creek	379200 5342800	R	W, Sp, Su, A	
Yolande River	376500 5347100	R	W, Sp, Su, A	
Henty River	373300 5349700	R	W, Sp, Su, A	
Eldon River	391700 5347900	R	W, Sp*, Su, A	
South Eldon River	391700 5347800	R	W, Sp*, Su, A	
Nelson River	395100 5337700	R	W, Sp, Su, A	W, Sp, Su, A
Governor River	393200 5330400	R	W, Sp, Su, A	
Cardigan River	403400 5335400	R	Sp, Su, A	
Collingwood River	411300 5331500	R	Sp, Su, A	
Franklin River 1	396700 5284900	R	Sp	
Franklin River 2	398500 5291200	R	Sp	
Franklin River 3	397900 5297100	R	Sp	
Gordon River 1	398000 5277500	R	Sp	
Gordon River 2	397300 5279800	R	Sp	
Gordon River 3	396900 5282800	R	Sp	
Jane River	408100 5300400	R	Sp	

M=monitoring sites; R=reference sites; W=Winter; Sp=Spring; Su=Summer, A=Autumn; * = duplicate kicking of three riffles

Table 2 Habitat, water quality and biological variables determined for all RAP stream sites sampled in the Mt Lyell region

Variable	Definition
Altitude	* Altitude of site (m)
Stream order	* Index of stream size and stream flow within the drainage network
Stream slope	* Distance along stream bed for 10 m rise in elevation (m)
Catchment size	* Area of catchment (km^2)
Distance from source	* Distance of site from stream source (km)
Disturbance category	Ranked from 0 (nil) to 3 (extensive)
Riffle area	* Proportion of riffle in 100 m section of stream (%)
Pool area	* Proportion of pool in 100 m section of stream (%)
Snag area	* Proportion of snag in 100 m section of stream (%)
Stream flow conditions	Ranked from 0 (no flow) to 3 (high flow)
Maximum stream velocity	Maximum stream velocity in sampled riffle (m/s)
Minimum stream velocity	Minimum stream velocity in sampled riffle (m/s)
Overhanging vegetation	Area of vegetation overhanging the stream, ranked from 0 (nil) to 3 (extensive)
Trailing bank vegetation	Area of bank vegetation trailing in stream, ranked from 0 (nil) to 3 (extensive)
Riparian vegetation: left and right bank	Cover and depth of riparian vegetation, ranked from 0 (nil) to 3 (extensive)
Stream depth	Stream depth ranked from 1 (<25m) to 5 (<2m)
Stream width	* Mean of 3 widths at 0, 50 and 100 m along a transect (m)
Algal cover	* Cover of periphytic algae on riffles (%)
Silt cover	* Cover of silt on riffles (%)
Moss cover	* Cover of moss on riffles (%)
Detrital cover	Cover of detritus on riffles (%)
Aquatic plant cover	Proportion of aquatic plant cover in 100 m section of stream (%)
Bedrock substrate	Proportion of riffle substratum as bedrock (%)
Boulder substrate	Proportion of riffle substratum as boulders (%)
Cobble substrate	* Proportion of riffle substratum as cobbles (%)
Pebble substrate	* Proportion of riffle substratum as pebbles (%)
Gravel substrate	Proportion of riffle substratum as gravel (%)
Sand substrate	Proportion of riffle substratum as sand (%)
Silt substrate	Proportion of riffle substratum as silt (%)
Clay substrate	Proportion of riffle substratum as clay (%)
Temperature	Water temperature at time of sampling (°C)
Conductivity	Water conductivity at time of sampling (µS/cm)
Water clarity	Ranked from 0 (clear) to 3 (poor)
Total copper	Measured in laboratory from water sampled on-site of water
Total dissolved copper	Measured in laboratory from water sampled on-site (µg /L)
Water pH	Measured in laboratory from water sampled on-site
Conductivity	* Measured in laboratory from water sampled on-site (µS/cm)
Sulphate concentration of water	Measured in laboratory from water sampled on-site (µg/L)
Humic content of water	Substances reducing Folin phenol reagent—measured in laboratory from water sampled on-site (mg phenol/L)
Dissolved organic carbon (DOC)	Measured in laboratory from water sampled on-site (mg/L)
Water colour	Measured in laboratory from water sampled on-site (apparent colour units)
Total suspended solids in water	Measured in laboratory from water sampled on-site (mg/L)
Macroinvertebrates	Number of taxa
	Abundance
	Community composition
Fish	Species composition
	Abundance

* = those variables selected for inclusion in final MLRIVPACS model development

b) Site representativeness In order to evaluate how representative a single riffle site was of a river reach, RAP sampling was conducted at three riffles within a 100–300 m reach on five different rivers (as indicated in table 1).

c) Operator comparability Duplicate RAP sampling was conducted at one riffle in each of the above five reaches by Laurie Cook and by Nicki Mitchell. Laurie Cook was used consistently as the point of comparison because he was the most experienced operator (sampler and sample picker). An additional six duplicate samples were collected, making 10 sample pairs for comparison of these two principal operators. This was repeated with Laurie Cook and Jean Jackson (six duplicate samples) and with Laurie Cook and Will Elvey (four duplicate samples). All samples were live-picked as described above. Locations where duplicate sampling was conducted are shown in table 1.

d) Accuracy of taxonomic identification Six RAP picked samples (5% of the four season sample set) were submitted, along with their identification data sheets, to Mr John Hawking (Murray Darling Freshwater Research Centre) for assessment against three criteria (as developed for the NRHP):

- accuracy of number of taxa (at 'family' level) identified in the sample;
- accuracy of counting of individuals of each taxon in the sample;
- similarity of sample composition (using a Bray Curtis dissimilarity criterion).

Quantitative macroinvertebrate sampling

Three sites were selected for intensive sampling on all four sampling occasions—Nelson River, Governor River and Comstock Creek 4 (table 1). Ten Surber sample units were collected at these sites in winter, summer and autumn, and twenty sample units were taken in spring. All of these samples were preserved in >75% ethanol and picked, without sub-sampling, in the laboratory. Identification was to 'family' level (as described for RAP samples), with the exception of the spring sample set which was also identified to 'species' level (all groups identified to species with the exception of mites, oligochaetes, chironomids and Coleoptera). An additional three sites (Halls Ck, West Queen River, Queen River 2) were also sampled (table 1) and the samples preserved and archived without further processing.

Fish sampling

a) General survey All RAP sampling sites were also electrofished with one or two passes in winter or spring to assess the presence/absence of fish (table 3). Of those at which fish were found, four sites were selected for quantitative survey in summer (January 1996). They were: Nelson and West Queen Rivers, Halls and Newall Creeks. At each site, a standard two-pass electrofishing operation was conducted with two (or occasionally three) operators using a backpack electroshocker (Smith Root Model 12, 400 W pulsed direct current). Fish were identified and counted from each run separately, held in buckets and all fish measured. Fish were then released and distributed along the study reach at completion of each site survey.

b) Survey of the King River and related streams: Small streams Following information derived from a conversation with a Queenstown resident, Mr Leo Deakin, and further conversations with other Queenstown and Strahan residents, an additional stream fish sampling program was implemented (see table 3 for the list of sites). Two-pass electrofishing surveys were conducted once at eight tributary streams of the lower King River, in January-February 1996. Three streams flowing into the northern end of Macquarie Harbour were selected as local controls for recruitment of native fish.

Table 3 List of all stream sites sampled by electrofishing in the Mount Lyell–Macquarie Harbour region during 1995/1996

Site name	Grid reference	Fish present	Species
Queen River and tributaries			
Queen River 1	380700 5341800		
Queen River 2	379200 5338200		
Queen River 3	377500 5334200		
Queen River 4	378300 5332200		
West Queen River	380500 5342200	y	Bt
East Queen River 1	381800 5344800		
East Queen River 2	381700 5344500		
East Queen River 3	342200 5380700		
Lynch's Creek	378600 5336700		
Conglomerate Creek	381300 5340800		
Hall's Creek	377300 5334300	y	Rt
Princess Creek	377400 5335300		
Other streams of Mount Lyell region			
Linda Creek	386700 5341200		
Mt Owen Creek	384900 5341600		
Comstock Creek 1	383500 5345500		
Comstock Creek 2	383500 5345500		
Comstock Creek 3	383600 5345500		
Comstock Creek 4	387400 5345100		
King River 1	378600 5331500	y	Bt
King River 2	370600 5327700		
King River 3	370200 5327800		
Crotty River	386000 5321400	(y)	Bt
Township Creek	385800 5323100	y	Bt,Aa
Newall Creek	378700 5331500	y	Bt
Pearl Creek	379200 5342800	(y)	Bt
Yolande River	376500 5347100	y	Bt
Henty River	373300 5349700	y	Bt
Eldon River	391700 5347900	y	Bt
South Eldon River	391700 5347800	y	Bt
Nelson River	395100 5237700	y	Bt, Gb
Governor River	393200 5230400	y	Bt
Cardigan River	403400 5335400	y	Bt
Collingwood River	411300 5331500	(y)	Bt
Macquarie Harbour streams			
Manuka River	361300 5333700	y	Bt, Gt, Gb, Pu, Aa, Ga
Porteus Ck	362900 5333600	y	Gb
Botanical Ck	362800 53320000	y	Bt, Gt, Gb, Pu, Aa, Ga
Connellys Point Ck	365100 5323100	y	Bt, Gt, Gb, Pu, Aa, Ga

Fish present: y = yes, (y) = reported elsewhere, blank = surveyed but no fish found
Species: Bt = brown trout, Rt = rainbow trout, Gt = *Galaxias truttaceus*, Gb = G *brevipinnis*, Aa = *Anguilla australis*, Pu = *Pseudaphritis urvillii*, Gm = *Gadopsis marmoratus*, Ga = *Geotria australis*

Table 3 cont'd

Site name	Grid reference	Fish present	Species
Lower Henty River and tributaries			
Lower Henty R	356600 5346900 – 357000 5345800	y	Bt, Gt, Gb, Pu, Aa
Tully River	357700 5343800	y	Bt, Gt, Gb, Pu, Aa, Ga
McCutcheon's Ck	360100 5344800	y	Bt, Gt, Pu, Ga
Lower King River and tributaries			
Lower King R	364900 5327300 – 369900 5327800		
Lucky Ck	366800 5327300	y	Gb
Kingfisher Ck	367500 5327200	y	Gt, Gb, Aa
Four Mile Ck	369400 5327700	y	Gb
Lower Landing Ck	370500 5327500	y	Aa
Virginia Ck	370100 5327900	y	Gb, Aa
Swift Ck	371000 5326700	y	Rt, Aa
Open Ck	375400 5328400	y	Bt,Aa
Starting Ck	373600 5328500	y	Rt
Lower Gordon River tributaries			
Ck 1	384300 5298800	y	Gt, Gb, Aa
Ck 2	387700 5299900	y	Gt, Gb, Aa
Little Eagle Ck	391100 5296700	y	Gt, Gb, Aa

Fish present: y = yes, (y) = reported elsewhere, blank = surveyed but no fish found
Species: Bt = brown trout, Rt = rainbow trout, Gt = *Galaxias truttaceus*, Gb = G *brevipinnis*, Aa = *Anguilla australis*, Pu = *Pseudaphritis urvillii*, Gm = *Gadopsis marmoratus*, Ga = *Geotria australis*

In addition, two streams flowing into the Henty River were selected as controls for recruitment into tributaries of West Coast rivers at distances from the tidal waters similar to those for the lower King tributaries. These were electrofished in March 1996. Following electrofishing of these streams, all of which had low gradient habitats typified by sand beds and high densities of woody debris, it was decided to survey additional relevant control sites with higher gradients and gravel-cobble beds similar to those of the lower King River tributaries. Three streams flowing into the lower Gordon River were therefore also surveyed in May 1996.

Between 50 and 200 m were electrofished at each site, depending on stream conditions, with two passes. All captured fish were measured, and a small sample (approx 2 per age class) of fish was kept (preserved in 90% ethanol following anaesthesia in benzocaine-water) for later age analysis. These fish were dissected in the laboratory and the otoliths removed following a dorso-ventral incision along the midline of the head.

Fish ages were determined by a combination of cutting and heating of the otoliths over a candle flame, or by embedding and sectioning, and observation under a stereo-microscope. Ages were checked using length-frequency histograms for the entire population sampled at the site.

c) Survey of the King River and related streams: Large rivers A survey was also conducted of fish populations in the lower King and Henty Rivers. A Smith-Root® electroshocking boat, manned with two operators, was operated in the lower King River between the delta and Teepookana (table 3) over a 7 km distance for a 2 hr period (comprising 1.9 hr generator operation and 3291 sec shock time) on 12 March 1996. This operation was repeated in the lower Henty River between the Queenstown-Zeehan Bridge and a position 0.9 km upstream (table 3), over an a 1.7 hr period (comprising 1.7 hr generator operation and 1344 sec shock time) on 13 March 1996. The shocker was operated at 1000 volts with 60 pulses/sec and 4.5–5 amp output. All fish observed were identified and recorded. A sub-sample of fish caught in the Henty River was collected, anaesthetised with MS222, and measured prior to release.

3.1.2 Data analysis

RAP sampling

a) Macroinvertebrate community composition The following data were derived from all RAP macroinvertebrate samples: total abundance, abundance of each taxon and number of taxa.

Each of the four seasonal data sets was screened for rare taxa by removing all taxa that occurred at 10% or less of sites. The data were then ln(x+1) transformed. Following this, a Bray Curtis dissimilarity site x site matrix was developed for all sites using the ASO routine in the PATN statistical package (Belbin 1993). The Bray Curtis dissimilarity index is defined as follows:

$$\sum(| x_i - y_i |) \ / \ \sum(x_i + y_i)$$

where xi and yi are the abundances of taxon i in sites x and $^{i=1 \text{ to } k}$ y, and k = total number of taxa at the sites.

This index gives an unweighted measure of the dissimilarity of community composition between two sites. It is zero if the sites are identical and 1.0 if the sites are completely dissimilar.

The matrix was then used to develop a nonlinear hybrid multidimensional scaling ordination (NLHMDS) ordination of each RAP data set using the SSH routine in PATN.

b) Relationships between community composition and environmental variables All environmental data were entered onto Excel® spreadsheets and transformed as indicated in table 4. Transformations of environmental variables were selected following inspection of normal probability plots for each variable. Relationships between the mean number of taxa and total abundance collected over the four sampling seasons and the mean value of each of the environmental variables at each site were examined by linear regression using the SYSTAT® statistical analysis package (Wilkinson et al 1992).

Development of RIVPACS models

RIVPACS models were developed (as described by Moss et al 1987, Wright et al 1989 and Wright 1995) for the spring data set only (due to time and resource constraints). The procedure used is illustrated in fig 3, and is described as follows:

a) Preparation of data sets The spring reference site data set was screened for rare taxa by removing all records of taxa that occurred at only one site. This was a less stringent criterion than used in the exploratory analyses above due to the smaller number of sites in the reference site data set.

The data set was then transformed to presence/absence data using the TRND routine in PATN and a Bray Curtis dissimilarity matrix developed from these data using ASO in PATN.

b) Ordination and classification NLHMDS ordination and UPGMA classification (using FUSE in PATN) were performed on the Bray Curtis dissimilarity matrices.

A subset of environmental variables was selected (the 'reference' environmental variables, see table 2) for the analysis of the relationships between site ordination scores and classification groupings and environmental data. No water quality data were included, to avoid confounding of predictions due to changes in water quality variables resulting from AMD.

The NLHMDS site ordination dimension scores were correlated with the reference environmental variables using the PCC subroutine in PATN. The significance of the correlation coefficient derived from PCC was tested by performing 100 Monte Carlo randomisations of the data set (Faith & Norris 1989, Belbin 1993) using the PATN MCAO sub routine. If the coefficients were higher than the top 5% or 1% of those derived for the MCAO simulated data, they were considered to be significant at the $\alpha = 0.05$ or 0.01 levels, respectively.

c) Identification of site groups Inspection of the UPGMA classification dendrogram and the NLHMDS ordination allowed identification of site groupings. This was assisted by developing a two-way table of site by species occurrences (using GDEF and TWAY in PATN) and relating group identity to taxon presences.

d) Discriminant analysis The reference site biological data, to which site group identifiers were added, were analysed in conjunction with the reference environmental data by stepwise discriminant function analysis (with a $p < 0.15$ acceptance criterion) using STEPDISC and DISCRIM in the SAS® statistical package. The overall canonical correlation coefficient, Pillai's trace and Wilks' lambda were calculated to ascertain the degree of discrimination provided by the final choice of environmental variables. Group assignment of individual reference sites was also checked to ascertain a misclassification rate. A rate of <35% was considered acceptable (as used in the National River Health Program, R Norris, CRC for Freshwater Ecology, pers comm).

e) Model construction A final RIVPACS model was developed for the spring data, as described by Moss et al (1987), using modifications of SAS® routines developed by R Norris, CRC for Freshwater Ecology (pers comm).

f) Model use—assessment of Mount Lyell monitoring sites Biological and environmental data from the 12 monitoring sites (see table 1) were entered into the spring model. Ratios of the number of observed over expected taxa were calculated for those taxa with a >50% predicted occurrence probability (O/E50 values).

Table 4 Data transformations applied for the analysis of Mt Lyell RAP biological and environmental data

Transformation	Variables
	Biological variables
Presence/absence	Spring RAP data used in developing MLRIVPACS model
ln (x+1)	Macroinvertebrate RAP abundance data for other exploratory RAP data analyses
	Environmental variables
None	Easting, northing, stream order, flow, clarity, max and min stream velocity, riparian vegetation characteristics, stream depth and width.
ln (x+1)	Elevation, slope, distance from source, catchment area, conductivity.
arcsine(√x)	% bedrock, boulder, cobble, pebble, gravel, sand, silt substrate; % detritus, moss and algal cover; % riffle, pool and snag in reach.

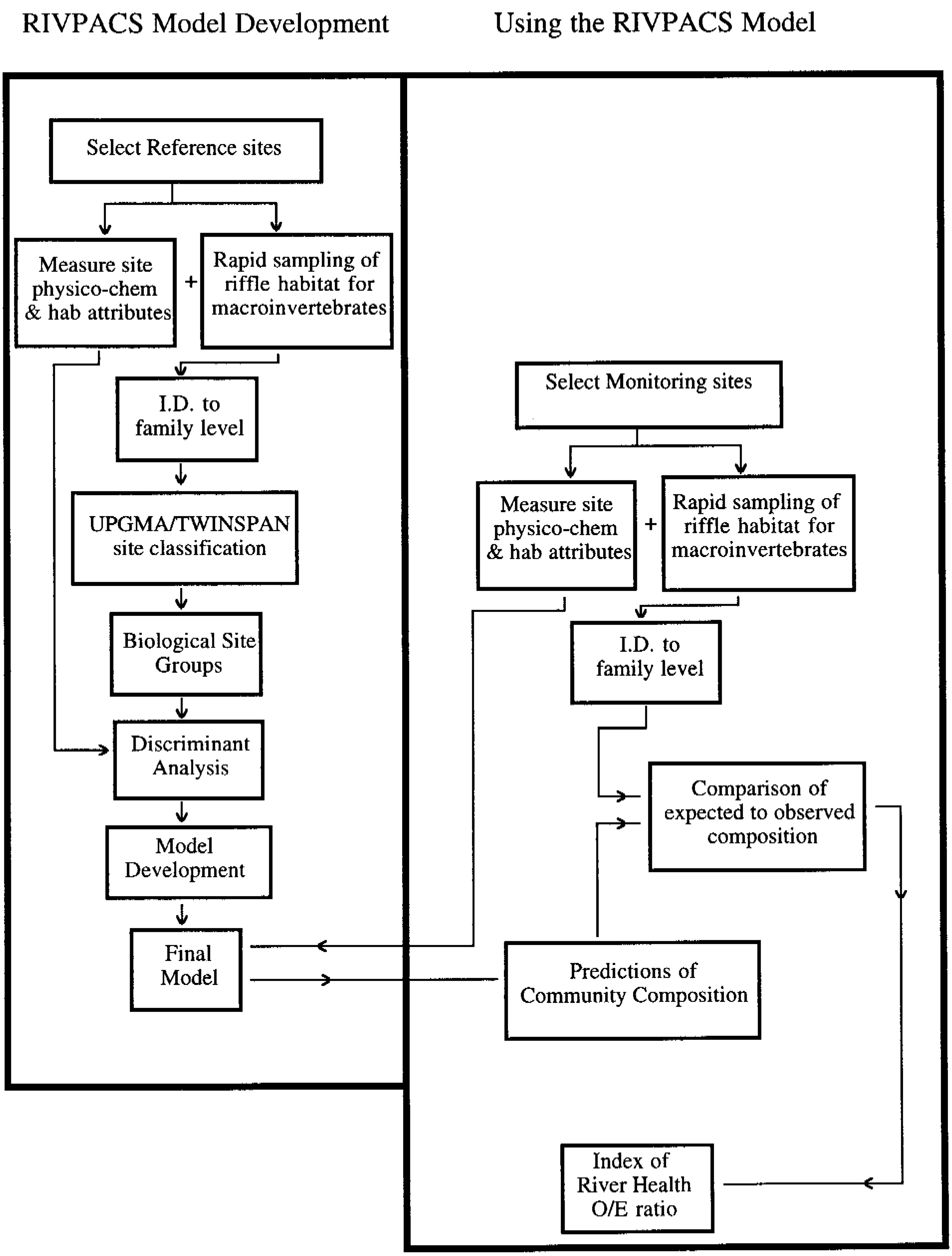


Figure 3 River invertebrate prediction and classification scheme (RIVPACS): model development and use

Analyses based on RIVPACS-style analyses use an index based on the number of taxa that are found at a particular monitoring site (the observed number of taxa) compared with the number of taxa that could be expected at that site based on which group of reference sites the monitoring site should belong to as judged by its environmental attributes. This index is referred to as the O/E ('O over E' or 'observed over expected'). In formulaic terms:

O/E = (Observed number of taxa)/(Expected number of taxa)

In practice, few monitoring sites belong unequivocally to one group of reference sites. Classification of a monitoring site using the discriminant functions based on the environmental data gives a series of probabilities of the monitoring site belonging to each group of reference sites. Accordingly, *E*, the expected number of taxa is better calculated as the sum of the probabilities of finding that taxon in each group weighted by the probability of the monitoring site belonging to each group (Moss et al 1987). This is best illustrated by the following example. Suppose the reference sites form 3 groups based on their faunal attributes, and suppose further that a monitoring site has been sampled and its environmental attributes substituted into the discriminant functions to yield the probability of this monitoring site belonging to each of the groups of reference sites. E_t, the number of taxa expected to occur at this site is calculated according to the procedure outlined in table 5.

Table 5 Worked example of computing p_i the combined, weighted probability of $taxon_i$ occurring at a monitoring site, and E_t, the expected number of taxa at the site (= sum of all these weighted probabilities)

Group	Probability that monitoring site belongs to group	Frequency of $taxon_i$ in the group	Contribution to the probability that $taxon_i$ will occur at the monitoring site
A	0.50	0.75	0.3750
B	0.35	0.60	0.2100
C	0.15	0.35	0.0525
Combined probability that $taxon_i$ will occur at monitoring site			0.6375

Note: Group refers to the group defined by the reference sites. *Probability that monitoring site belongs to a group* refers to the probability of allocating a monitoring site to each group of reference sites based on the discriminant analysis of the environmental attributes of the monitoring site. *Frequency of $taxon_i$ in the group* is computed by counting the number of times a taxon is found in the reference sites within a group and expressed as a proportion; eg a value of 0.75 shows that the taxon was present in 75% of the reference sites in the group. *Contribution to the probability that $taxon_i$ will occur at the monitoring site* is the weighted probability of finding that taxon in the site and is computed by multiplying the values of the previous two columns together. The probability of occurrence of this taxon at this site is then given by the sum of the values in the right-most column, ie *the combined probability that $taxon_i$ will occur at the monitoring site*. Thus let p_i denote this combined, weighted probability of $taxon_i$ occurring at the monitoring site, then E_t, the expected number of taxa at the site will be the sum of all these weighted probabilities, ie $E_t = \Sigma p_i$ (modified after Institute of Freshwater Ecology 1991, p 17).

Thus the index O/E is now computed as:

$$O/E = O/E_t$$

A further refinement of the index has been to restrict the number of taxa that enter the calculation to those with a reasonably high expectation of occurrence. Taxa with low values of E_t could reasonably be presumed to be chance occurrences in a sampling event. Two thresholds have been proposed (Moss et al 1987): $E_t \geq 0.5$ and $E_t \geq 0.7$, with 0.5 being applied in the present study so as to include a wider range of taxa in site assessment.

In summary, small values of O/E_t indicate impact, values close to 1 indicate the monitoring site has as many taxa as would be expected for that site based on reference conditions, while values >>1 may indicate exceptional sites worthy of special conservation management (Moss et al 1987).

In theory O/E should obtain a maximum value of 1, while values substantially <1 should indicate impact.

Taxon richness varies from site to site within a given group; since the comparison of a new site is being made with the expectation for the *average* of the reference sites within a group, an unusually rich site may achieve O/E>1. Elevated richness may result from environmental factors other than those used to make the prediction. Therefore, on internal tests of validity, (ie using the reference sites themselves) there will be a distribution of O/E values centred on 1. High O/E values for external tests (ie new sites) can indicate taxon-rich sites of potentially high conservation value provided the prediction is valid (Institute of Freshwater Ecology 1991, 18).

Reference sites with low O/E ratios are possibly sites of low quality that could bias estimates of true O/E values for groups (Institute of Freshwater Ecology 1991, 18).

Variations in sampling effort, especially the inclusion or exclusion of habitats under the RIVPACS system, or in sorting intensity, could result in unusually high or low values (Institute of Freshwater Ecology 1991, 19). The former is less of a problem with the Australian Rapid Assessment Protocol (RAP) implemented under National River Health Program (Davies 1994) because habitat information has been kept separate, with standardised methods employed in each.

O/E_t is a continuous measure with a minimum value of 0 and a maximum value of at least 1. In terms of deciding whether a site has been impacted, this continuous scale needs to be divided into categories or bands. The approach adopted here follows that used by RIVPACS II to arrive at a provisional banding of values based on the data themselves (Institute of Freshwater Ecology 1991, 17–18). This method uses a randomisation technique to generate 1000 random samples in a computer where the species composition of each of those samples is based on the expected probabilities, p_i, of the taxa in the monitoring site. This is done by generating a random number between 0 and 1 for each taxon in each randomisation and recording that taxon as present in the sample if $p_i \geq$ random number. The number of taxa for each of the 1000 samples are tallied and the mean number of taxa and the standard deviation, s, recorded. Thus 95% confidence limits for E_t are approximately the mean ± 2s; this specifies the expected variation in E_t, the expected number of taxa for that monitoring site.

The degree of impact observed at a site is assessed by comparing its O/E value with several O/E 'bands' derived by the above procedure. The lower bound of the top or highest quality band or category (Band I) is given by the mean E_t -2s; subsequent bands (Bands II–IV) are given by subtracting additional increments of 2s from the mean E_t., as follows:

Band	Description	No of SDs from mean
I	Unimpacted	± 2
II	Mildly impacted	-4 to -2
III	Heavily impacted	-6 to -4
IV	Extremely impacted	> -6

These bands were used to assign the degree of impact on the biota of the monitoring sites listed in table 1, including King River 1 and Comstock Ck 2. Lists of taxa predicted and observed of each of the 12 monitoring sites were also developed to illustrate the nature of the impact.

Analysis of quantitative data

Spring Surber sampling data from three sites (Nelson and Governor Rivers and Comstock Creek 4) were used to determine the number of sample units required for:

- obtaining a representative estimate of the total density and number of taxa of macro-invertebrates within sites and of community similarity (between sites); and
- detecting changes in abundance and number of taxa of known magnitudes.

a) Representative samples Plots were generated of mean density and total number of taxa against number of Surber sample units for each of the three sites. A randomly selected series of Surber sample units were used to calculate cumulative mean density and cumulative number of taxa for 1 to 20 Surber units. This was repeated five times for each data set, and the results averaged.

Plots of cumulative Bray Curtis dissimilarity were also generated for the three paired combinations of quantitatively sampled sites (Nelson-Governor, Nelson-Comstock 4, Comstock 4-Governor). Thus, a series of Surbers was chosen randomly from each of two sites and a cumulative Bray Curtis dissimilarity calculated for an increasing number of Surber samples from 1 to 20. The number of sample units was considered satisfactory when the Bray Curtis dissimilarity fell within 0.1 of that value found for 20 Surber samples. The value for 20 Surber sample units was used as the best estimate of the 'true value'.

b) Detecting changes of a given magnitude The spring Surber data were also subjected to power analyses for abundance and number of taxa according to the method described by Sokal & Rohlf (1981), and enlarged on by Norris et al (1993). Thus, the following equation was used to calculate N (the minimum number of sample units):

$$N = 2(s/d)^2 * \{t_{\alpha[n]} + t_{2(1-p)[n]}\}^2$$

where: s = true standard deviation (calculated from 20 samples); d = difference between means expressed as a percent of Y, eg = 20 for a 20% difference between means; p = desired probability that a difference is found to be significant; n = degrees of freedom of the sample standard deviation with a groups and m replications per group; $t_{\alpha[n]}$ and $t_{2(1-p)[n]}$ = values from a Student's t table with degrees of freedom and corresponding to probabilities of α and 2(1 - p), respectively.

Plots of percentage change in abundance and diversity detected at given levels of α and β (= 1 - p), ie with given Type I and Type II error rates, were generated for each of the Nelson and Governor River and Comstock Site 4 Surber data sets.

QA/QC

a) Live picking representativeness In order to generate data representative of a preserved and sub-sampled kick sample, live pick data for each site were combined with residue data as follows.

The data from each of the spring RAP live pick samples were randomly sampled, using an Excel® macro developed by C Walsh (CRC for Freshwater Ecology, Water Studies Centre, pers comm) which randomly re-samples a list of taxa to a prescribed level of subsampling. These data were then added to the data from the corresponding 20% sub-sampled residues. The resulting 'whole kick' data were analysed to determine total abundance and number of taxa for each site. A plot of abundance in 'whole kick' samples against those in the live pick samples for the same sites were generated and correlations between the two sets of values examined. A plot of the number of taxa in 'whole kick' samples against those in the live pick samples for the same sites was also generated after re-scaling the 'whole kick' sample data to the same abundance as the corresponding live pick sample (using the Excel® macro mentioned above), and correlations between the two sets of values examined.

Bray Curtis dissimilarity values were also calculated for each pair of live pick and 'whole kicks' using both rank abundance and presence/absence data for the following 14 spring reference sites (Mount Owen, Henty, Halls, Governor, South Eldon, Eldon, Pearl, Newall, Comstock Ck 2, Nelson, King 1, Princess, Yolande, West Queen). The latter were calculated after re-scaling the abundances of the 'whole kick' sample to that of the live pick.

Rank correlations (using Spearman's Rho, ρ) were performed for all 14 sample pairs, to test the agreement of family level rank abundances from live pick and 'whole kick' samples.

b) Site representativeness All presence/absence data from the five streams RAP sampled at three separate riffles were used to derive a single UPGMA classification. Single riffles were considered representative of a river if they were all classified within a single group for that river. One-way analysis of variance was also performed on the Bray Curtis dissimilarities for the samples paired by riffle, with river as treatment.

c) Operator comparability Operator consistency (the person performing the kick sampling and live-picking) was assessed comparatively in three ways. Non parametric paired Wilcoxon (signed rank) tests were conducted on both abundance and number of taxa using SYSTAT®, for each set of paired sampling (L Cook vs J Jackson, L Cook vs W Elvey, and L Cook vs N Mitchell).

Rank correlations (using Spearman's Rho) were performed for all 24 sample pairs to test the agreement of family level ranks between samples collected by different operators at the same riffle.

Bray Curtis dissimilarities were calculated for all 24 sample pairs, with data transformed to presence/absence. Mean values were compared with those average dissimilarities used to differentiate rivers in the UPGMA clustering of riffle (above) and to differentiate site groups in the spring MLRIVPACS model.

The significance of inter-operator differences in relation to biological site classifications was also explored qualitatively by combining all the parallel pick data with the multiple riffle data in a single UPGMA classification (based on Bray Curtis dissimilarities derived using presence/ absence data). The acceptance criterion for operator comparability was the absence of misclassification of a riffle sample from a river's group as defined in the UPGMA dendrogram.

3.2 Water quality monitoring

3.2.1 Data acquisition

The only new water quality data derived in the course of this project were those collected on each RAP sampling occasion. This represents four sample sets collected from 28–32 sites. Analytes are listed in table 2.

Several other data sets were examined. A full listing of data sets relevant to the Mount Lyell region is presented in McQuade et al (1995). Data sets analysed in more detail, obtained from the HEC, DELM or RGC are as follows:

- Water quality and flow data for King River MLMRCL sites 29 and 14 (all of record pre-MLMRCL mine closure). These raw data sets consist of single daily samples of dissolved Cu, Mn, Fe and Al, and either hourly or mean daily discharge at the King River below Queen junction;
- Water quality and flow data for the King River at DELM site 18 (Koehnken unpub data), and the Queen River at Lynchford (all post-MLMRCL mine closure). These raw data sets consist of four-hourly samples of dissolved Cu, Mn, Fe and Al and either hourly or mean daily discharge.

3.2.2 Data analysis

Water quality data were analysed for three reasons:

- to assess the general properties of the data (particularly relationships between water quality variables and with flow and time) as an aid in formulation of a water quality monitoring program;
- to assist in assessing the nature of relationships between fish and macroinvertebrate community/populations and water quality; and
- to assess appropriate sampling frequencies.

Relationships between water quality variables and between water quality and biological variables were examined graphically and by correlation and regression for the combined data set of all water quality data collected during the RAP macroinvertebrate sampling program.

Relationships amongst water quality variables and between the variables and discharge were examined for all data collected in the lower King River (MLMRCL site 29, DELM site 18), separately for the periods 8/1/91–19/12/94 and 12/12/94–16/4/95 (pre- and post- MLMRCL mine closure, respectively).

In order to assess suitable sampling frequencies for King and Queen River waters under post-MLMRCL mine closure conditions, the data collected by Koehnken (DELM, unpub data) were analysed to develop a relationship between mean, median and standard deviation Cu, Mn, Fe and Al concentrations, and sampling frequency. Thus, the site 18 data set was reduced to a set containing only records in which four hourly sampling (at 0000, 0400, 0800, 1200, 1600, 2200) had occurred on each day of record (a total of 714 records per analyte). Means, medians and standard deviations were calculated from combinations of the data sampled at four hour intervals (ie all data) as well as 12 hour, 24, 48 and 96 hour and 8 day and 16 day intervals. Sampling times in each period were *fixed* (ie sampling at the same time of day). This analysis was repeated with *random* sampling times with respect to time of day. The means, medians and standard deviation for each analyte were plotted against sampling frequency for both analyses.

A similar process was used to derive plots of mean, median and standard deviations of the same analytes against sampling frequency for the Queen River @ Lynchford data. The raw DELM data set was also reduced to include only those data for which four hourly sampling had occurred on each day of record (a total of 102 records per analyte, except Al for which n = 54) and the means, medians and standard deviations calculated for four hourly, 12 hourly and daily sampling. A second reduced set of data was produced containing only a single record per day (total of 86 records per analyte) and means, medians and standard deviations calculated for sampling at 1, 2, 4, 8 and 16 day intervals.

4 Results

4.1 Biological health

4.1.1 Macroinvertebrates

RAP sampling

Sampling of riffle fauna was successfully conducted as described in the Methods. Two attempts to repeat the autumn sampling (April-May 1996) of sites in the Gordon, Franklin and Jane Rivers were unsuccessful due to high river levels and poor weather conditions. All environmental data (physical habitat and site variables) collected for each site on each sampling occasion are shown in appendix 1.

Macroinvertbrate abundance data derived from the RAP sampling of all sites are attached in appendix 2. Total abundance and number of taxa are shown for all site riffles and sampling occasions in table 6. Abundances and number of taxa for all four sampling events are displayed graphically in figs 4 to 7 for all sites. The total number of aquatic taxa identified at 'family' level from the RAP samples during the study was 85. The mean number of taxa per site over all sampling occasions ranged between 14 and 24 for reference sites and 3 and 7 for AMD-affected monitoring sites. Only 2 samples contained no fauna. Thus, all sites supported some fauna, even in the heavily polluted Queen and King Rivers and in Comstock and Linda Creeks.

Figures 8 and 9 illustrate the fauna typical of the unpolluted sites in the Mount Lyell region contrasted with the fauna typical of the AMD polluted streams. The latter streams were typified by low abundances of oligochaetes (worms), chironomids (midges) and scirtid beetle larvae, with the addition of other fauna at downstream sites which experience greater dilution of AMD-associated pollutants.

Results of NLHMDS ordination and UPGMA classification indicated the presence of two primary groups of sites based on their macroinvertebrate community composition (figs 10 and 11). These groups corresponded with the two groups of reference and monitoring sites designated at the commencement of the study, with the exception of Comstock 2 and King 1. All sites in group A in the ordination plots (see fig 10) had conductivities > 100 µS/cm on all four sampling occasions and had low numbers of taxa.

Development of RIVPACS models

a) Ordination and classification of reference sites The UPGMA classification dendrogram of the spring presence/absence data is shown in fig 12. Four site groups were identified. A two way table for this analysis is shown in fig 13. Five taxonomic associations were identified. Site group 1 comprised four sites, all of which were smaller streams with high gradients, but with little overhanging riparian vegetation, in the upper Queen, Linda and Yolande catchments. They were differentiated from other sites by having relatively depauperate faunas (fig 13) with low occurrences of oligochaetes, podonimine and chironomine chironomids, philorheithrids, austroperlids and taxa in associations four and five.

Group 2 comprised the 10 larger river reference sites outside the lower Franklin-Gordon catchments as well as several smaller streams in the King drainage. They were characterised by having numerous occurrences of taxa in association three (austroperlids, tipulids, philorheithrids, blepharocerids, notonemurids, scirtids – see fig 13).

Group 3 comprised seven larger river sites in the Franklin and lower Gordon Rivers. They were characterised by having poor representation of both faunal associations three and four (fig 13). One, site, Franklin River 1 (also known as G18), had an anomalously low number of taxa (and abundance) but was still clustered in this site group.

Group 4 comprised six sites from small creeks in the Queen River valley, as well as upper Comstock Creek. These were characterised by high incidences of group four fauna, but low occurrences of group three fauna. These were high gradient streams with heavy riparian shading.

Principal axis correlation (PCC and MCAO in PATN) was used to select a subset of environmental variables that correlated significantly with site group positions in ordination space (see table 2). Thus, for the spring data, the following variables were significantly correlated and were used in the discriminant analysis: slope, elevation, stream order, distance from source, catchment size, % cobble, pebble and silt substrate, algal and moss cover, stream width, ranked conductivity, % riffle, pool and snag.

Table 6 Number of taxa and total abundance for macroinvertebrates derived from live-picked RAP samples from all sites sampled in the Mount Lyell region in 1995/96

		Number of taxa					Total abundance				
Site	Type	Winter	Spring	Summer	Autumn	Mean	Winter	Spring	Summer	Autumn	Mean
Cardigan R	R		17	20	17	18.00		182	162	188	177.33
Collingwood R	R		17	19	13	16.33		310	206	188	234.67
Comstock Ck 1	R	18	19	24	19	20.00	138	279	234	231	220.50
Conglomerate Ck	R	10	12	16	16	13.50	198	152	177	154	170.25
Crotty R	R		20	20	11	17.00		204	167	149	173.33
East Queen R1	R	14	10	22	21	16.75	58	59	114	158	97.25
Eldon R	R	16	14	21	12	15.75	151	188	288	224	212.75
Franklin R 1	R		4					37			
Franklin R 2	R		9					73			
Franklin R 3	R		13					172			
Gordon R 1	R		12					92			
Gordon R 2	R		8					205			
Gordon R 3	R		9					59			
Governor R	R	13	16	25	14	17.00	105	185	198	149	159.25
Halls Ck	R	11	16	19	20	16.50	53	115	105	203	119.00
Henty R	R	15	26	21	23	21.25	161	192	221	160	183.50
Jane R 1	R		11					269			
Lynchs Ck	R		18	20	17	18.33		164	257	205	208.67
Mt Owen Ck	R	10	13	23	14	15.00	93	121	166	124	126.00
Nelson R	R	9	19	10	17	13.75	117	161	133	231	160.50
Newall Ck	R	19	18	25	20	20.50	213	175	237	273	224.50
Pearl Ck	R	13	18	19	18	17.00	213	251	168	171	200.75
Princess Ck	R	15	17	17	22	17.75	170	85	205	193	163.25
South Eldon R	R	10	20	24	14	17.00	114	134	205	171	156.00
Township Ck	R		25	26	21	24.00		257	228	224	236.33
West Queen R	R	21	22	25	25	23.25	262	222	244	198	231.50
Yolande R	R	13	10	20	19	15.50	80	103	173	207	140.75
Comstock Ck 2	M/R	16	14	16	20	16.50	267	176	120	233	199.00
King R 1	M/R	8	12	17	9	11.50	131	195	243	82	162.75
Comstock Ck 3	M	0	3	5	5	3.25	0	3	8	9	5.00
Comstock Ck 4	M	3	8	0	8	4.75	8	52	0	10	17.50
East Queen R 2	M	1	4	8	6	4.75	2	8	16	8	8.50
East Queen R 3	M	6	1	6	5	4.50	16	1	14	9	10.00
King R 2	M	1	1	8	3	3.25	11	1	15	3	7.50
King R 3	M	4	1	6	9	5.00	13	1	8	17	9.75
Linda Ck	M	7	7	3	12	7.25	18	10	5	22	13.75
Queen R 1	M	4	3	11	7	6.25	8	3	22	9	10.50
Queen R 2	M	4	6	11	4	6.25	17	10	21	4	13.00
Queen R 3	M	10					32				
Queen R 4	M	1	9	4	5	4.75	2	20	4	5	7.75

R = reference sites, M = monitoring sites

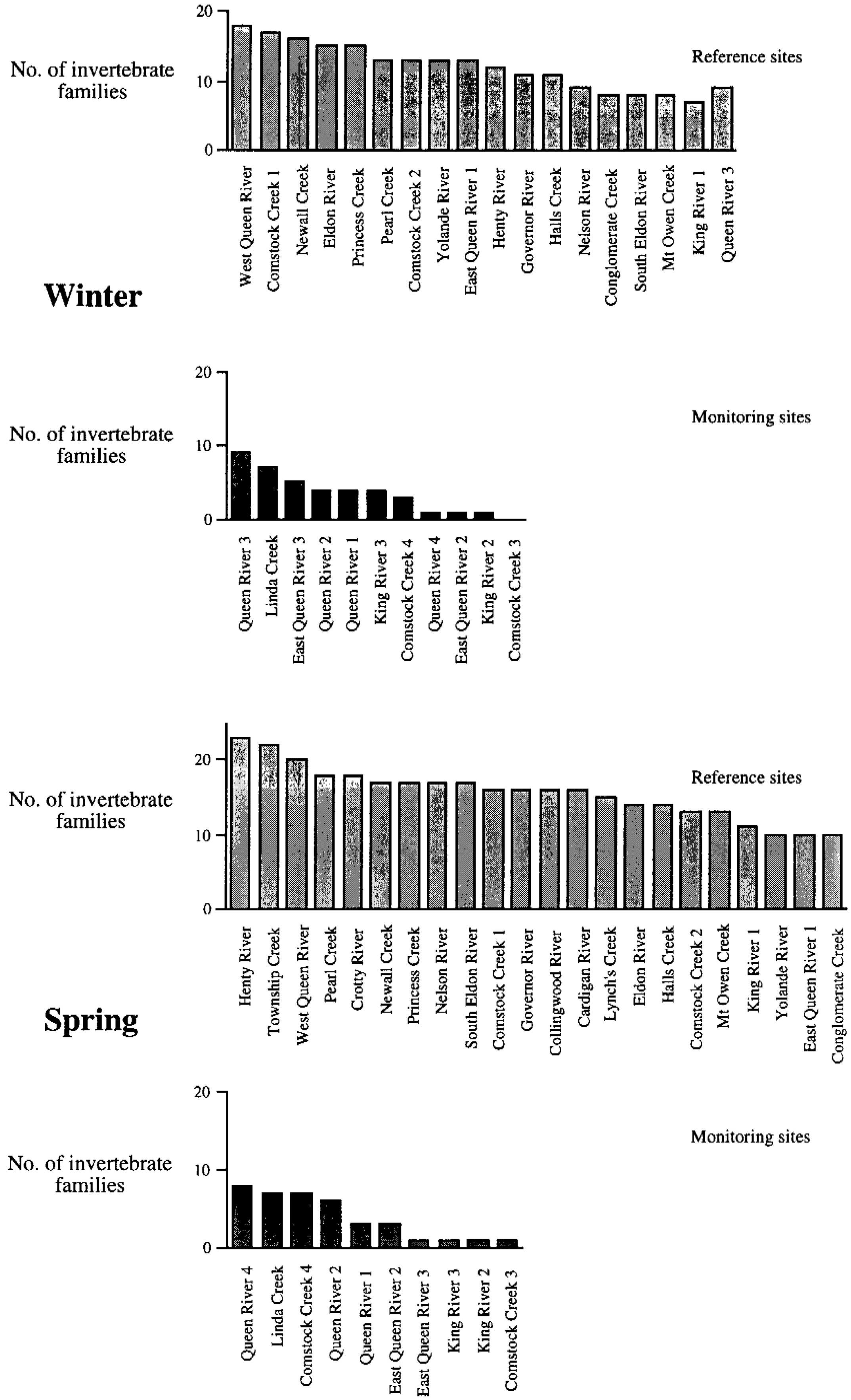


Figure 4 Number of macroinvertebrate taxa collected in riffle samples at RAP sampled reference and monitoring sites in winter and spring 1995

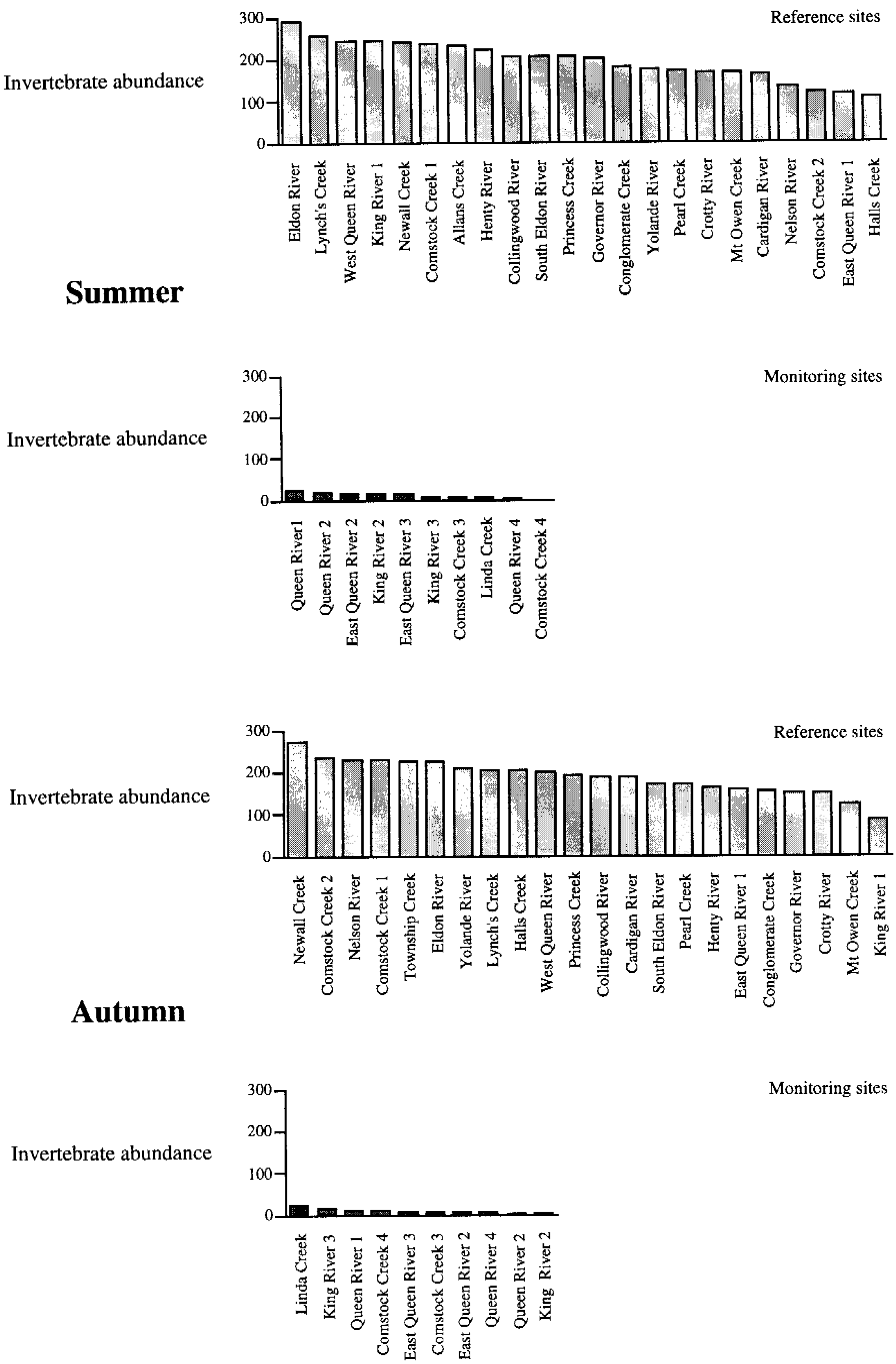


Figure 5 Number of macroinvertebrate taxa collected in riffle samples at RAP sampled reference and monitoring sites in summer and autumn 1996

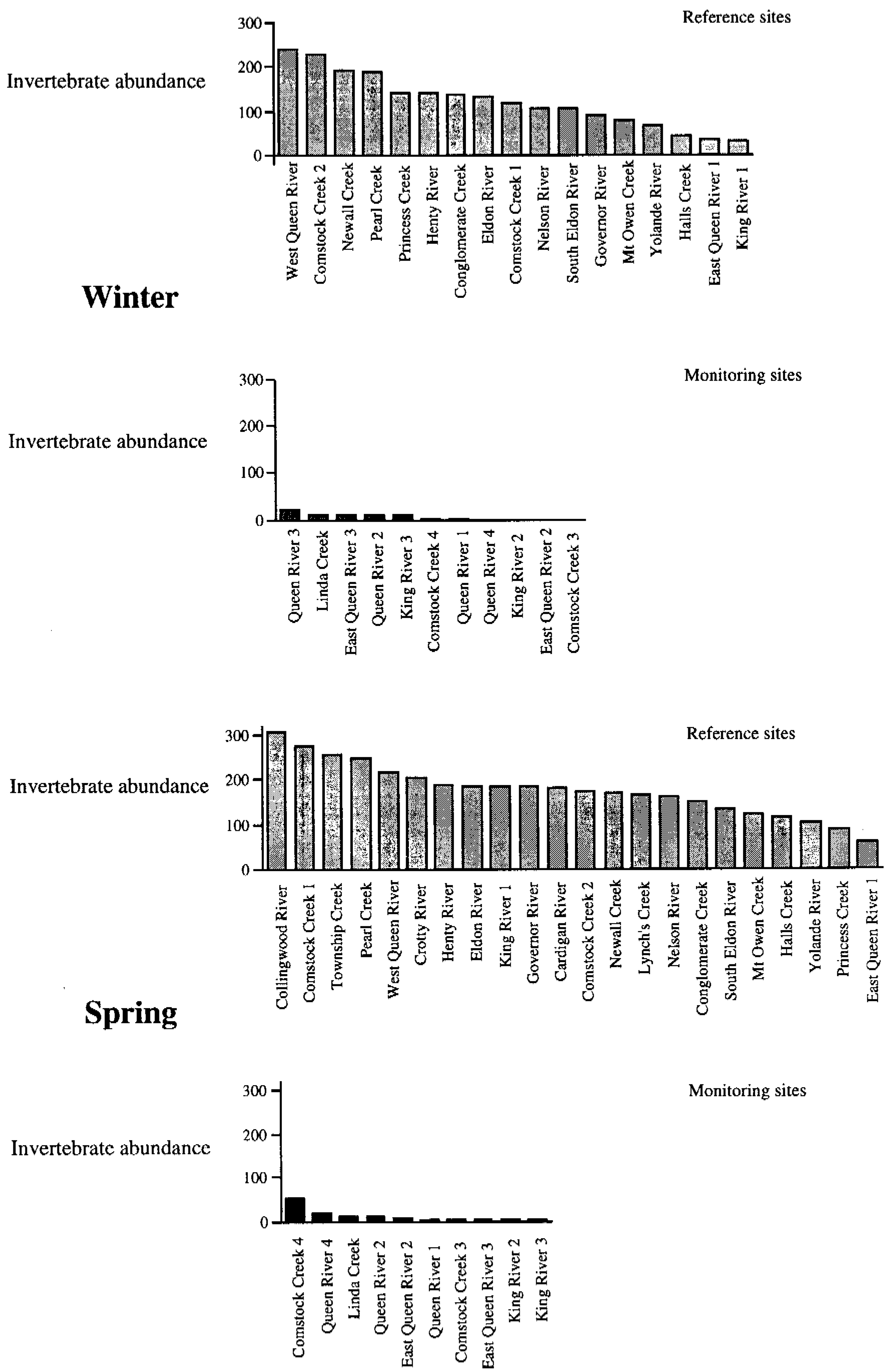


Figure 6 Abundance of macroinvertebrates collected in riffle samples at RAP sampled reference and monitoring sites in winter and spring 1995

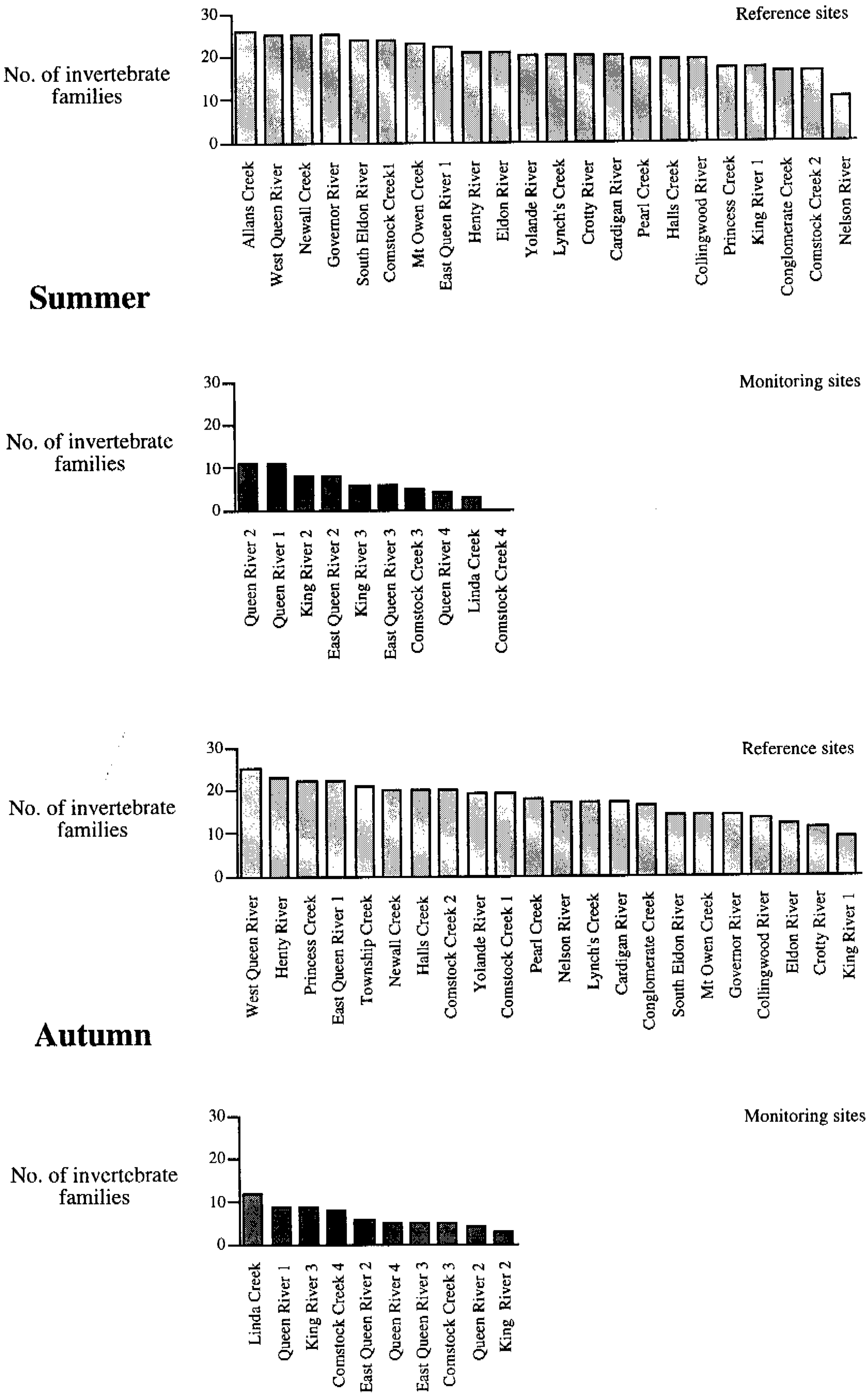


Figure 7 Abundance of macroinvertebrates collected in riffle samples at RAP sampled reference and monitoring sites in summer and autumn 1996

b) Discriminant analysis Results of the stepwise discriminant analyses for the spring data are shown in appendix 3. The environmental variables which best discriminated the four biological site groups, and therefore incorporated into the spring MLRIVPACS model were:

- elevation (ln(x+1) transformed)
- distance from source (ln(x+1) transformed)
- % moss cover of riffle substrate (arcsine √ transformed)
- % of site as snag habitat (arcsine √ transformed)

The discriminant function resulted in acceptable values of the canonical correlation coefficient, Wilks' lambda and Pillai's trace. Reference sites were misclassified at a rate of 18% (see appendix 3), much lower than the 35% criterion adopted by the National River Health Program.

c) Assessment of monitoring sites using the MLRIVPACS model Data from the 12 monitoring sites collected in spring were entered into the MLRIVPACS model and O/E50 ratios and their respective bands calculated. O/E50 values, bands and predicted taxa are shown for all 12 monitoring sites in tables 7 to 10.

All monitoring sites were classified as heavily or extremely disturbed, with the exception of King River 1 and Comstock Ck 2. These two sites had been classed as monitoring sites for the purposes of the MLRIVPACS modelling, due to the unknown level of impact from flow regulation and AMD, respectively. Comstock Ck 2 was assessed as being unimpacted by human activity, while King 1 was mildly impacted, presumably by the operations of the John Butters power station. This result justified the exclusion of King River 1 from the reference sites used to develop the MLRIVPACS model. All King River sites were assigned by the MLRIVPACS model most closely to Group 3 in the reference site groupings (Franklin, Gordon and Jane River sites) and the predicted fauna is therefore closely representative of the fauna of those river sites.

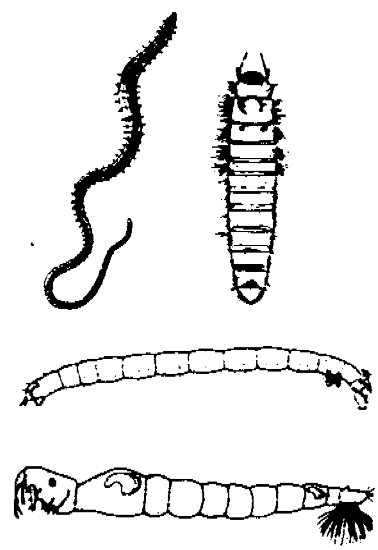


Figure 8 Typical macroinvertebrate taxa observed at AMD affected sites in the Mount Lyell area

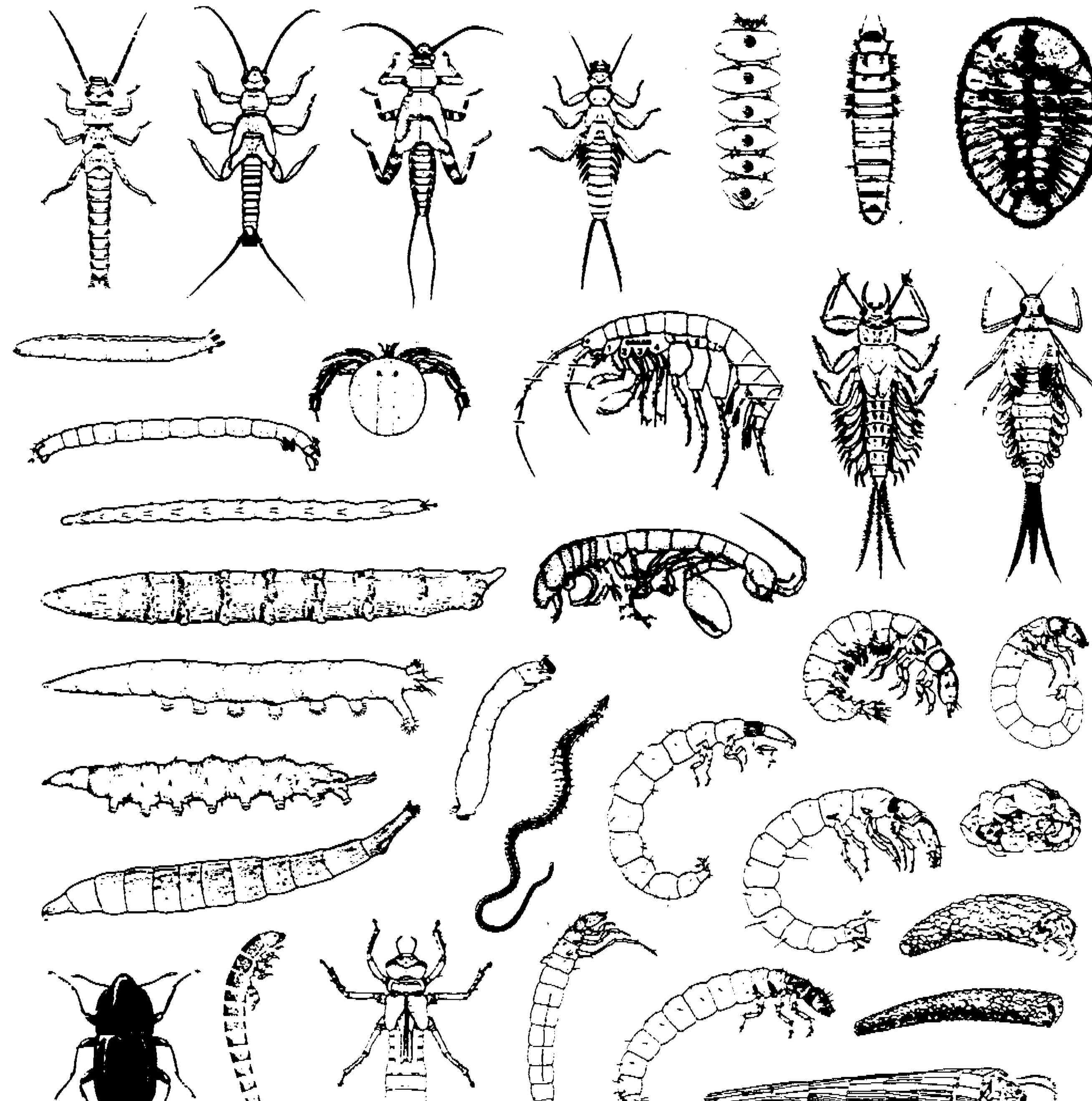


Figure 9 Typical macroinvertebrate taxa observed at reference sites in the Mount Lyell area

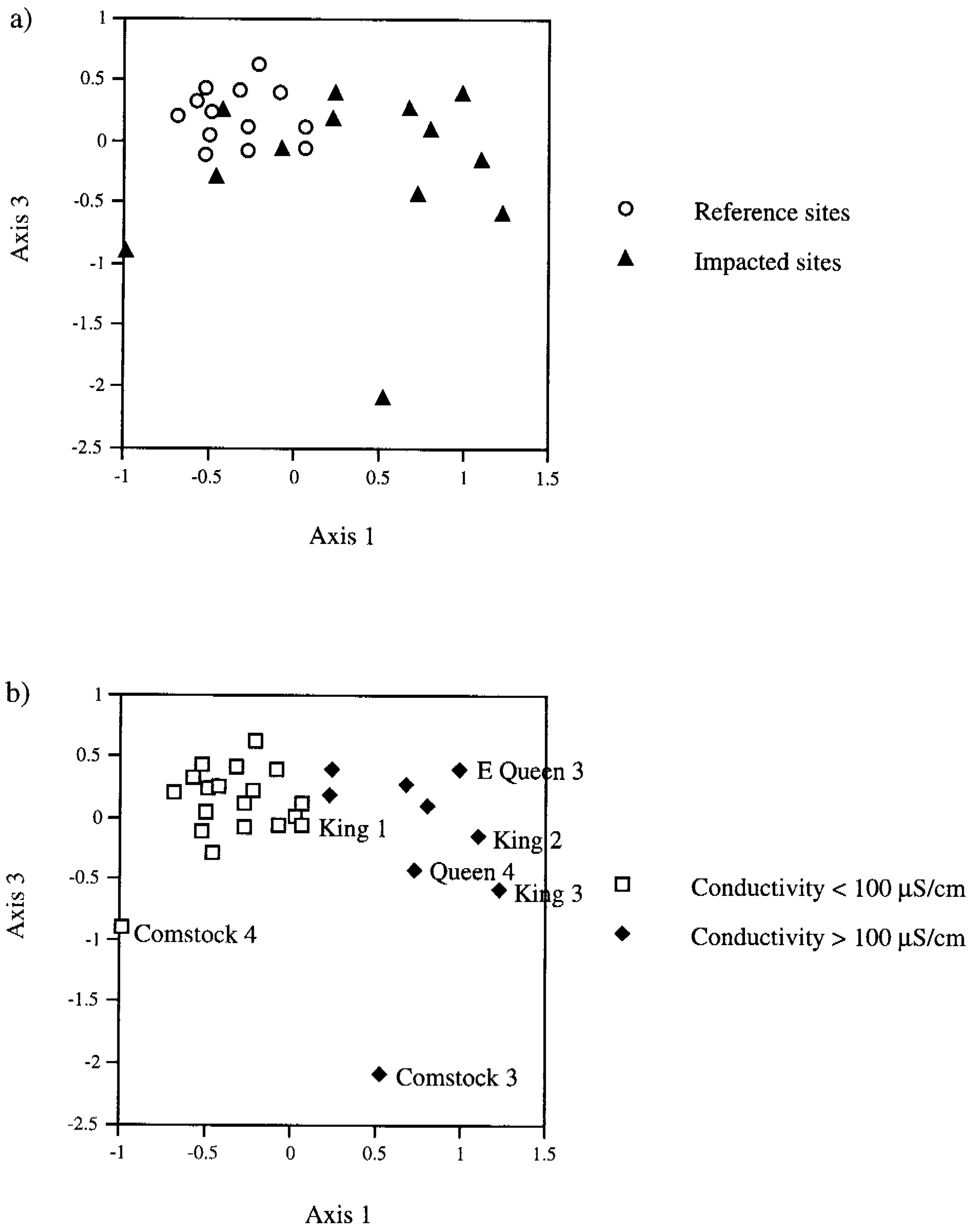


Figure 10 NLHMDS ordination plots of sites based on Bray Curtis dissimilarities of raw, ln(x+1) transformed winter invertebrate family data: a) identified as reference and monitoring sites, and b) grouped using water conductivity data

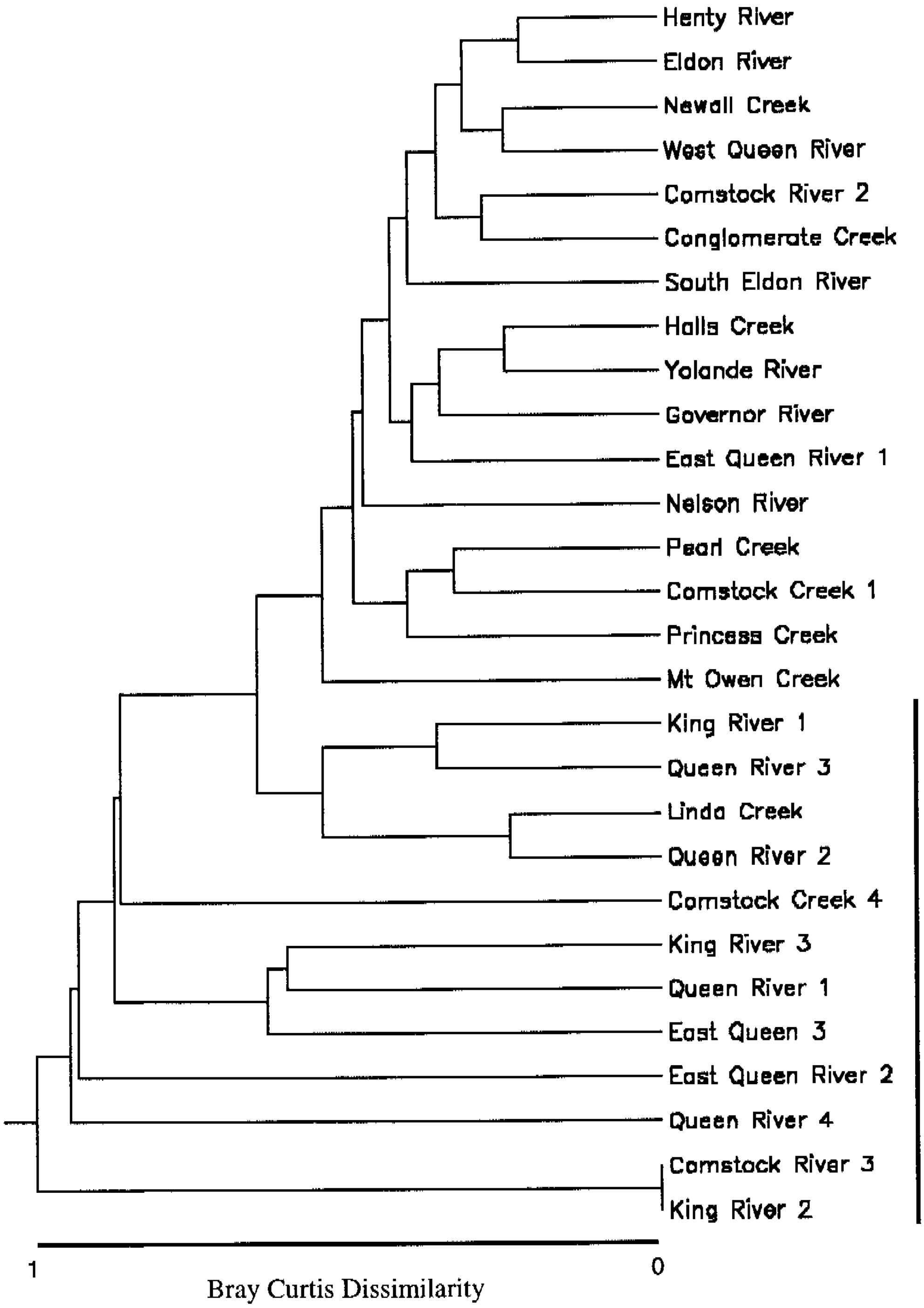


Figure 11 Dendrogram resulting from UPGMA classification (beta = -0.1) of stream sites sampled for macroinvertebrates in winter 1995. Bold vertical line indicates monitoring sites

Table 7 MLRIVPACS output for the 12 Mount Lyell region monitoring sites

Site name	NTE50 1	NTP50 2	NTC50 3	PPTE50 4	PTO50 5	OE50 6
COMSTTWO	8.48	11	10	77.06	90.91	1.18
COMSTHRE	7.79	10	1	77.91	10.00	0.13
QUENFOUR	9.56	12	5	79.63	41.67	0.52
LINDA	7.85	10	4	78.53	40.00	0.51
KINGTHRE	7.71	9	1	85.71	11.11	0.13
EQUENTWO	7.78	10	3	77.77	30.00	0.39
KINGONE	7.71	9	6	85.71	66.67	0.78
QUEENTWO	8.97	11	3	81.51	27.27	0.33
COMSTFOR	7.95	10	3	79.53	30.00	0.38
KINGTWO	7.71	9	0	85.65	0.00	0.00
QUEENONE	7.98	10	1	79.76	10.00	0.13
EQUENTHR	7.93	10	0	79.28	0.00	0.00

1 NTExx = no. of taxa expected with > = xx% chance of occurrence if site unimpacted. This is the sum of the weighted probability of occurrence of all taxa at that site.

2 NTPxx is the no. of taxa predicted at a site. Simply a sum of presences of all taxa with >xx% of occurrence at the site.

3 NTCxx is the no. of taxa counted at the test site that have a probability >xx% of occurring at that site.

4 PPTExx is % of predicted taxa expected (ie NTE/NTP). If this <<100% indicates taxa expected mostly have low probs of occurrence.

5 PTOxx is % of predicted taxa captured in test site (ie NTC/NTP).

6 OExx (observed/expected) = NTC/NTE.

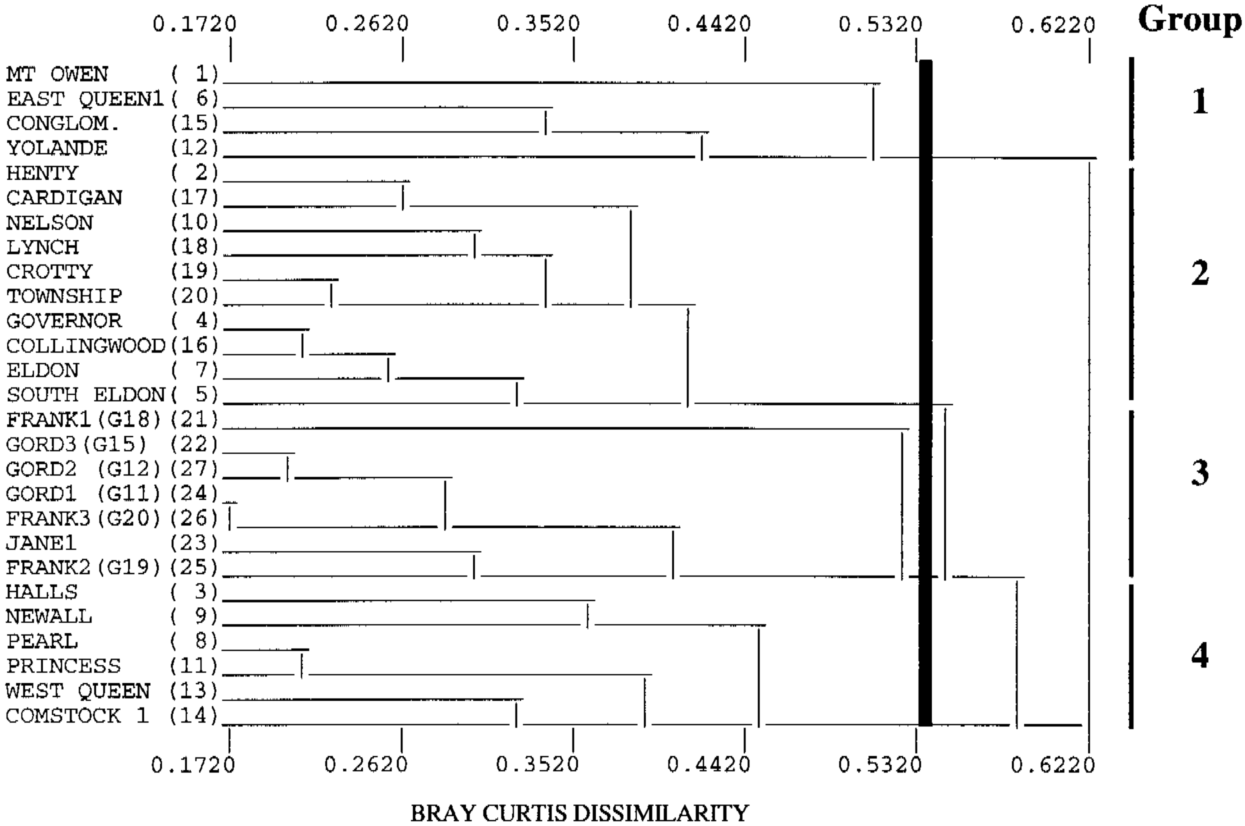


Figure 12 Dendrogram of UPGMA clustering of spring RAP data (as presence/absence and using a Bray Curtis dissimilarity matrix) for all reference sites only. Site names are listed on the left and are consistent with those listed in table 1. Sites that separate furthest to the right are the most dissimilar. Thick vertical line indicates the cutoff used to define the site groups for further analysis, and site group numbers are indicated on the right.

Faunal Associations

```
                        1         2            3        4        5
                     ______ ______________ _______ __________ _____

                                         Taxa

              NOEBD|OPSGHLOCECLALP|ATPBNSD|HHTATPAHPG|CHCHP
              EDMAI|LOIRYETHUOEDAH|UUHLOCU|YYATUAEESL|AEEYO
              MOPEA|IDMIDPHISNPTRI|SPIETIN|DDNHNRSLEO|LLRDL
              ANITM|GOUPRTORTOTEEL|TULPORI|RRYEIAHIPS|OIARY
              TTDIE|OMLOOOCOHEOLLO|RLOHNTD|AOPRDMNCHS|CCTOC
              OOADS|CIIPBPLNESCMMR|OIPEEIP|CPOIPEIOEO|IOOPE    Site
Sites         DCDAI|HNDTIHAONUEIIH|PDORMDU|ASDCULDPNM|DPPTN    Groups
              AR EN|    OLDM CRDDE|  T   P|RY  P  H  | SGIT

MTOWEN             |*  ** * ***   |  * ***| *        |    *    1
EAST Q 1           |  *****       |     * |**     *  |
CONGLOM       *   *|  *****  *    |     **| **       |
YOLANDE            |* ****  *    *|   * * | *        |
              -----+--------------+-------+----------+-----
HENTY         *****|**********   *| *  * *|**        |
CARDIGAN       *   |****** ***   *|***  **|*         |
NELSON           **|******* **    | * * **|     *  **| *
LYNCH            **|**********   *| **    |     **   |*
CROTTY             |********** *  |**** * |    ***  *|
TOWNSHIP           |**********    |****   |* *   ** *|   **    2
GOVERNOR           |******  **  * |****** | *        |
COLLINGW           |******* ***** |****  *|          |
ELDON              |******  * **  | * ****|          |
STH ELDON          |**************|**  *  |  **      |  *
              -----+--------------+-------+----------+-----
FRANK1(G18)        |***  ***      |    *  |  *       |
G15                |*******  * *  |       |     *    |
G12                | ******* * *  |       |*         |
G11                |********* **  | *   * |*         |         3
FRANK3(G20)        |******** **** |     * |*         |  *
J1               * |******     ***|       |          |
FRANK2(G19)        |* * ****   ***|     * |          |
              -----+--------------+-------+----------+-----
HALLS              | ******** ****|       |       ***|*
NEWALL             |** **** ** ** |    ** |*   * ****|
PEARL              |  ***** ****  |       |** ****** |
PRINCESS           |   *** ***** *|       |**   **** | *       4
WEST Q1         ** |*  ******** * |  *    |******    |   *
COMST1            *|**********    |     * |** ***  * |
```

Figure 13 A two way table of taxon associations and site groupings for the spring RAP reference site data. Site groupings are derived from the UPGMA clustering shown in fig 12. The presence of taxa at a site is indicated by an asterisk. Site and taxon names are indicated on the left and at the top, respectively. Taxon names are abbreviated and are to be read vertically; see appendix 2 for the meaning of name abbreviations

Table 8 Predicted and observed macroinvertebrate taxa in riffles of the Queen and East Queen Rivers, Mount Lyell (spring data)

East Queen Site 2			
		O/E50 = 0.39	
Taxon	Predicted	Prob.	Obs.
SP07	**Gripopterygidae**	**1.00**	•
SP29	**Hydrobiosidae**	**1.00**	
SP30	**Hydropsychidae**	**0.94**	
SP40	**Scirtidae**	**0.93**	
SP09	**Leptophlebiidae**	**0.78**	
SP13	**Orthocladiinae**	**0.75**	•
SP17	**Simuliidae**	**0.75**	
SP05	**Eusthenidae**	**0.56**	
SP25	**Conoesucidae**	**0.54**	
SP02	**Oligochaeta**	**0.53**	•
SP23	Diptera (Pupae)	0.47	
SP03	Hydracarina	0.29	
SP32	Leptoceridae	0.28	
SP27	Helicophidae	0.27	
SP34	Philopotamidae	0.27	
SP35	Philorheithridae	0.26	
SP19	Blephariceridae	0.26	
SP08	Notonemuridae	0.25	
SP16	Diamesinae	0.25	
SP15	Tanypodinae	0.24	
SP01	Nematoda	0.23	
SP36	Polycentropodidae	0.23	
SP14	Podonominae	0.09	•
SP12	Chironominae	0.07	
SP38	Elmidae (adults)	0.06	
SP18	Tipulidae	0.06	
SP04	Parameletidae	0.05	
SP11	Aeshnidae	0.05	
SP39	Elmidae (larvae)	0.05	
SP37	Trichoptera (Pupae)	0.04	
SP41	Psephenidae	0.04	
SP26	Glossosomatidae	0.04	
SP06	Austroperlidae	0.03	
SP20	Athericidae	0.03	
SP10	Baetidae	0.03	
SP21	Empididae (adults)	0.02	
SP24	Calocidae	0.02	
SP28	Helicopsychidae	0.02	
SP31	Hydroptilidae	0.02	
SP33	Odontoceridae	0.01	
SP22	Ceratopogonidae	0.00	

East Queen Site 3			
		O/E50 = 0.00	
Taxon	Predicted	Prob.	Obs.
SP07	**Gripopterygidae**	**1.00**	
SP29	**Hydrobiosidae**	**1.00**	
SP09	**Leptophlebiidae**	**0.84**	
SP17	**Simuliidae**	**0.82**	
SP40	**Scirtidae**	**0.81**	
SP13	**Orthocladiinae**	**0.74**	
SP30	**Hydropsychidae**	**0.72**	
SP05	**Eusthenidae**	**0.69**	
SP02	**Oligochaeta**	**0.67**	
SP25	**Conoesucidae**	**0.65**	
SP23	Diptera (Pupae)	0.48	•
SP34	Philopotamidae	0.36	
SP19	Blephariceridae	0.35	
SP14	Podonominae	0.35	
SP18	Tipulidae	0.33	
SP35	Philorheithridae	0.30	
SP08	Notonemuridae	0.30	
SP03	Hydracarina	0.29	
SP32	Leptoceridae	0.28	
SP16	Diamesinae	0.26	
SP15	Tanypodinae	0.23	
SP12	Chironominae	0.23	
SP27	Helicophidae	0.23	
SP06	Austroperlidae	0.20	
SP01	Nematoda	0.19	
SP36	Polycentropodidae	0.19	
SP38	Elmidae (adults)	0.16	
SP04	Parameletidae	0.13	
SP39	Elmidae (larvae)	0.12	
SP11	Aeshnidae	0.12	
SP26	Glossosomatidae	0.11	
SP10	Baetidae	0.11	
SP33	Odontoceridae	0.07	
SP37	Trichoptera (Pupae)	0.06	
SP41	Psephenidae	0.06	
SP20	Athericidae	0.05	
SP21	Empididae (adults)	0.04	
SP24	Calocidae	0.04	
SP28	Helicopsychidae	0.04	
SP31	Hydroptilidae	0.04	
SP22	Ceratopogonidae	0.03	

Queen Site 1			
		O/E50 = 0.13	
Taxon	Predicted	Prob.	Obs.
SP07	**Gripopterygidae**	**1**	
SP29	**Hydrobiosidae**	**1**	
SP09	**Leptophlebiidae**	**0.87177**	
SP17	**Simuliidae**	**0.83906**	
SP40	**Scirtidae**	**0.74555**	•
SP05	**Eusthenidae**	**0.74354**	
SP13	**Orthocladiinae**	**0.73437**	
SP02	**Oligochaeta**	**0.71083**	
SP25	**Conoesucidae**	**0.69047**	
SP30	**Hydropsychidae**	**0.64086**	
SP23	Diptera (Pupae)	0.46728	
SP14	Podonominae	0.45437	•
SP18	Tipulidae	0.42165	
SP34	Philopotamidae	0.39212	
SP19	Blephariceridae	0.38121	
SP35	Philorheithridae	0.3187	
SP03	Hydracarina	0.30925	
SP08	Notonemuridae	0.30779	
SP32	Leptoceridae	0.29835	
SP12	Chironominae	0.29662	
SP16	Diamesinae	0.26563	
SP06	Austroperlidae	0.25299	
SP27	Helicophidae	0.22492	
SP15	Tanypodinae	0.22346	
SP38	Elmidae (adults)	0.21229	•
SP01	Nematoda	0.17039	
SP36	Polycentropodidae	0.17039	
SP04	Parameletidae	0.17012	
SP11	Aeshnidae	0.15921	
SP39	Elmidae (larvae)	0.15921	
SP26	Glossosomatidae	0.1483	
SP10	Baetidae	0.1374	
SP37	Trichoptera (Pupae)	0.08579	
SP41	Psephenidae	0.08579	
SP33	Odontoceridae	0.08433	
SP20	Athericidae	0.07488	
SP21	Empididae (adults)	0.05307	
SP24	Calocidae	0.05307	
SP28	Helicopsychidae	0.05307	
SP31	Hydroptilidae	0.05307	
SP22	Ceratopogonidae	0.04217	

Queen Site 2			
		O/E50 = 0.34	
Taxon	Predicted	Prob.	Obs.
SP07	**Gripopterygidae**	**1.00**	
SP29	**Hydrobiosidae**	**1.00**	•
SP09	**Leptophlebiidae**	**0.94**	
SP05	**Eusthenidae**	**0.89**	
SP17	**Simuliidae**	**0.87**	
SP02	**Oligochaeta**	**0.81**	•
SP25	**Conoesucidae**	**0.80**	
SP13	**Orthocladiinae**	**0.73**	•
SP14	**Podonominae**	**0.70**	
SP18	**Tipulidae**	**0.63**	
SP40	**Scirtidae**	**0.59**	
SP12	Chironominae	0.47	
SP34	Philopotamidae	0.46	
SP30	Hydropsychidae	0.45	
SP19	Blephariceridae	0.43	
SP23	Diptera (Pupae)	0.43	
SP06	Austroperlidae	0.38	
SP03	Hydracarina	0.37	•
SP35	Philorheithridae	0.36	
SP38	Elmidae (adults)	0.35	•
SP32	Leptoceridae	0.34	
SP08	Notonemuridae	0.33	
SP04	Parameletidae	0.29	
SP16	Diamesinae	0.27	
SP39	Elmidae (larvae)	0.26	
SP11	Aeshnidae	0.26	
SP27	Helicophidae	0.24	
SP26	Glossosomatidae	0.24	
SP10	Baetidae	0.21	
SP15	Tanypodinae	0.21	
SP37	Trichoptera (Pupae)	0.16	
SP41	Psephenidae	0.16	
SP20	Athericidae	0.14	
SP33	Odontoceridae	0.13	
SP01	Nematoda	0.12	
SP36	Polycentropodidae	0.12	
SP21	Empididae (adults)	0.09	
SP24	Calocidae	0.09	
SP28	Helicopsychidae	0.09	
SP31	Hydroptilidae	0.09	
SP22	Ceratopogonidae	0.06	

Queen Site 4			
		O/E50 = 0.52	
Taxon	Predicted	Prob.	Obs.
SP09	**Leptophlebiidae**	**0.99**	
SP17	**Simuliidae**	**0.99**	
SP29	**Hydrobiosidae**	**0.94**	
SP02	**Oligochaeta**	**0.92**	•
SP14	**Podonominae**	**0.90**	
SP07	**Gripopterygidae**	**0.89**	•
SP13	**Orthocladiinae**	**0.77**	•
SP25	**Conoesucidae**	**0.70**	
SP05	**Eusthenidae**	**0.64**	
SP12	**Chironominae**	**0.63**	•
SP18	**Tipulidae**	**0.62**	•
SP38	**Elmidae (adults)**	**0.57**	
SP40	Scirtidae	0.49	•
SP03	Hydracarina	0.35	
SP35	Philorheithridae	0.35	
SP34	Philopotamidae	0.35	
SP19	Blephariceridae	0.35	
SP39	Elmidae (larvae)	0.34	
SP06	Austroperlidae	0.34	
SP23	Diptera (Pupae)	0.30	•
SP32	Leptoceridae	0.30	•
SP08	Notonemuridae	0.29	
SP04	Parameletidae	0.23	
SP10	Baetidae	0.23	
SP15	Tanypodinae	0.18	
SP16	Diamesinae	0.18	
SP11	Aeshnidae	0.17	
SP26	Glossosomatidae	0.17	
SP30	Hydropsychidae	0.15	
SP22	Ceratopogonidae	0.11	
SP33	Odontoceridae	0.11	
SP27	Helicophidae	0.07	
SP01	Nematoda	0.06	
SP36	Polycentropodidae	0.06	
SP37	Trichoptera (Pupae)	0.06	
SP41	Psephenidae	0.06	
SP20	Athericidae	0.06	
SP21	Empididae (adults)	0.06	
SP24	Calocidae	0.06	
SP28	Helicopsychidae	0.06	
SP31	Hydroptilidae	0.06	

Taxa predicted at or above the 0.5 probability level are in bold

Table 9 Predicted and observed macroinvertebrate taxa in riffles of Comstock and Linda Creeks, Mt Lyell (spring data)

Comstock Site 2			
		O/E50 = 1.18	
Taxon	Predicted	Prob.	Obs.
SP07	**Gripopterygidae**	**1.00**	•
SP29	**Hydrobiosidae**	**1.00**	•
SP09	**Leptophlebiidae**	**0.90**	•
SP05	**Eusthenidae**	**0.81**	•
SP17	**Simuliidae**	**0.81**	•
SP13	**Orthocladiinae**	**0.75**	•
SP25	**Conoesucidae**	**0.73**	•
SP02	**Oligochaeta**	**0.71**	
SP40	**Scirtidae**	**0.66**	•
SP30	**Hydropsychidae**	**0.60**	•
SP14	**Podonominae**	**0.51**	•
SP18	Tipulidae	0.42	
SP23	Diptera (Pupae)	0.40	
SP03	Hydracarina	0.38	
SP12	Chironominae	0.38	
SP34	Philopotamidae	0.38	•
SP32	Leptoceridae	0.35	
SP19	Blephariceridae	0.35	
SP35	Philorheithridae	0.33	
SP27	Helicophidae	0.30	•
SP38	Elmidae (adults)	0.30	
SP08	Notonemuridae	0.30	
SP04	Parameletidae	0.25	•
SP16	Diamesinae	0.25	
SP06	Austroperlidae	0.25	
SP11	Aeshnidae	0.22	
SP39	Elmidae (larvae)	0.22	
SP15	Tanypodinae	0.21	
SP26	Glossosomatidae	0.19	
SP37	Trichoptera (Pupae)	0.17	•
SP41	Psephenidae	0.17	
SP10	Baetidae	0.16	
SP20	Athericidae	0.14	
SP01	Nematoda	0.14	
SP36	Polycentropodidae	0.14	
SP33	Odontoceridae	0.08	
SP21	Empididae (adults)	0.07	
SP24	Calocidae	0.07	
SP28	Helicopsychidae	0.07	
SP31	Hydroptilidae	0.07	
SP22	Ceratopogonidae	0.04	

Comstock Site 3			
		O/E50 = 0.13	
Taxon	Predicted	Prob.	Obs.
SP07	**Gripopterygidae**	**1.00**	
SP29	**Hydrobiosidae**	**1.00**	
SP30	**Hydropsychidae**	**0.86**	
SP40	**Scirtidae**	**0.83**	
SP09	**Leptophlebiidae**	**0.82**	
SP13	**Orthocladiinae**	**0.76**	•
SP17	**Simuliidae**	**0.73**	
SP05	**Eusthenidae**	**0.64**	
SP25	**Conoesucidae**	**0.60**	
SP02	**Oligochaeta**	**0.55**	
SP23	Diptera (Pupae)	0.41	
SP03	Hydracarina	0.36	
SP27	Helicophidae	0.34	
SP32	Leptoceridae	0.33	
SP35	Philorheithridae	0.28	
SP34	Philopotamidae	0.27	
SP08	Notonemuridae	0.25	
SP19	Blephariceridae	0.24	
SP16	Diamesinae	0.24	
SP15	Tanypodinae	0.23	•
SP01	Nematoda	0.19	
SP36	Polycentropodidae	0.19	
SP14	Podonominae	0.19	
SP12	Chironominae	0.18	•
SP38	Elmidae (adults)	0.16	
SP04	Parameletidae	0.15	
SP37	Trichoptera (Pupae)	0.13	
SP41	Psephenidae	0.13	
SP11	Aeshnidae	0.12	
SP39	Elmidae (larvae)	0.12	
SP18	Tipulidae	0.10	
SP20	Athericidae	0.10	
SP26	Glossosomatidae	0.09	
SP06	Austroperlidae	0.06	
SP10	Baetidae	0.06	
SP21	Empididae (adults)	0.04	
SP24	Calocidae	0.04	
SP28	Helicopsychidae	0.04	
SP31	Hydroptilidae	0.04	
SP33	Odontoceridae	0.02	
SP22	Ceratopogonidae	0.01	

Comstock Site 4			
		O/E50 = 0.38	
Taxon	Predicted	Prob.	Obs.
SP07	**Gripopterygidae**	**1.00**	•
SP29	**Hydrobiosidae**	**1.00**	•
SP09	**Leptophlebiidae**	**0.88**	
SP17	**Simuliidae**	**0.82**	
SP05	**Eusthenidae**	**0.75**	
SP13	**Orthocladiinae**	**0.74**	•
SP40	**Scirtidae**	**0.72**	
SP25	**Conoesucidae**	**0.70**	
SP02	**Oligochaeta**	**0.69**	
SP30	**Hydropsychidae**	**0.65**	
SP14	Podonominae	0.45	
SP23	Diptera (Pupae)	0.44	
SP18	Tipulidae	0.39	
SP34	Philopotamidae	0.38	
SP19	Blephariceridae	0.36	
SP03	Hydracarina	0.34	•
SP32	Leptoceridae	0.32	
SP35	Philorheithridae	0.32	
SP12	Chironominae	0.31	
SP08	Notonemuridae	0.30	•
SP27	Helicophidae	0.26	
SP16	Diamesinae	0.26	
SP38	Elmidae (adults)	0.24	•
SP06	Austroperlidae	0.23	
SP15	Tanypodinae	0.22	•
SP04	Parameletidae	0.20	
SP11	Aeshnidae	0.18	
SP39	Elmidae (larvae)	0.18	
SP01	Nematoda	0.16	
SP36	Polycentropodidae	0.16	
SP26	Glossosomatidae	0.16	
SP10	Baetidae	0.14	
SP37	Trichoptera (Pupae)	0.12	
SP41	Psephenidae	0.12	
SP20	Athericidae	0.10	
SP33	Odontoceridae	0.08	
SP21	Empididae (adults)	0.06	
SP24	Calocidae	0.06	
SP28	Helicopsychidae	0.06	
SP31	Hydroptilidae	0.06	
SP22	Ceratopogonidae	0.04	

Linda Site 1			
		O/E50 = 0.51	
Taxon	Predicted	Prob.	Obs.
SP07	**Gripopterygidae**	**1.00**	•
SP29	**Hydrobiosidae**	**1.00**	
SP40	**Scirtidae**	**0.87**	
SP30	**Hydropsychidae**	**0.83**	
SP09	**Leptophlebiidae**	**0.81**	•
SP17	**Simuliidae**	**0.79**	
SP13	**Orthocladiinae**	**0.74**	•
SP05	**Eusthenidae**	**0.62**	
SP02	**Oligochaeta**	**0.60**	•
SP25	**Conoesucidae**	**0.59**	
SP23	Diptera (Pupae)	0.48	•
SP34	Philopotamidae	0.31	
SP19	Blephariceridae	0.31	
SP03	Hydracarina	0.29	•
SP35	Philorheithridae	0.28	
SP32	Leptoceridae	0.28	
SP08	Notonemuridae	0.28	
SP16	Diamesinae	0.26	
SP27	Helicophidae	0.25	
SP15	Tanypodinae	0.24	
SP14	Podonominae	0.22	
SP01	Nematoda	0.21	
SP36	Polycentropodidae	0.21	
SP18	Tipulidae	0.19	
SP12	Chironominae	0.15	
SP06	Austroperlidae	0.12	
SP38	Elmidae (adults)	0.11	
SP04	Parameletidae	0.09	
SP11	Aeshnidae	0.08	
SP39	Elmidae (larvae)	0.08	
SP26	Glossosomatidae	0.07	
SP10	Baetidae	0.07	
SP37	Trichoptera (Pupae)	0.05	
SP41	Psephenidae	0.05	
SP20	Athericidae	0.04	
SP33	Odontoceridae	0.04	
SP21	Empididae (adults)	0.03	
SP24	Calocidae	0.03	
SP28	Helicopsychidae	0.03	
SP31	Hydroptilidae	0.03	
SP22	Ceratopogonidae	0.02	

Taxa predicted at or above the 0.5 probability level are in bold

Table 10 Predicted and observed macroinvertebrate taxa in riffles of the King River, Mount Lyell (spring data)

King Site 1				King Site 2				King Site 3			
		O/E50 = 0.78				O/E50 = 0.00				O/E50 = 0.13	
Taxon	Predicted	Prob.	Obs.	Taxon	Predicted	Prob.	Obs.	Taxon	Predicted	Prob.	Obs.
SP09	**Leptophlebiidae**	**1.00**	•	**SP09**	**Leptophlebiidae**	**1.00**		**SP09**	**Leptophlebiidae**	**1.00**	
SP17	**Simuliidae**	**1.00**	•	**SP17**	**Simuliidae**	**1.00**		**SP17**	**Simuliidae**	**1.00**	
SP29	**Hydrobiosidae**	**0.86**	•	**SP29**	**Hydrobiosidae**	**0.86**		**SP02**	**Oligochaeta**	**0.86**	
SP02	**Oligochaeta**	**0.86**	•	**SP13**	**Orthocladiinae**	**0.86**		**SP13**	**Orthocladiinae**	**0.86**	
SP14	**Podonominae**	**0.86**		**SP38**	**Elmidae (adults)**	**0.86**		**SP14**	**Podonominae**	**0.86**	•
SP13	**Orthocladiinae**	**0.86**	•	**SP02**	**Oligochaeta**	**0.86**		**SP29**	**Hydrobiosidae**	**0.86**	
SP38	**Elmidae (adults)**	**0.85**		**SP14**	**Podonominae**	**0.86**		**SP38**	**Elmidae (adults)**	**0.86**	
SP07	**Gripopterygidae**	**0.72**	•	**SP07**	**Gripopterygidae**	**0.72**		**SP07**	**Gripopterygidae**	**0.71**	
SP12	**Chironominae**	**0.71**		**SP12**	**Chironominae**	**0.71**		**SP12**	**Chironominae**	**0.71**	
SP25	Conoesucidae	0.43	•	SP25	Conoesucidae	0.43		SP03	Hydracarina	0.43	
SP40	Scirtidae	0.43		SP03	Hydracarina	0.43		SP25	Conoesucidae	0.43	
SP03	Hydracarina	0.43		SP39	Elmidae (larvae)	0.43		SP39	Elmidae (larvae)	0.43	
SP39	Elmidae (larvae)	0.43		SP40	Scirtidae	0.43		SP40	Scirtidae	0.43	
SP35	Philorheithridae	0.29	•	SP32	Leptoceridae	0.29		SP32	Leptoceridae	0.29	
SP32	Leptoceridae	0.29		SP35	Philorheithridae	0.29		SP35	Philorheithridae	0.29	
SP05	Eusthenidae	0.15		SP05	Eusthenidae	0.15		SP04	Parameletidae	0.14	
SP18	Tipulidae	0.15		SP04	Parameletidae	0.15		SP05	Eusthenidae	0.14	
SP08	Notonemuridae	0.14	•	SP08	Notonemuridae	0.14		SP08	Notonemuridae	0.14	
SP04	Parameletidae	0.14		SP10	Baetidae	0.14		SP10	Baetidae	0.14	
SP10	Baetidae	0.14		SP15	Tanypodinae	0.14		SP15	Tanypodinae	0.14	
SP15	Tanypodinae	0.14		SP18	Tipulidae	0.14		SP18	Tipulidae	0.14	
SP22	Ceratopogonidae	0.14		SP22	Ceratopogonidae	0.14		SP22	Ceratopogonidae	0.14	
SP34	Philopotamidae	0.00	•	SP27	Helicophidae	0.00		SP01	Nematoda	0.00	
SP19	Blephariceridae	0.00		SP30	Hydropsychidae	0.00		SP06	Austroperlidae	0.00	
SP06	Austroperlidae	0.00		SP37	Trichoptera (Pupae)	0.00		SP11	Aeshnidae	0.00	
SP23	Diptera (Pupae)	0.00		SP41	Psephenidae	0.00		SP16	Diamesinae	0.00	
SP11	Aeshnidae	0.00		SP11	Aeshnidae	0.00		SP19	Blephariceridae	0.00	
SP26	Glossosomatidae	0.00		SP20	Athericidae	0.00		SP20	Athericidae	0.00	
SP16	Diamesinae	0.00	•	SP26	Glossosomatidae	0.00		SP21	Empididae (adults)	0.00	
SP30	Hydropsychidae	0.00		SP34	Philopotamidae	0.00		SP23	Diptera (Pupae)	0.00	
SP33	Odontoceridae	0.00		SP21	Empididae (adults)	0.00		SP24	Calocidae	0.00	
SP27	Helicophidae	0.00		SP24	Calocidae	0.00		SP26	Glossosomatidae	0.00	
SP37	Trichoptera (Pupae)	0.00		SP28	Helicopsychidae	0.00		SP27	Helicophidae	0.00	
SP41	Psephenidae	0.00		SP31	Hydroptilidae	0.00		SP28	Helicopsychidae	0.00	
SP20	Athericidae	0.00		SP16	Diamesinae	0.00		SP30	Hydropsychidae	0.00	
SP21	Empididae (adults)	0.00		SP06	Austroperlidae	0.00		SP31	Hydroptilidae	0.00	
SP24	Calocidae	0.00	•	SP19	Blephariceridae	0.00		SP33	Odontoceridae	0.00	
SP28	Helicopsychidae	0.00		SP01	Nematoda	0.00		SP34	Philopotamidae	0.00	
SP31	Hydroptilidae	0.00		SP23	Diptera (Pupae)	0.00		SP36	Polycentropodidae	0.00	
SP01	Nematoda	0.00		SP33	Odontoceridae	0.00		SP37	Trichoptera (Pupae)	0.00	
SP36	Polycentropodidae	0.00		SP36	Polycentropodidae	0.00		SP41	Psephenidae	0.00	

Taxa predicted the at or above the 0.5 probability level are in bold

Relationships between the O/E50 values, mean number of taxa and mean abundance and water quality variables were explored by Pearson correlation after log [x+1] transformation (fig 14). Mean number of taxa and abundance were significantly negatively correlated ($p < 0.0001$, $n = 32$) with mean concentrations of total copper, but less so with pH ($p < 0.01$) and DOC ($p < 0.05$). Total copper was highly correlated with the other water quality variables—sulphate, dissolved copper, conductivity, colour, TDS, TSS—at $p < 0.001$ with $n = 32$, with the exception of 'tannins and lignins', DOC and pH, for which all correlations had $p > 0.2$, 0.1 and 0.01 respectively. The correlations indicate that a relationship exists between O/E50, macroinvertebrate diversity and abundance and water quality indicators of AMD pollution. The degree of scatter in plots (fig 14) suggests that other factors may also be contributing to the relationship between community composition and human impact, however, which are not water quality related. The lack of any 'moderately impacted' sites also makes the nature of the relationship unclear, as there were few sites with mean copper values in the range 50–200 µg/L (fig 14).

Edge samples

Sampling of edges revealed similar numbers of taxa and abundances to those found in riffle habitats (fig 15). Although the composition of the faunas found in the two habitats differed slightly, the overall trends were similar across all sites to those found for riffles.

Quantitative analysis
Data from the quantitative Surber sampling are shown in appendix 4.

a) Evaluation of representative sample size Plots of number of taxa (family and species level) and total abundance against number of Surber sample units are shown in figs 16, 17 and 18 for the Nelson, Governor River and Comstock 4 sites respectively. Plots of the Bray Curtis dissimilarity index for all three site pairs against number of Surber sample units are shown in figs 19 and 20. For these plots, it can be seen that 10 Surber sample units are sufficient to estimate the 'true' total abundance within 25% and the number of taxa within 40% at unimpacted sites (eg Nelson and Governor Rivers) and within 50% at impacted sites (eg Comstock 4), at both family and species level. Ten samples satisfied the Bray Curtis dissimilarity criterion for dissimilarity of pairs of sites at family level. At species level, however, 20 samples are required to adequately characterise the dissimilarity between sites. Thus, overall, a sample comprising 10 sample units is deemed adequate to represent the site in terms of the three variables (abundance, number of taxa and Bray Curtis dissimilarity from other sites) at family level.

b) Detecting changes of a given magnitude Curves of % change in abundance against number of Surber sample units are shown for the Nelson River site for differing β values in fig 21. No significant change in the minimum detectable changes was found for β values ranging from 0.05 to 0.2 for any of the three sites.

Curves of minimum detectable % change in abundance and number of taxa (family and species level) against number of Surber sample units are shown for the Nelson and Governor River and Comstock 4 sites at α and $\beta = 0.05$ in fig 22. Overall, samples consisting of 10 Surber sample units will be sufficient to detect changes in site macroinvertebrate faunal communities of the following magnitude:

	Minimum % change detectable in abundance, 10 Surbers	Minimum % change detectable in number of taxa, 10 Surbers (family or species level)
Unimpacted sites		
High abundance and diversity		
eg Nelson	50	50
Moderate abundance and diversity		
eg Governor	40	55
AMD polluted sites		
eg Comstock 4	120	140

Significant reductions in the minimum detectable changes are only achieved with high numbers of sample units (> 40). Such high numbers makes monitoring impractical due to manpower and cost considerations. Ten Surber sample units are therefore adequate for detecting large changes in abundance and number of taxa at AMD-polluted sites, as a possible adjunct to assessment by MLRIVPACS.

QA/QC
a) Live picking representativeness Plots of the number of taxa and total abundance for live pick versus 'whole kick' spring RAP samples are shown in fig 23. The raw data are shown in appendix 2. A high correlation ($r^2 = 0.79$, $n = 21$) was found for number of taxa (after re-scaling the 'whole kick' sample to the same abundance as the live pick), with a regression line slope and intercept not significantly different from 1.00 and 0.00 respectively (t-test, both $p > 0.2$.

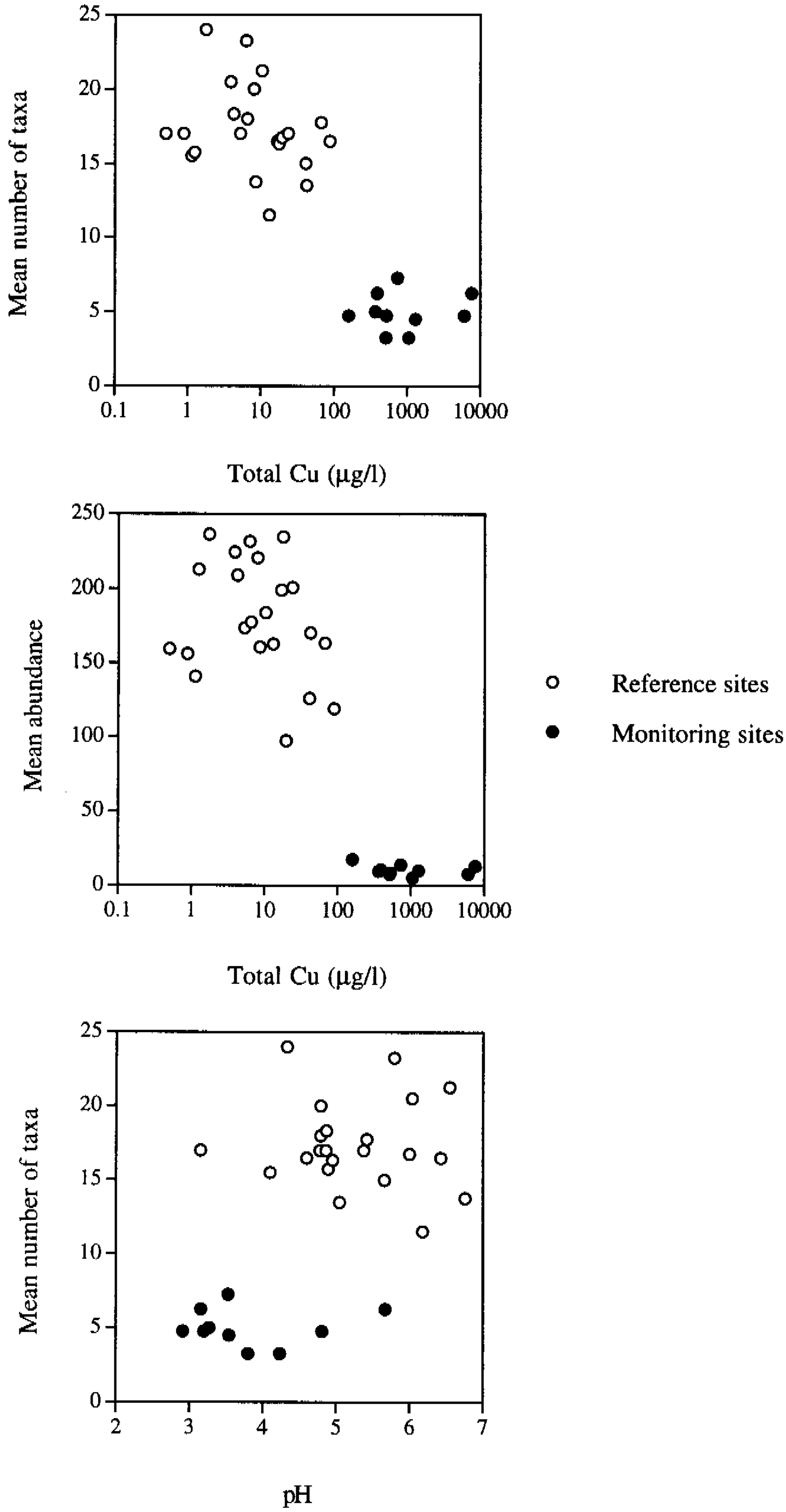


Figure 14 Mean number of taxa and total abundance of macroinvertebrates in RAP samples from the Mt Lyell region plotted against mean total copper concentration and pH

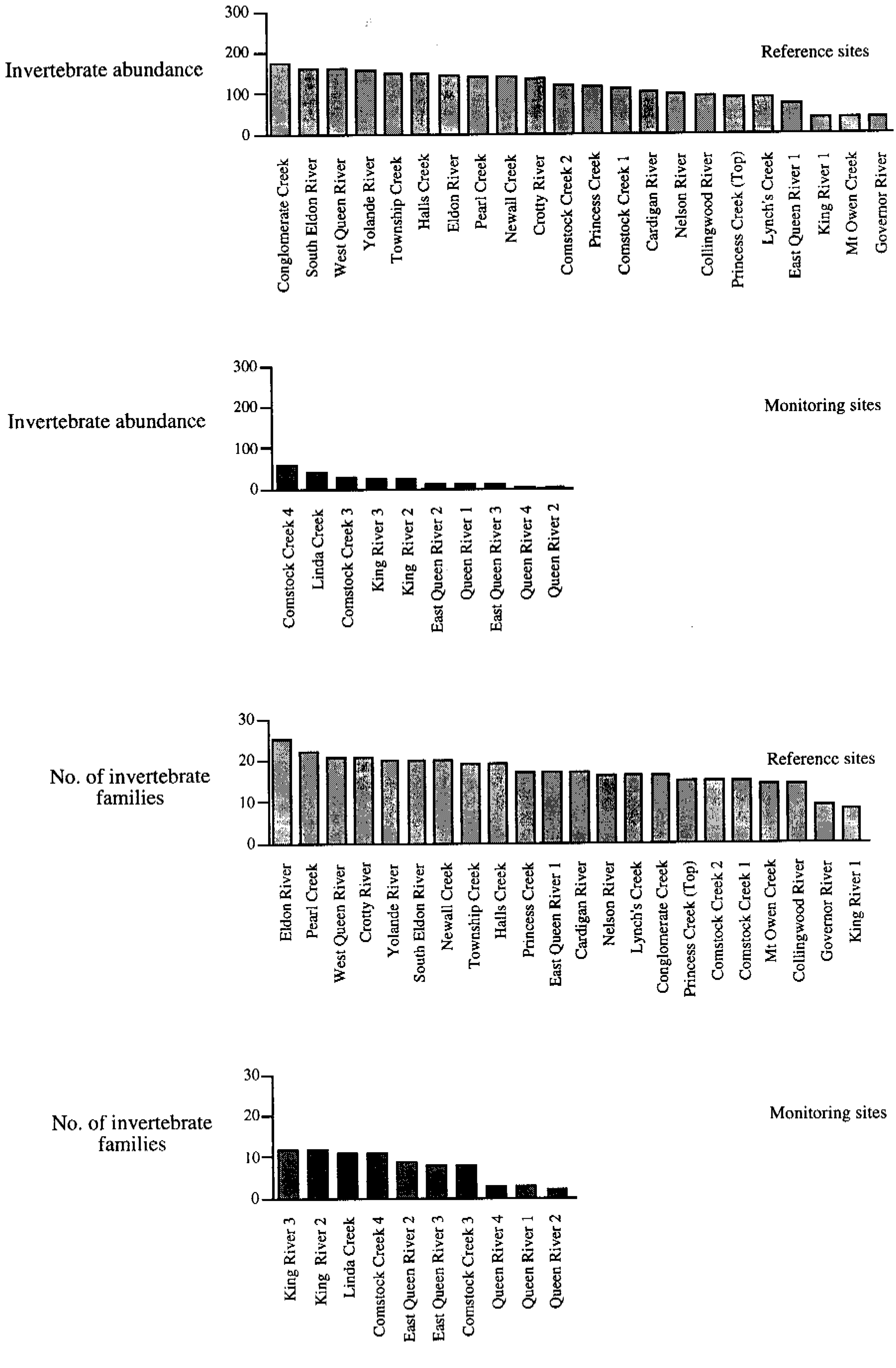


Figure 15 Number of taxa and total abundance of macroinvertebrates collected in riffle samples at RAP sampled reference and monitoring sites in autumn 1996

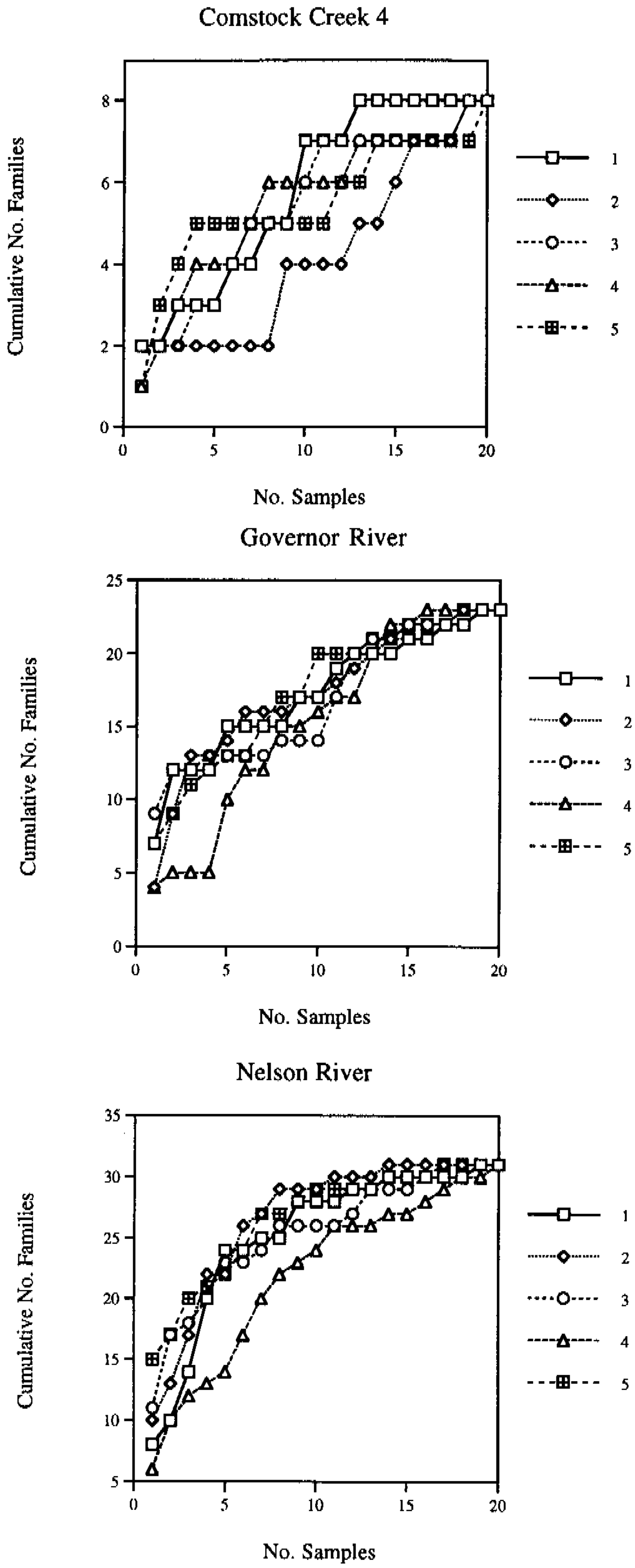


Figure 16 Plots of cumulative number of macroinvertebrate families against number of Surber sample units for three riffle sites in the Mount Lyell region. Each plot contains five series of randomly selected Surber samples (see Methods for details)

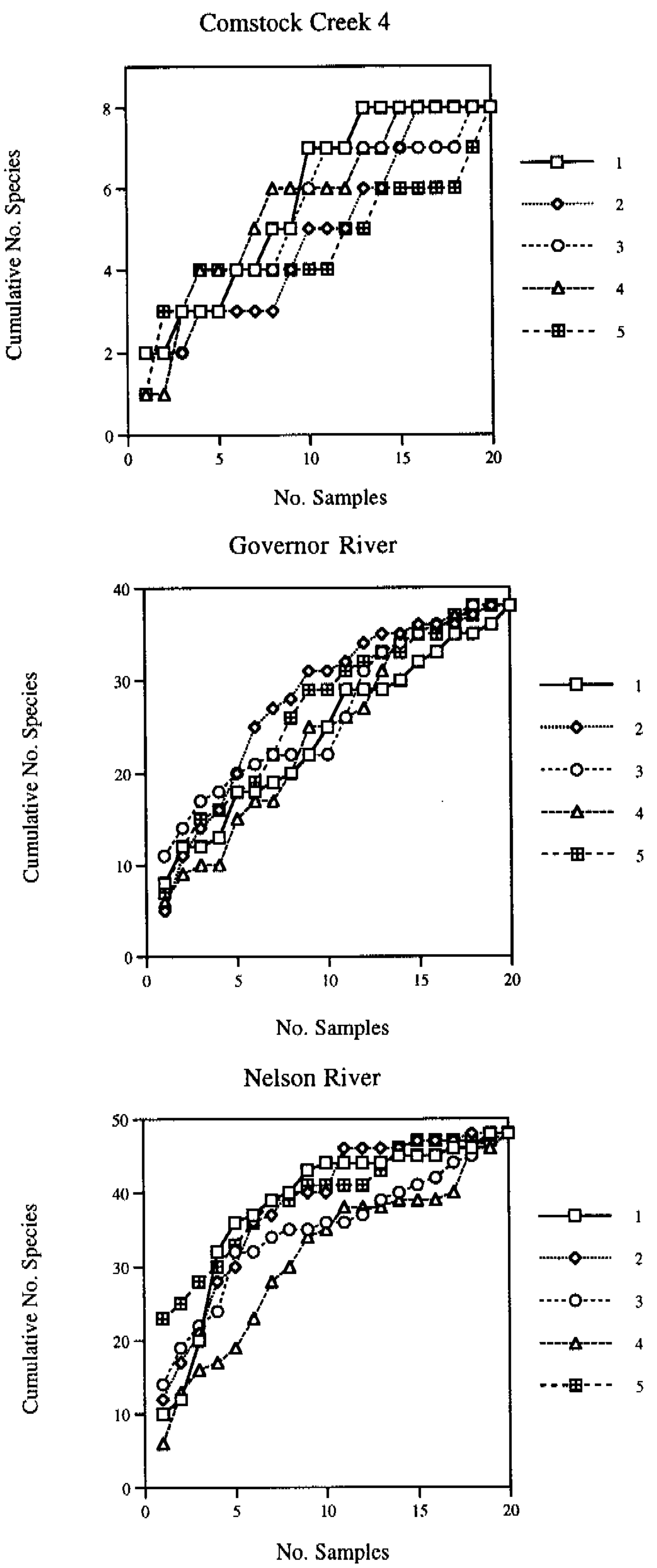


Figure 17 Plots of cumulative number of macroinvertebrate species against number of Surber sample units for three riffle sites in the Mount Lyell region. Each plot contains five series of randomly selected Surber samples (see Methods for details)

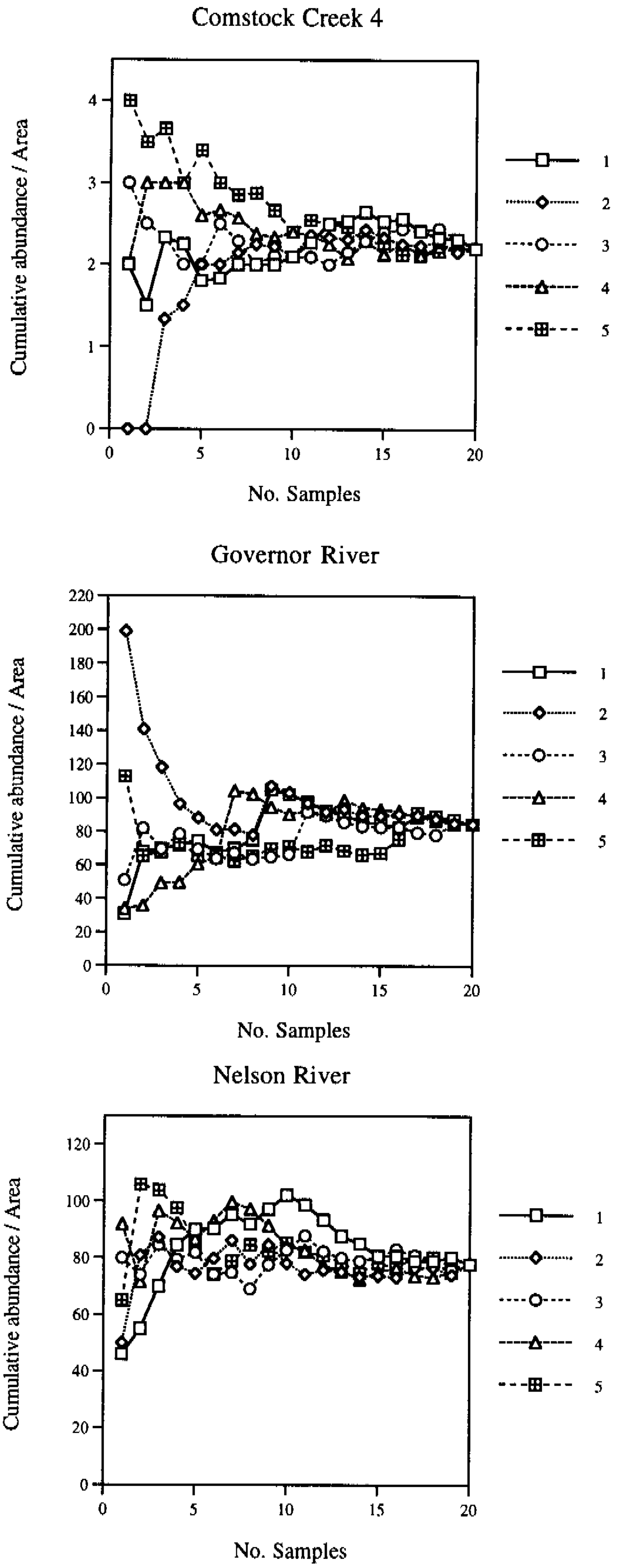


Figure 18 Plots of cumulative total macroinvertebrate abundance against number of Surber sample units for three riffle sites in the Mount Lyell region. Each plot contains five series of randomly selected Surber samples (see Methods for details)

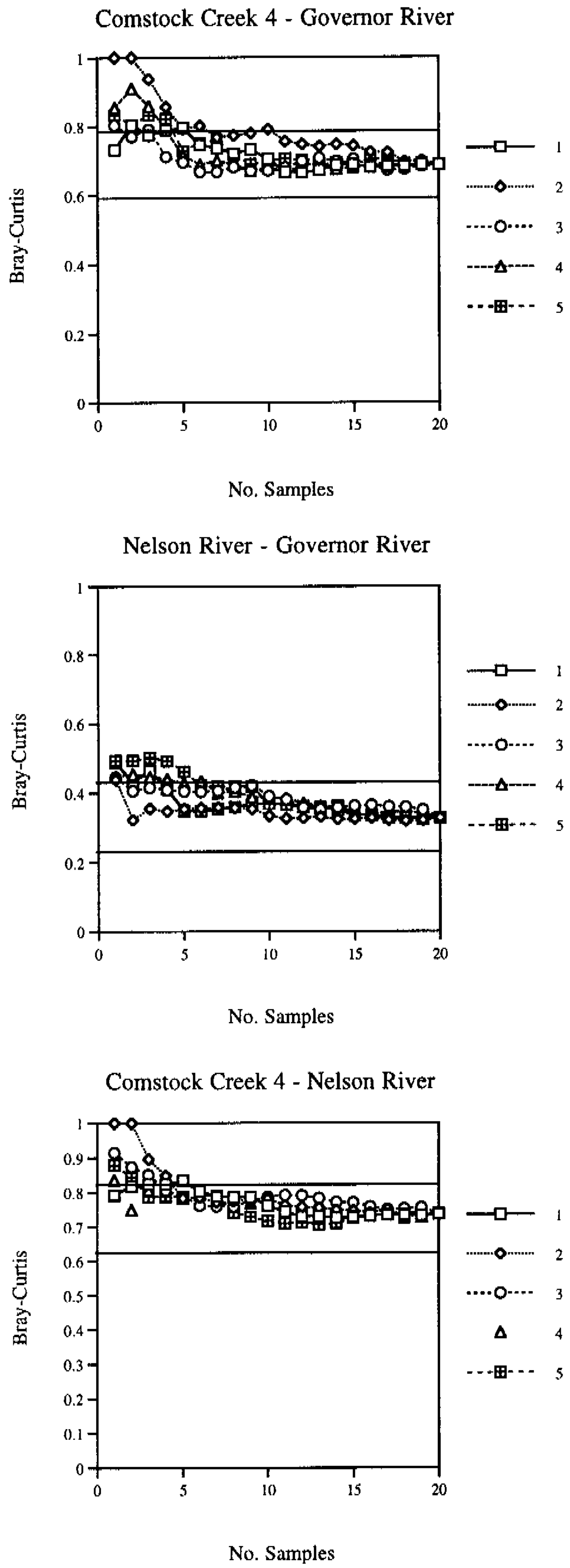


Figure 19 Bray Curtis dissimilarity values for riffle macroinvertebrate communities derived using family data plotted against number of Surber sample units for pairs of sites in the Mount Lyell region. Each plot contains five series of randomly selected Surber samples (see Methods for details). Lines represent ± 0.1 unit bounds about the final mean

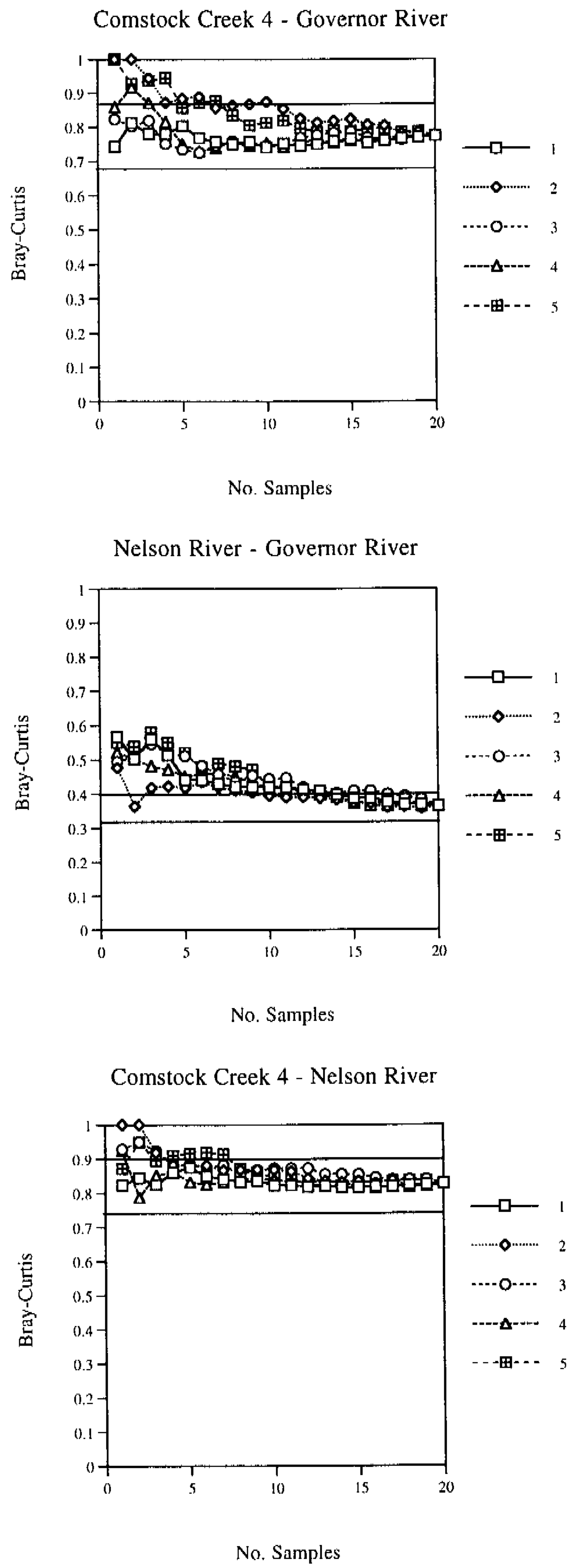


Figure 20 Bray Curtis dissimilarity values for riffle macroinvertebrate communities derived using species data plotted against number of Surber sample units for pairs of sites in the Mount Lyell region. Each plot contains five series of randomly selected Surber samples (see Methods for details). Lines represent ± 0.1 unit bounds about the final mean

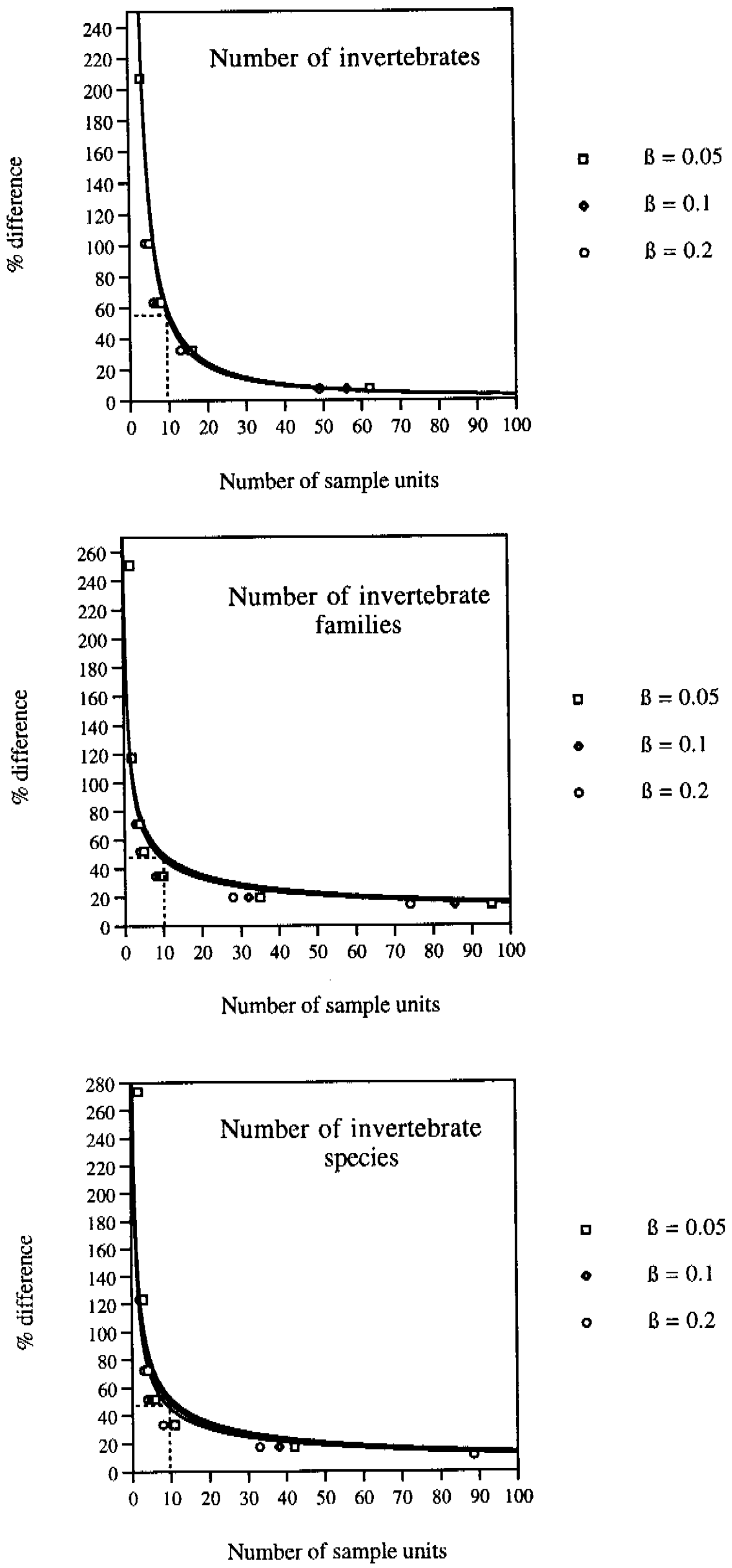


Figure 21 Plots of minimum % change in abundance and number of taxa detectable in Nelson River riffle against the number of Surber sample units, at different beta values. Spring 1995, alpha = 0.05

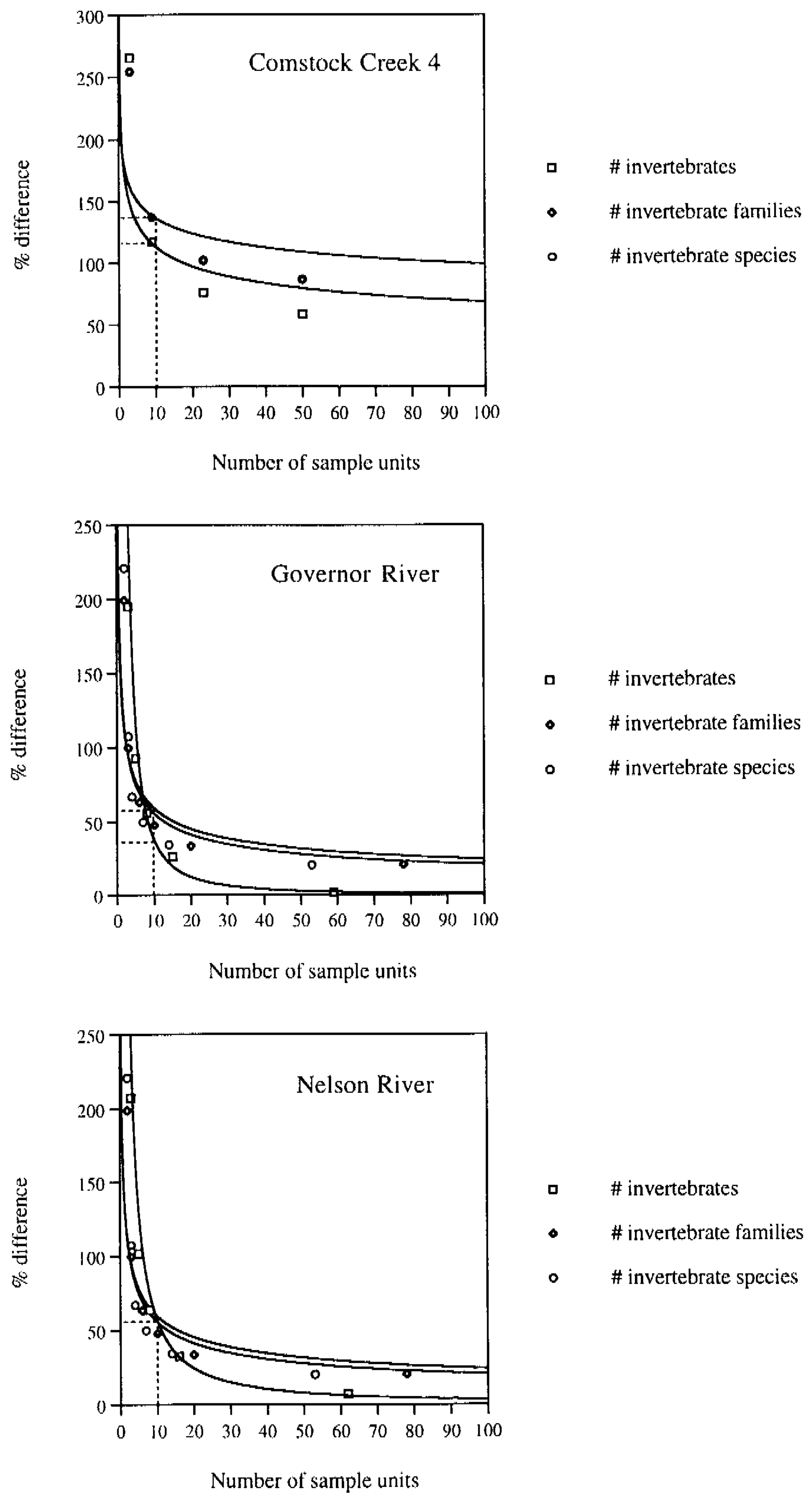


Figure 22 Plots of minimum % detectable change in abundance and number of taxa of macroinvertebrates against number of Surber sample units for three riffle sites in the Mount Lyell region (see Methods for details), all with alpha = 0.05 and beta = 0.05

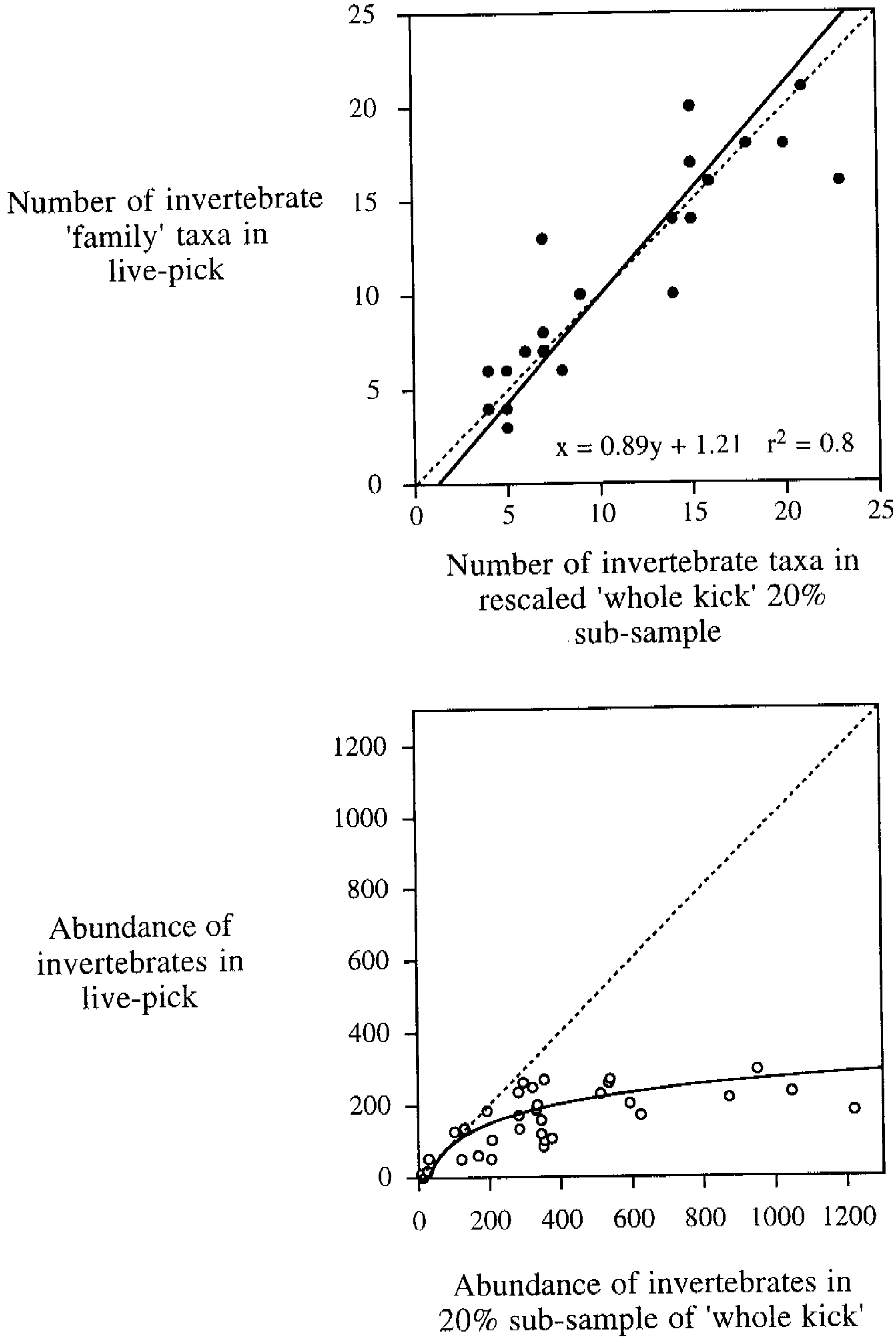


Figure 23 Number of taxa and total abundance of macroinvertebrates in RAP live-pick vs 20% sub-sample of the same sample ('whole kick' sample) for 37 riffles sampled in the Mount Lyell region in spring 1995 (see Methods for details)

No overall significant correlation was found for abundance, with all live pick samples with 'whole kick' abundances > 200 not being significantly different from 200. A significant correlation was found for abundance data < 200 ($r^2 = 0.49$, $p < 0.01$).

Thus, live pick data adequately represents the diversity at a site, but does not adequately represent abundances for unimpacted sites. On interviewing staff involved in live-picking, a general consensus was expressed that 200-250 animals was approximately the maximum that could be routinely picked in 30 minutes from samples collected at faunally diverse sites.

On examination of Spearman rank correlations, all bar one sample pair had significant correlations ($p < 0.05$). Mean Bray Curtis dissimilarities between live pick and 'whole kick' samples from the same site were 0.27 and 0.31, for rank abundance and presence/absence data (the latter developed after standardising abundances—see under 3.1.2 QA/QC) respectively. These results indicate that live picking is reasonably representative of the 'whole kick' sample in terms of rank abundance and community composition (measured as dissimilarity).

b) Site representativeness UPGMA classification of multiple riffle sampling of five streams indicated a close fidelity of riffles within rivers (fig 24). No riffle was misclassified by river, with the exception of a single riffle in Newall Creek which was classified with the Eldon River riffles. This particular riffle was, unlike the other two immediately upstream, devoid of overhanging and heavily shading riparian vegetation. It was not unexpected, therefore, that it should classify biologically with the unshaded, open riffles of the Eldon River with which it was similar in substrate and slope.

These results therefore indicate that single riffles, with characteristics representative of the overall stream reach in which they are located, are representative of that reach in their macroinvertebrate fauna.

c) Operator comparability No paired comparison between operators showed significant differences in either abundance or number of taxa at the $p < 0.05$ level (table 11). This lack of difference was reflected in the rank abundances of fauna in paired samples, all of which had significant Spearman rank correlations, $p < 0.05$ with the vast majority (20 out of 24 samples) with $p < 0.001$.

Mean Bray Curtis dissimilarities for each operator pair were ≤ 0.27. This level was lower than the mean dissimilarity values at which rivers were differentiated in the multiple riffle sampling, 0.35, (fig 24) and significantly lower than the minimum value at which the four site groups were differentiated in the spring reference site UPGMA clustering, 0.53 (fig 12). Of the three operators, none had Bray Curtis dissimilarities > 0.3 when compared with Laurie Cook (the experienced operator), when the first two sample duplicates were discounted. These two samples were performed as part of each operator's training in sampling and picking procedures, in winter, before they were allowed to collect RAP data used in site assessment.

Table 11 Results of pairwise comparison of RAP sampling operator performance

Comparison	Wilcoxon signed rank test p Number of taxa	Abundance	Mean Bray Curtis Dissimilarity	Spearman rank correlation	N
L. Cook - N. Mitchell	0.24	0.29	0.25	all p < 0.05	11
L. Cook - J. Jackson	0.34	0.92	0.18	all p < 0.001	11
L. Cook - W.Elvey	0.07	0.07	0.27	all p < 0.01	4

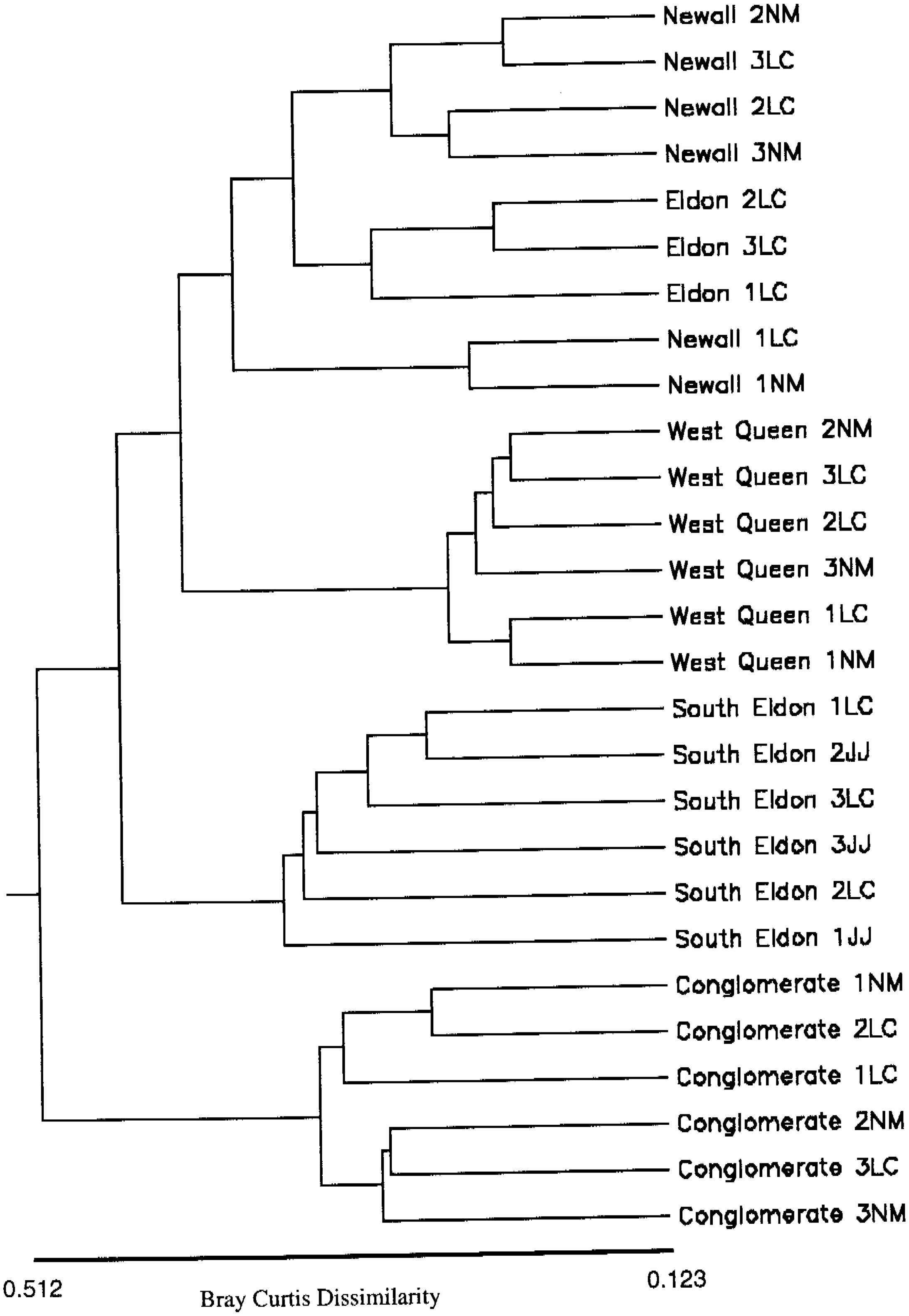


Figure 24 Dendrogram resulting from UPGMA classification (beta = –0.1) of sites sampled for comparison of variation between riffles and sampling operators. Site nomenclature as follows: river name, riffle number (1–3), operator initials (LC or NM.

All riffles sampled in duplicate by different operators classified with other riffles from the same river (fig 24), with no misclassifications. Riffle samples collected by different operators did not, however, consistently classify with the samples from the same riffles.

These results indicate that operators were highly comparable with regard to the number of taxa, total and rank abundances of macroinvertebrate fauna collected from the same riffle. They also indicate that inter-operator differences in sampling and picking were not significant enough to obscure differences between rivers or river groups, although they were sufficient to obscure differences between similar riffles within reaches. Inter-operator differences were therefore not seen as a significant source of error in developing a RIVPACS model nor in monitoring sites using that model.

4.1.2 Fish sampling

General survey

The general survey of streams in the Mount Lyell region identified 33 streams with fish and 8 streams or stream sections without. The site locations are shown in fig 25. No tributary stream of the Queen River had native fish, indicating that migration of juveniles, and possibly mature adults, is not occurring through the AMD-polluted waters of the Queen River. Trout, both brown and rainbow, were found in a number of tributaries of the Queen and King Rivers, with evidence of regular recruitment through spawning as a full range of age classes was found in each. Anecdotal information indicates that most, if not all, of these populations have resulted from stocking as opposed to local migration of fish.

Survey of the King River and related streams

Electrofishing with the boat mounted shocker revealed no fish in the lower King River, while in the lower Henty River, a large number of fish of five species was sampled (table 3). Deep water precluded entirely quantitative sampling in the Henty River, but results were sufficient to indicate that the King River would be likely to contain a diversity and high abundance of native and introduced fish (trout and salmon) if unpolluted.

Electrofishing also revealed populations of native fish (shortfin eel, climbing galaxias and mountain galaxias) in the most downstream tributaries of the lower King River (table 3). The diversity and abundance of these native fish decreased rapidly upstream through the catchment of the lower King River (fig 25). Only eels or trout were found in Lower Landing, Swift, Open and Starting Creeks, while only trout were found in the furthest upstream tributaries—West Queen, Halls and Newall Creeks and in the King River upstream of the Queen River confluence.

Fish length frequency distributions are shown in fig 26 to 28 and length data are listed in appendix 5. The sizes of *Galaxias truttaceus* and *G brevipinnis* in the lower King River tributaries ranged from 132 to 180 mm and 128 to 180 mm, respectively.

Electrofishing of two tributaries of the Henty River (Tully River and McCutcheons Creek) and of three streams draining into the northern arm of Macquarie Harbour (Manuka River, Connellys Point and Botanical Creeks) revealed large populations of *Galaxias truttaceus* (as well as several other fish species) with size classes ranging from 50 to 150 mm (fig 26, appendix 5). Few *G brevipinnis* were found in these streams, with the exception of Porteus Creek, but small (46–100 mm) size classes of this species were found in each of Manuka and Tully Rivers and McCutcheons Creek (fig 27). The sample of *G brevipinnis* from Porteus Creek did not contain any small, young fish. This may be due to the nature of the stream (a small, steep tributary of the Manuka River high in the drainage network) which may be a more suitable habitat for older *G brevipinnis*, or it may be a result of the small sample size.

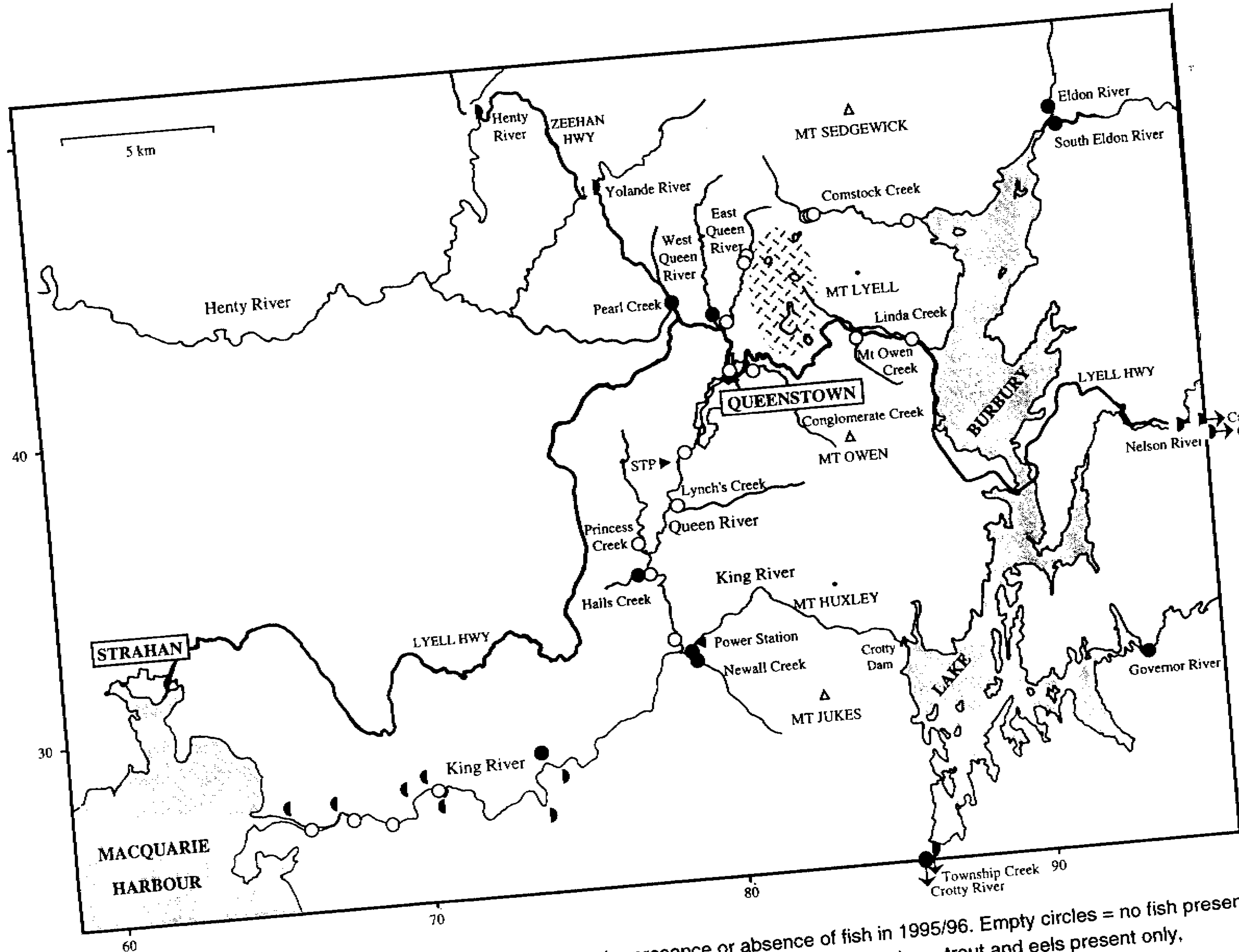


Figure 25 Map of the King and Queen River catchments indicating the presence or absence of fish in 1995/96. Empty circles = no fish present, filled left-hand half circles = native galaxiid fish and eels present only, filled right-hand half circles = trout and eels present only, filled circles = trout present only. Cross-hatched area = Mount Lyell Copper Mine.

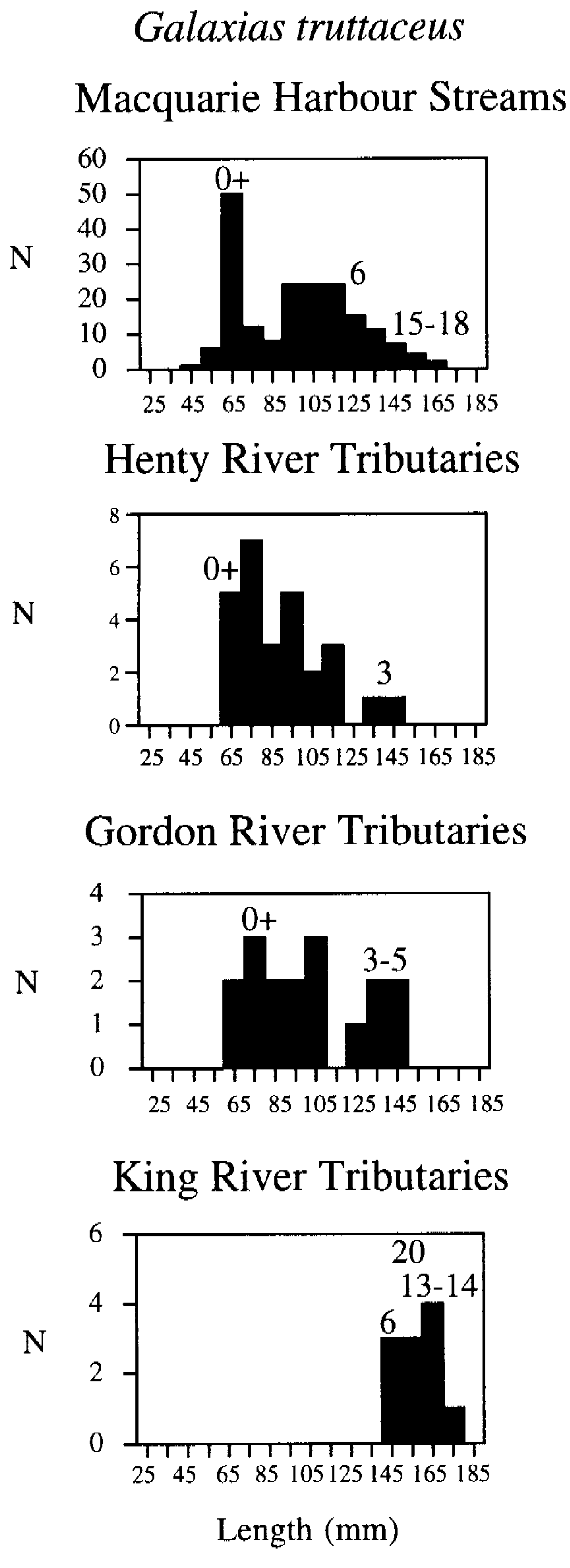


Figure 26 Length frequency distributions for spotted mountain galaxias (*Galaxias truttaceus)* in streams of the Macquarie Harbour-Henty River area (see text), during late summer 1996. Ages determined from otoliths are shown superimposed over the corresponding length intervals.

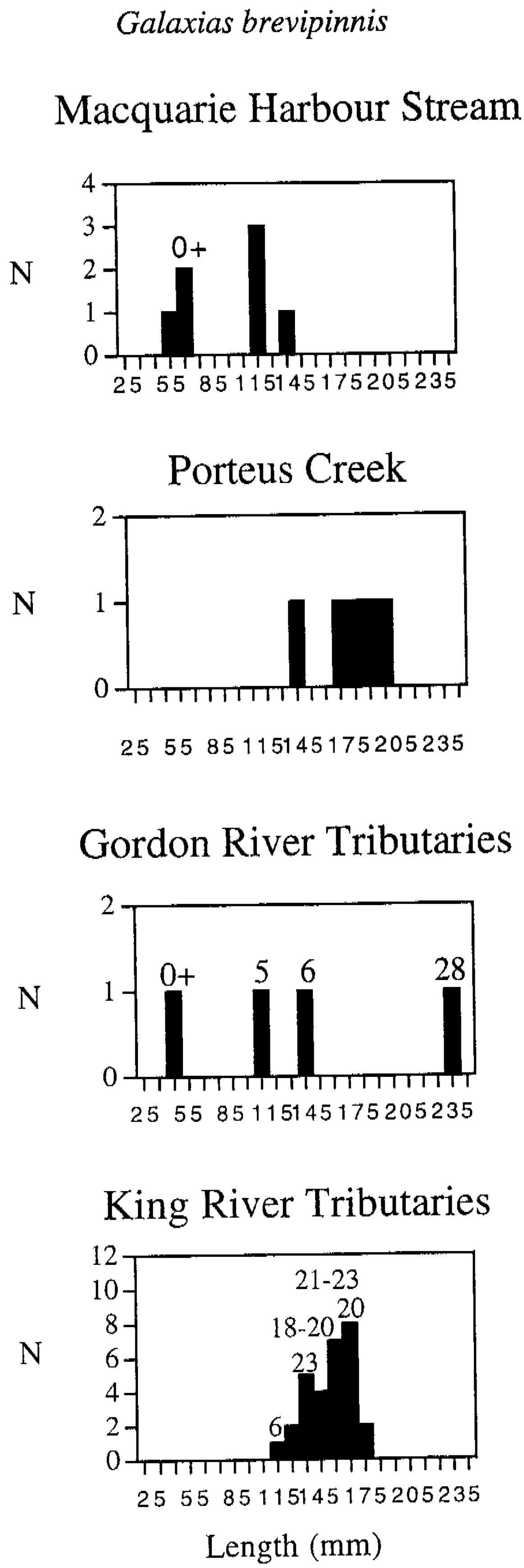


Figure 27 Length frequency distributions for climbing galaxias (*Galaxias brevipinnis)* in streams of the Macquarie Harbour-Henty River area (see text), during late summer 1996. Ages determined from otoliths are shown superimposed over the corresponding length intervals.

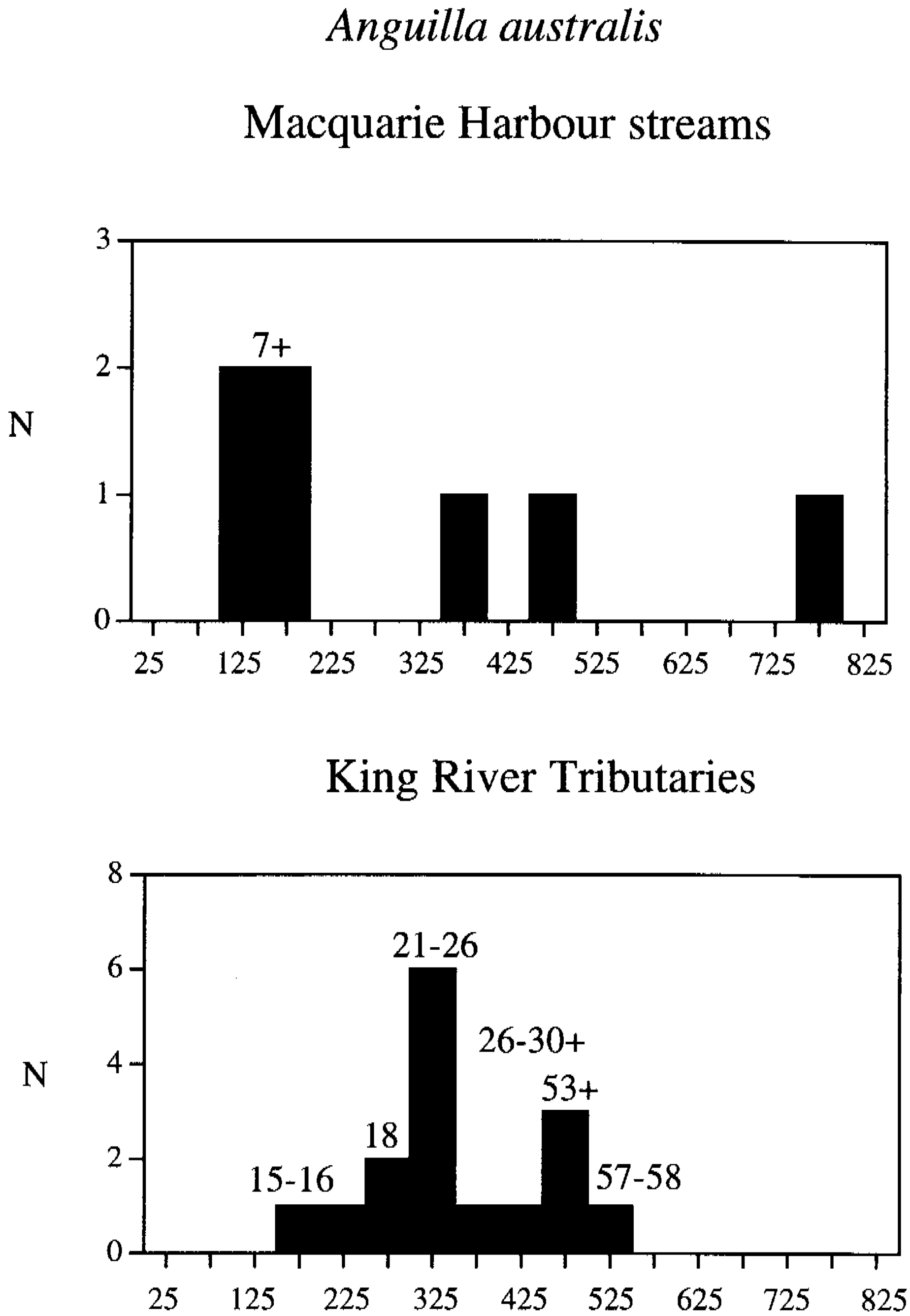


Figure 28 Length frequency distributions for short fin eel (*Anguilla australis*) in streams of the Macquarie Harbour-Henty River area (see text), during late summer 1996. Ages determined from otoliths are shown superimposed over the corresponding length intervals.

Three small tributary streams of the Gordon River with catchment sizes and confluence distances from Macquarie Harbour similar to the tributaries of the lower King River were electrofished. This also revealed high densities of *G truttaceus*, with predominantly younger fish (sizes ranging from 60 to 145 mm, fig 26, appendix 5).

Samples of fish from a range of size classes and all stream types were aged by examining otoliths. Clear increments were observed across the majority of otoliths. These were assumed to be annual increments due to:

- the confirmation of annual increments in otoliths of *Galaxias truttaceus, G brevipinnis* and *A australis* in other studies (although generally only at young ages)

- the general consistency of age-size class relationships between streams for the same species
- the strong linear regression of otolith size against weight for all three species (all $r^2 > 0.95$)

Ages ranged up to 18, 28 and 58 years for *Galaxias truttaceus, G brevipinnis* and *A australis*, respectively (figs 26 to 28). The youngest ages recorded for the two galaxiid species in tributaries of the King River were 6 years, and not all age classes were represented at larger sizes in these populations. In contrast, 0+ fish of both species were found at all sites sampled in streams draining into Macquarie Harbour and in tributaries of the Gordon and Henty Rivers, and in these streams, all size and age classes were represented. This indicates that regular, annual recruitment of the two galaxiid species is occurring in all unimpacted streams draining into Macquarie Harbour and in tributaries of rivers in the region, with the single exception of the King River.

Shortfin eels (*A australis*) sampled in tributaries of the King River were all older than 15+ years of age. Eels sampled from Manuka River, Connellys Point Creek and Botanical Creek contained younger age classes (7+), but the small sample size precludes further analysis.

Overall, these data indicate that annual or frequent recruitment of both species of galaxiids and eels is a typical feature of rivers draining into Macquarie Harbour and the adjacent West Coast, and that juvenile galaxiids are found in high abundance in all coastal streams and rivers and their tributaries. This is in contrast to the tributaries of the lower King River where recruitment is apparently intermittent and has ceased since 1989.

These results indicate therefore that:

- water and habitat quality in most tributaries of the Queen and King River are sufficient to support a diverse and abundant macroinvertebrate fauna (see section 4.1.2) as well as a native and introduced (trout) fish fauna;
- that the fish fauna of King and Queen River tributaries upstream of Open Creek is restricted to introduced and self-sustaining populations of introduced trout, most probably due to poor water quality acting as a barrier to upstream migration from the main rivers;
- eels are able to migrate further upstream and more frequently in the King River (to Open Creek) than the galaxiid fishes which only migrate as far upstream as Virginia Creek;
- while recruitment of catadromous galaxiid fish into other streams of the region is occurring annually, recruitment into the tributaries of the lower King is intermittent and has ceased since 1989.

4.2 Water quality

4.2.1 Pre-mine closure

Examination of pre-mine closure water quality data for the lower King (MLMRCL site 29) reveals high concentrations of total copper, aluminium, iron, and manganese (typically in the 0.5 to 5 mg/L range with occasional high concentrations up to 17 mg/L), moderate levels of zinc (typically 0.05–0.25 mg/L range, up to 1.6 mg/L) and low concentrations of arsenic (up to 0.2 mg/L). All ANZECC (1992) guidelines for metals were exceeded at all times at this site. pH ranged between 3.8 and 6, with a median of 4.7. Sulphate concentrations were very high, typically 10–60 mg/L with maxima up to 650 mg/L, accompanied by high conductivities (in the range 100–1000 µS/cm). Suspended solid concentrations were extreme, in the 100–10,000 mg/L range. Further details are described by Locher (1995).

Water quality in the Queen River at Queenstown (MLMRCL site 14) was consistent with that in the lower King in its nature, but was more extreme. Very high concentrations of total copper, and zinc and manganese were recorded (typically in the 2.5 to 25 mg/L range with occasional high copper concentrations up to 46 mg/L), as well as high concentrations of arsenic (typically 0.5–2.0 mg/L range, up to 3.5 mg/L). Concentrations of aluminium and iron were extreme (typically 15–150 mg/L). All ANZECC (1992) guidelines for metals were exceeded at all times. pH ranged between 2.9 and 6.5, with a median of 4.5. Sulphate concentrations were extreme, typically 100–1200 mg/L with maxima up to 3000 mg/L, accompanied by very high conductivities (in the range 400–2800 µS/cm). Suspended solid concentrations were also extreme, in the 10,000–250,000 mg/L range.

Relationships between water quality variables and river discharge are shown for the lower King River (MLMRCL site 29) and the Queen River at Queenstown (MLMRCL site 14) in figs 29 to 32. The trend for most analytes was for a negative correlation with discharge, with all extreme values at low (< 50 m^3s^{-1}) discharges. No such trend was shown for pH, which reflects the complex nature of the tailings and AMD pollution pre-mine closure, with tailings providing a marked degree of pH buffering at all discharges. The negative correlations with discharge were considerably stronger for analytes in the Queen River, where the relationship between concentrations and discharge was dictated primarily by dilution from runoff than for the King River, in which flow and dilution conditions were more complex both pre- and post-construction of Crotty Dam (see Koehnken 1996). Most relationships shown in figs 31 and 32 are markedly curvilinear.

4.2.2 Post-mine closure

Extensive survey of RAP sites

The sampling of all streams on four occasions allowed a broad 'snapshot' of the water quality of streams in the Mount Lyell region to be obtained. All samples were taken at or near base flow on each sampling occasion and therefore do not represent flood conditions. Water quality data for all sites are shown in appendix 1. Results are summarised in table 12. The monitoring sites are typified by having low pH and high conductivities associated with high sulphate and copper concentrations. Some key relationships between water quality variables were explored (figs 33 and 34). Correlations between dissolved and total copper over all samples collected indicate that in all AMD-affected sites, all copper was dissolved (or adsorbed to fine < 0.45 µm colloids). Only at two sites was there some significant particulate copper, on two separate occasions. Total copper was highly correlated with sulphate concentration over all sites sampled, with few exceptions (fig 33), indicating the close relationship between these two ions across the region. Conductivity was highly correlated with sulphate and copper (r^2 = 0.94, 0.90, respectively, both $p < 0.0001$, $n = 117$), and not surprisingly, with total dissolved solids (fig 33). Dissolved organic carbon, only sampled on two occasions, ranged from 0.2 to 14 mg/L, with higher levels associated with higher pH values in unpolluted sites (fig 34). No AMD-polluted sites had high (>3 mg/L) DOC levels. DOC was not well correlated with colour at AMD-polluted sites due to the presence of other colour sources in those waters, but was correlated with an independent measure of 'tannins and lignins' (substances reducing folin-phenol reagent).

Intensive monitoring, Queen and King Rivers

Relationships between water quality variables for the lower King River (DELM site 18) and for the Queen River at Lynchford are shown in figs 35 and 36. Both of these data sets comprised bursts of short-interval sampling and represent the only post-mine data sets with sufficient data density for further analysis. Data for the period from mine closure to present for the Queen River at Queenstown were insufficient for analysis.

Close correlations between dissolved copper and manganese, and copper and aluminium are found (figs 35, 36) at both sites (note that it is uncertain whether the lower limb in the copper-manganese plots is either 'real' or due to laboratory error). These relationships indicate a common origin (the AMD source material) and may also suggest adsorption onto common colloidal hydroxide material < 0.45 μm in size (Koehnken pers comm). Further detailed analysis is required to evaluate the form of metals in the Queen River at various points downstream and under a range of flow and pH conditions.

Plots of mean, median and variability (standard deviation around the mean) for copper and iron against sampling frequency (with sampling at the same *fixed* time of day) are shown for the two DELM sites in figs 37 to 41. In figs 37 and 38, these relationships are shown, along with values determined at eight-daily sampling performed at *randomly* defined times of day. Note that the following trends for manganese (not shown here) are similar. They indicate that, for the lower King and Queen Rivers:

- any sampling frequencies greater than four hourly, ranging up to fortnightly, cause substantial distortions in the estimate of mean, medians and standard deviations (sampling daily causes medians and standard deviations to be in error by up to 67% and means by up to 40%; sampling weekly increases these errors to up to 160% and 55%, respectively); and
- that while some improvement is shown with randomly allocated sampling times during the day, this is not great (random sampling would also be impractical for spot sampling purposes, either by hand or by automatic sampler).

These results suggest that high sampling frequencies would be required for the King and Queen Rivers respectively, in order to estimate the mean, standard deviation and median values for all four metals with an acceptable error.

5 General discussion

5.1. Condition of streams of the Mount Lyell region

This project has described the biological condition and general water quality characteristics of the streams of the Mount Lyell region for the first time. Previous biological sampling on only two occasions in the Queen River at Queenstown by S Lake and PE Davies (unpub data) in the 1970s and 1993 failed to detect any macroinvertebrate fauna, in contrast to the present study's results. Though this may suggest some change since mine closure, coincident with some improvement in water quality, it is insufficient evidence of recovery due to differences in sampling effort and lack of replication in the earlier sampling events.

Previous monitoring of the upper King River, Comstock and Linda Creeks indicated that their biological condition was poor (Lake et al 1977, Swain et al 1981, Fulton 1989), with a depauperate macroinvertebrate fauna, in contrast to the upper King, Princess and Nelson Rivers.

While the fish fauna of the unpolluted Henty River is both abundant and diverse, fish are completely absent from the lower King River. The survey of tributaries of the King River revealed the presence of two species of native galaxiid fishes and shortfin eels. These species are, in contrast to trout, incapable of reproducing without a marine life stage. Thus, stream populations are sustained only by migration of juveniles from marine waters. This suggests that water quality is occasionally sufficient to allow migration of juvenile galaxiids and eels through the lower King River, but that juvenile galaxiids are less tolerant of the water quality conditions during migration than eels (elvers).

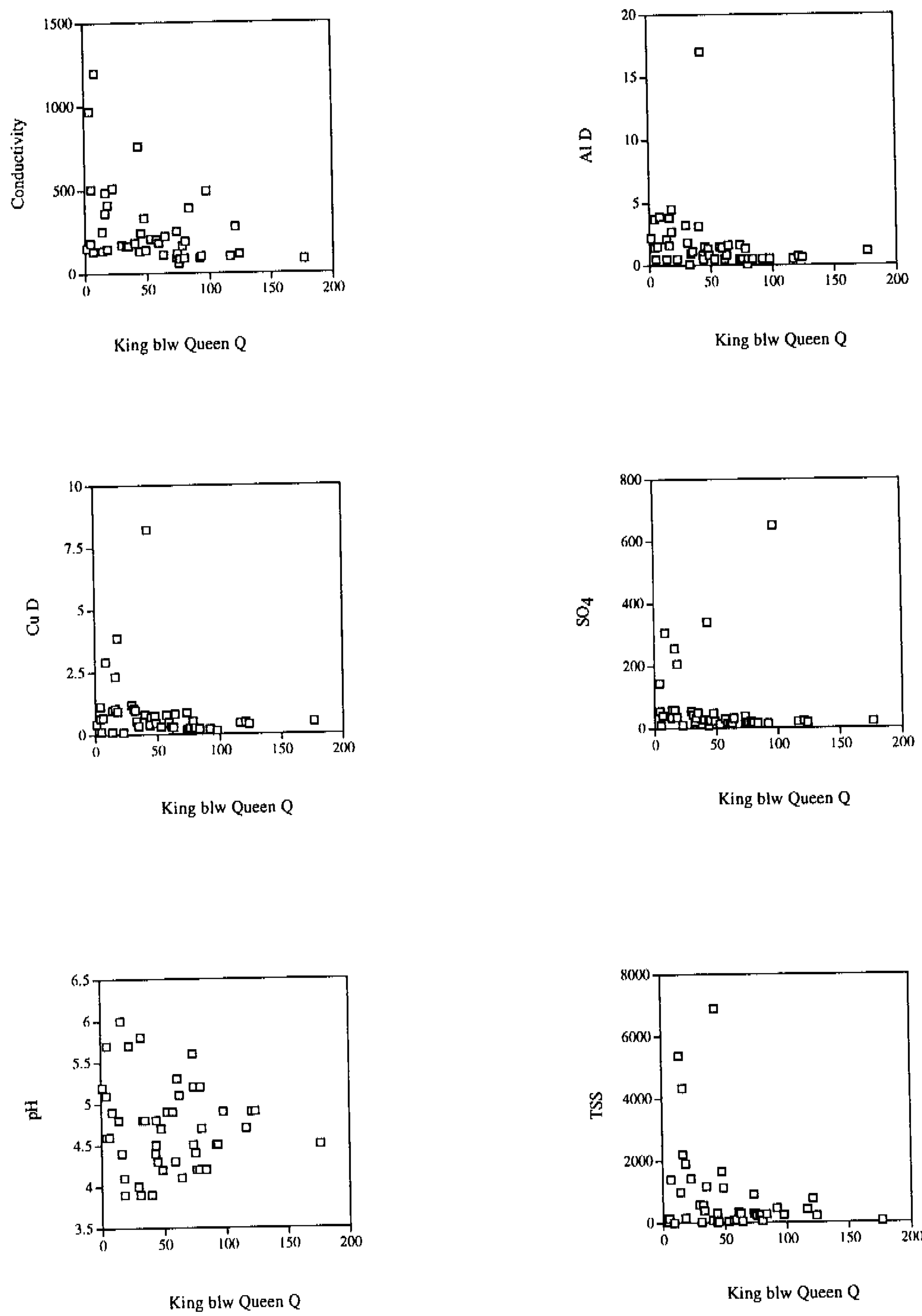


Figure 29 Plots of water quality in the lower King River at MLMRC site 29 against mean daily discharge for the period 8/1/1991 to 19/12/1994. All units in mg/L except conductivity (μS/cm) and pH. Discharge is in m^3s^{-1}. D = dissolved, T = total

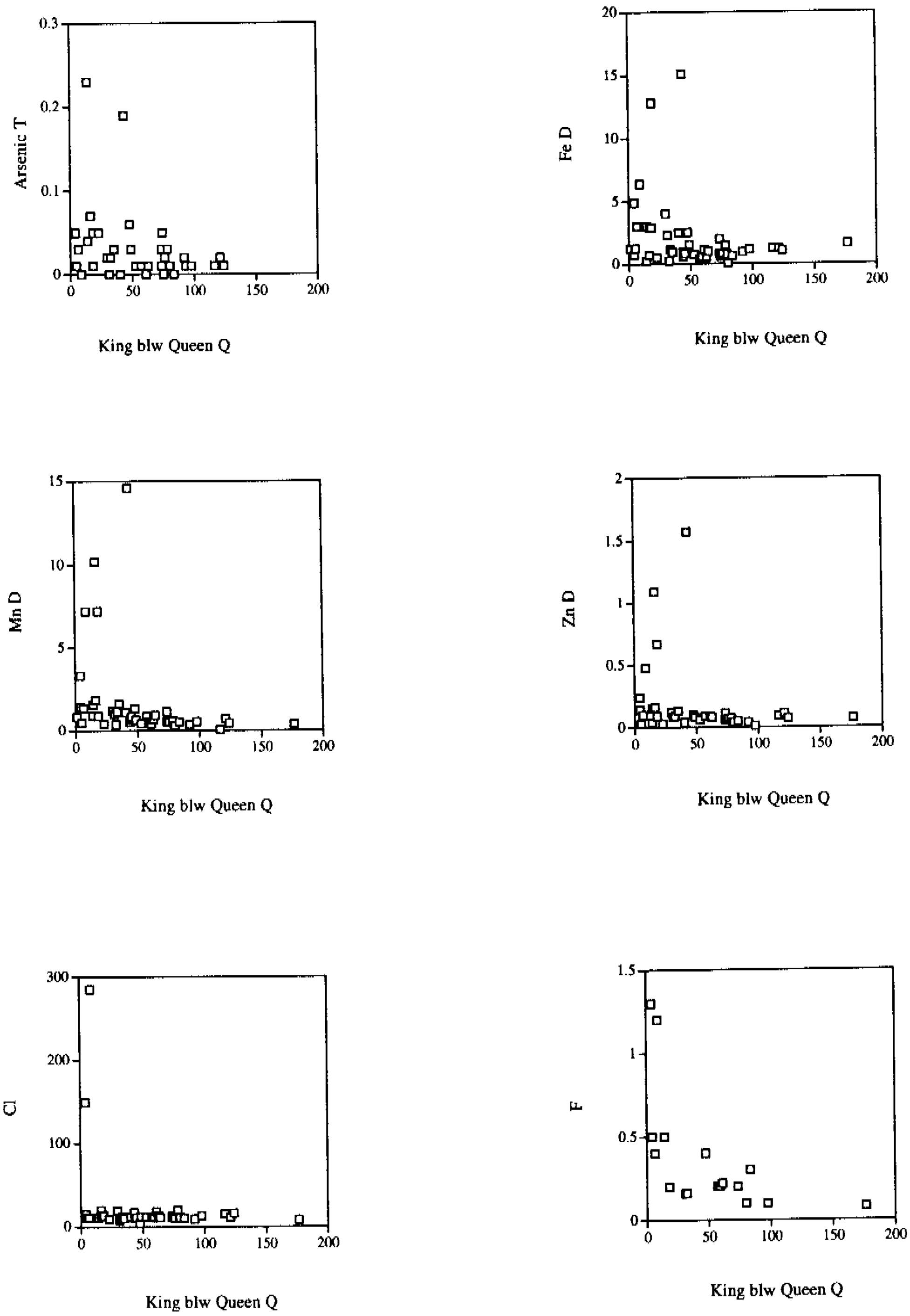


Figure 30 Plots of water quality in the lower King River at MLMRC site 29 against mean daily discharge for the period 8/1/1991 to 19/12/1994. All units in mg/L except conductivity (µS/cm) and pH. Discharge is in m^3s^{-1}. D = dissolved, T = total

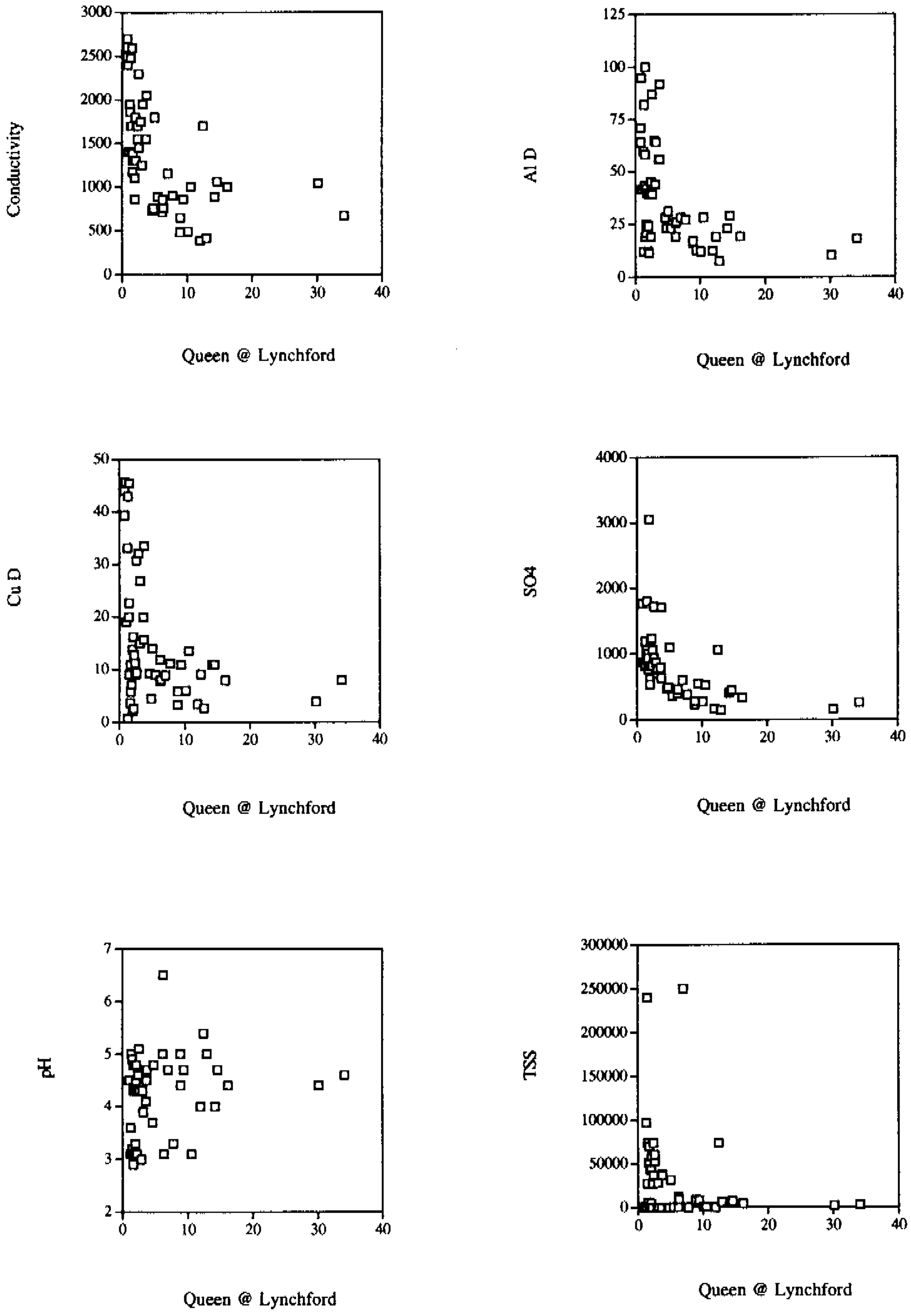


Figure 31 Plots of water quality in the Queen River at Queenstown (MLMRC site 14) against mean daily discharge for the period 8/1/1991 to 19/12/1994. All units in mg/L except conductivity (μS/cm) and pH. Discharge is in m^3s^{-1}. D = dissolved, T = total

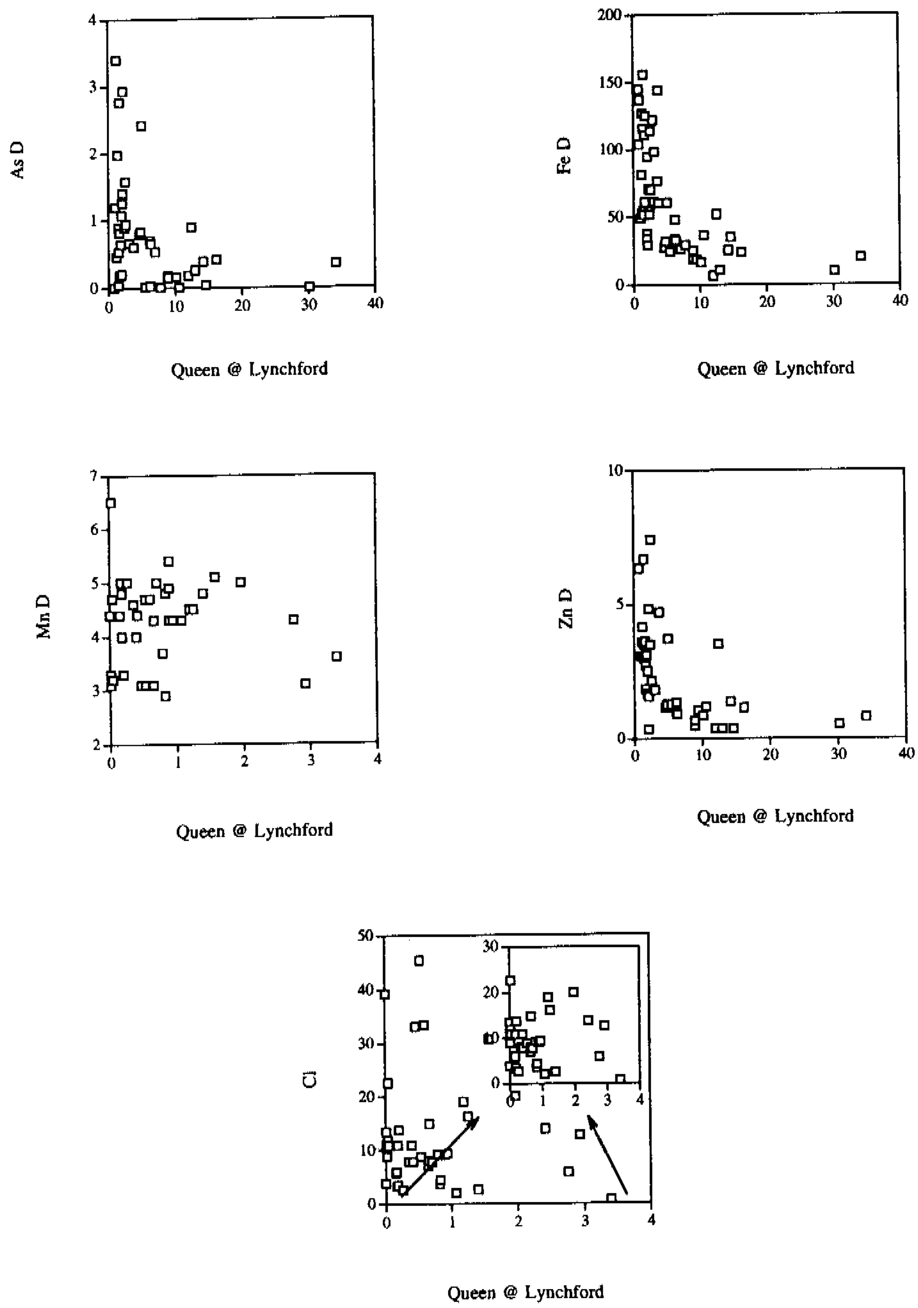


Figure 32 Plots of water quality in the Queen River at Queenstown (MLMRC site 14) against mean daily discharge for the period 8/1/1991 to 19/12/1994. All units in mg/L except conductivity (μS/cm) and pH. Discharge is in m^3s^{-1}. D = dissolved, T = total

Table 12 Mean of all water quality variables for RAP sampled sites, 1995/96, Mt Lyell region

Site	Type	Total Cu µg/L	Dissolved Cu µg/L	pH	Conductivity µS/cm	Sulphate mg/L	Colour Hazen	'Tannins & Lignins' mg/L phenol	TDS mg/L	TSS mg/L	DOC mg/L
Cardigan R	R	6.50	0.63	4.79	28.68	1.13	59.00	0.29	45	0.50	2.85
Collingwood R	R	17.75	0.38	4.95	45.08	1.70	44.50	0.55	42	1.50	2.30
Comstock Ck 1	R	8.00	6.00	4.79	48.05	1.25	144.50	2.04	50	0.51	1.33
Conglomerate Ck	R	42.00	30.25	5.05	52.38	4.25	43.25	0.64	45	10.50	1.10
Crotty R	R	5.25	0.38	4.86	45.00	1.15	76.00	0.75	51	1.88	2.80
East Queen R1	R	19.50	15.50	6.00	46.53	4.60	58.25	0.74	59	0.50	2.33
Eldon R	R	1.25	0.38	4.89	48.95	1.20	59.50	0.37	44	0.38	0.38
Governor R	R	0.50	0.25	3.15	28.35	1.18	27.50	0.00	28	0.25	0.38
Halls Ck	R	88.25	3.75	6.43	96.30	3.56	92.75	0.89	92	1.25	0.65
Henty R	R	10.25	3.75	6.55	49.33	2.53	94.50	0.94	42	1.46	0.38
Lynchs Ck	R	4.25	2.25	4.87	45.50	12.93	33.00	0.23	58	1.38	0.23
Mt Owen Ck	R	41.00	22.75	5.66	40.95	2.23	89.75	1.08	54	1.88	2.48
Nelson R	R	8.50	1.63	6.76	56.98	2.73	73.00	0.53	52	1.75	0.45
Newall Ck	R	3.88	1.88	6.04	55.75	2.00	128.50	2.81	61	1.50	4.28
Pearl Ck	R	23.75	17.00	5.38	42.55	3.03	70.00	1.24	53	1.63	2.35
Princess Ck	R	66.50	16.75	5.42	69.58	7.23	125.75	1.05	84	11.63	0.60
South Eldon R	R	0.88	0.38	4.78	44.33	6.28	90.00	1.43	27	1.00	2.00
Township Ck	R	1.75	0.75	4.33	28.53	2.15	38.50	0.30	47	0.50	0.30
West Queen R	R	6.25	4.50	5.79	44.58	3.58	77.25	0.67	59	0.75	0.38
Yolande R	R	1.13	0.63	4.10	23.38	1.83	77.50	0.56	64	0.75	0.48
Comstock Ck 2	M/R	16.75	12.25	4.60	40.40	1.58	141.00	1.21	47	0.50	0.63
King R 1	M/R	13.00	5.38	6.18	52.18	11.50	107.25	1.53	46	4.25	4.03
Comstock Ck 3	M	1055.00	935.00	3.80	186.38	58.05	177.50	0.72	90	20.50	0.13
Comstock Ck 4	M	159.00	92.75	4.81	73.93	12.78	79.50	0.75	58	4.13	0.08
East Queen R 2	M	522.50	352.50	2.91	94.70	16.75	85.75	0.14	45	9.50	0.53
East Queen R 3	M	1290.00	672.50	3.54	227.75	51.56	63.75	0.18	96	13.75	0.88
King R 2	M	515.00	365.00	4.23	114.13	31.50	149.00	0.76	120	15.63	0.18
King R 3	M	367.50	222.50	3.27	122.50	25.50	106.50	0.36	125	11.88	0.20
Linda Ck	M	732.50	460.00	3.53	218.03	65.50	148.50	0.53	95	17.25	0.08
Queen R 1	M	392.50	236.25	5.67	202.35	51.32	97.25	0.36	300	23.00	0.65
Queen R 2	M	7552.50	6207.50	3.16	791.25	437.15	446.00	1.15	1150	160.75	1.08
Queen R 4	M	6035.00	4760.00	3.20	638.75	283.50	263.00	1.80	350	70.25	1.20

All n = 4 except TDS, DOC (n = 1), and dissolved copper and 'tannins & lignins' (n = 3)

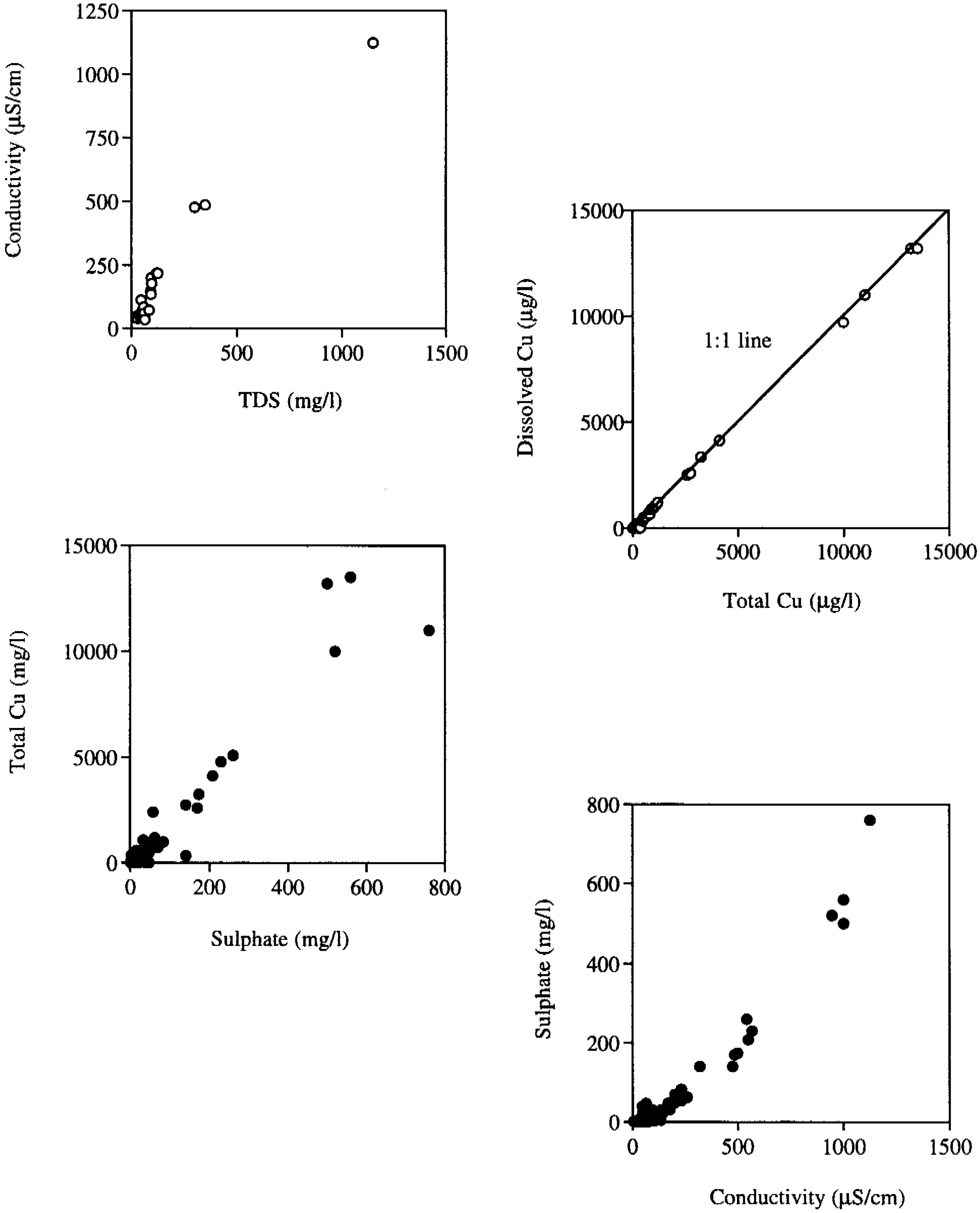


Figure 33 Plots of relationships of key water quality variables for all Mount Lyell RAP sites sampled in 1995/96

Anecdotal information gathered from discussions with a variety of Strahan and Queenstown residents, indicates that galaxiids (known locally as 'tiddlies') have been resident in the lower King River tributaries since at least the 1930s, although not necessarily continuously, and that there was an eel fishery in the lower King River in the early part of this century.

Juvenile galaxiids and elvers migrate into river mouths in the spring-summer period, typically in Sept–Dec. Migration is intermittent, with pulses associated with the period immediately following floods (Fulton & Pavuk 1988). The present age distributions of the two galaxiid species indicate that recruitment into the lower King River has not occurred in the last six years, since 1989. This is in contrast to other streams entering Macquarie Harbour and the Henty and Gordon Rivers, which experience regular annual migrations of *G truttaceus* and *G brevipinnis*.

It is probable that reductions in flood peaks in spring-summer, as a result of the construction of the Crotty Dam (in mid 1991) and the operation of the John Butters power station (which commenced in early 1992), are inhibiting recruitment of native fish to the lower King River tributaries. Marked changes in the hydrology of the lower King are evident from a plot of river heights at Cutten Creek gauging station in the lower King River (fig 43). Flood peaks over 2.0 m gauge height have been essentially eliminated since commencement of power station operations. A similar plot of flows in the Queen River indicates that these changes do not result from changes in rainfall patterns (unpub data).

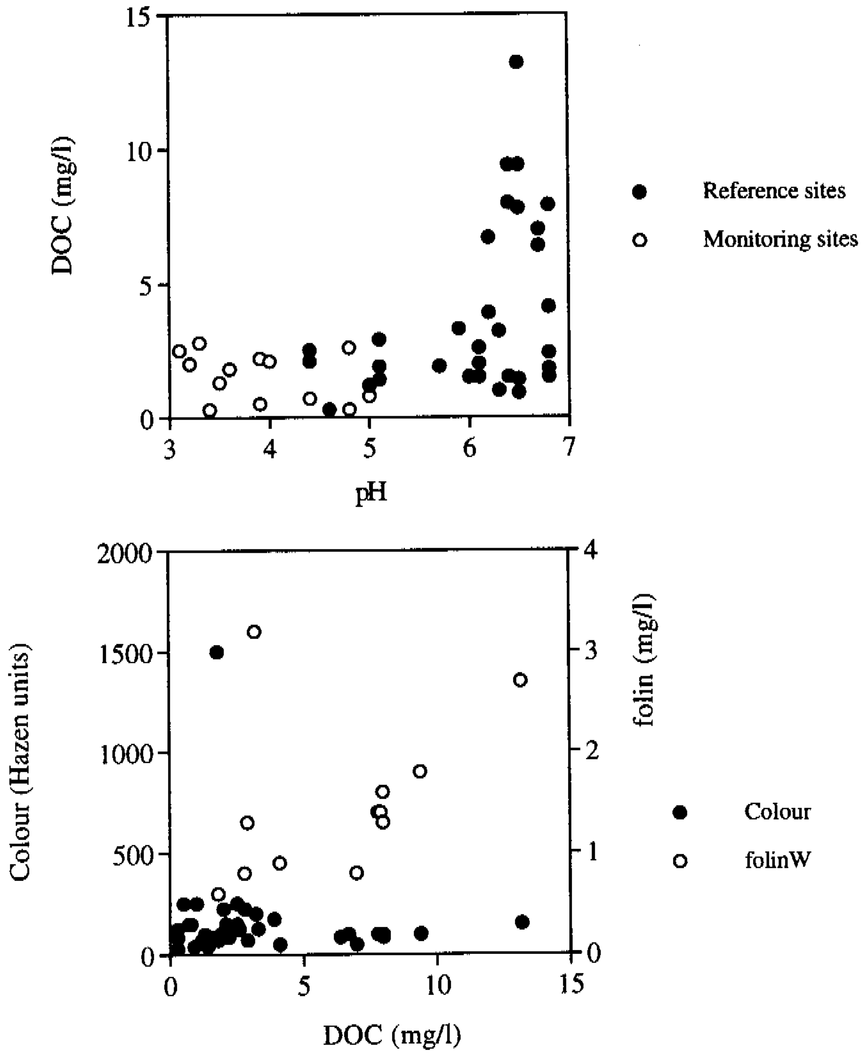


Figure 34 Plots of DOC against pH, colour and tannins/lignins for all Mount Lyell RAP sites sampled in 1995/96

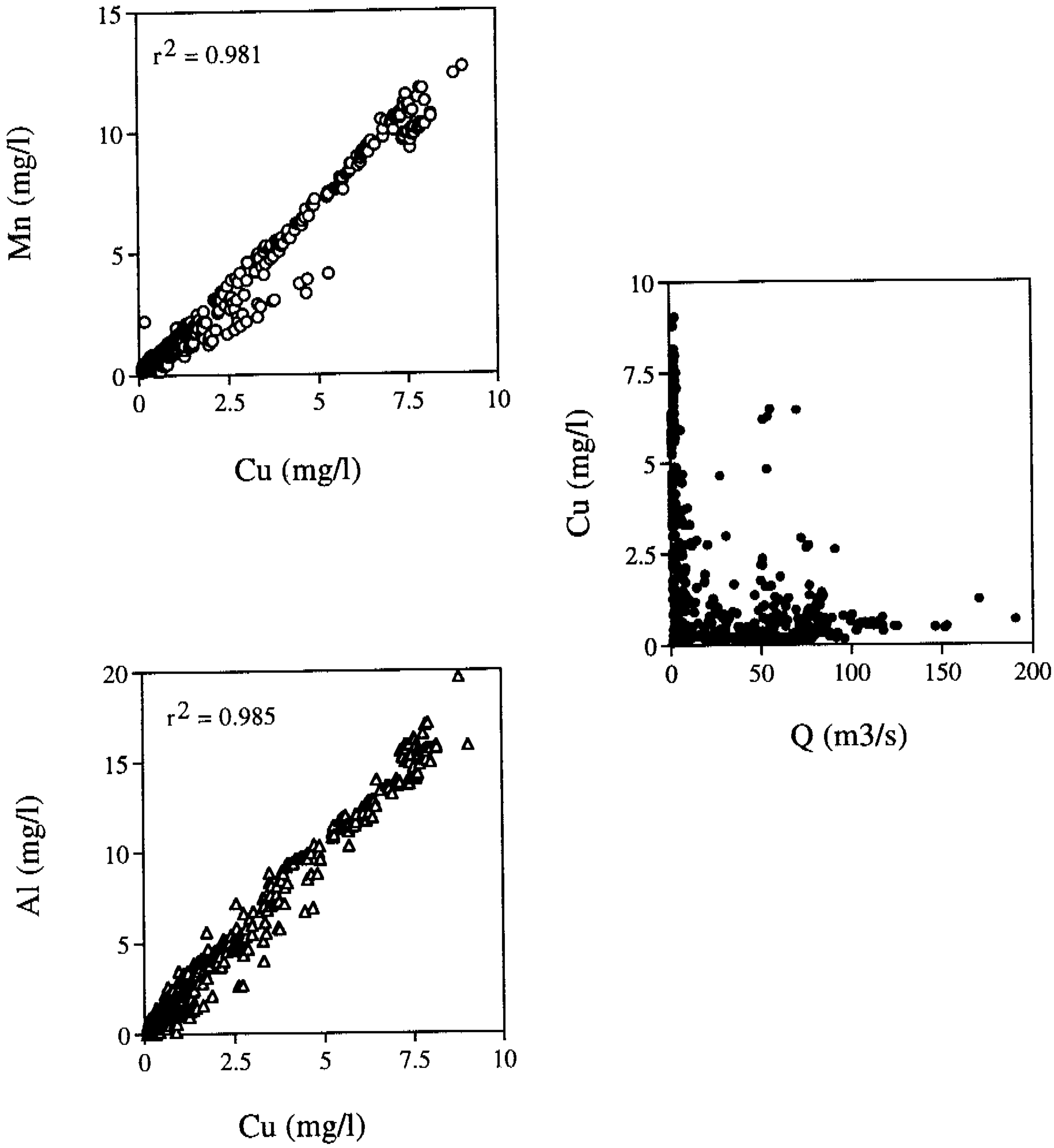
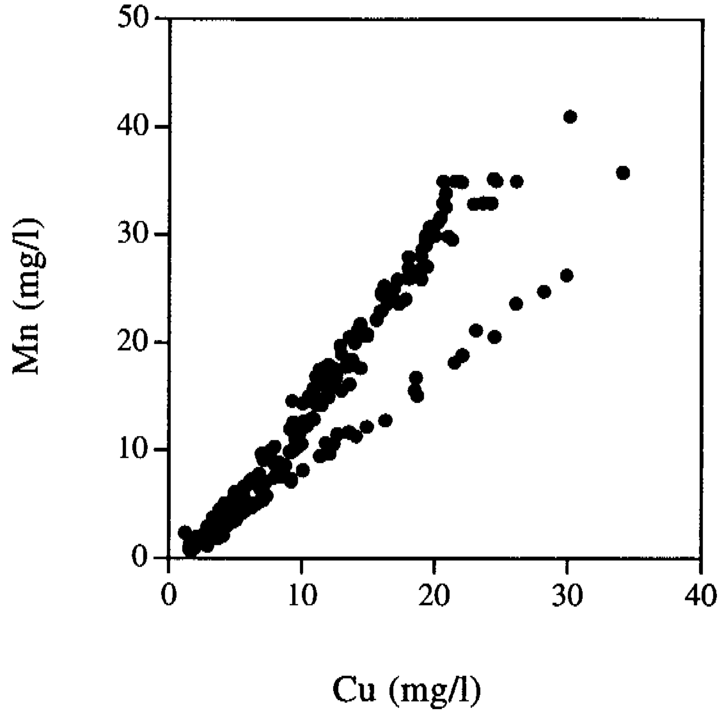


Figure 35 Relationships between dissolved copper concentrations, dissolved manganese and aluminium concentrations, and instantaneous discharge in the King River at Cutten Creek following mine closure in the period 12/12/94 to 16/4/95 (Koehnken, DELM, unpub data)



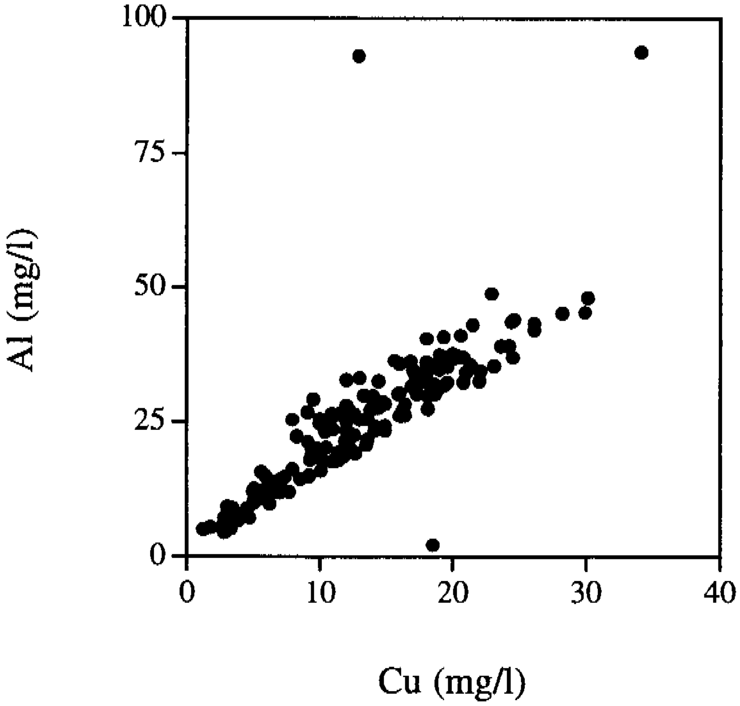


Figure 36 Relationships between dissolved copper concentrations and dissolved manganese and aluminium concentrations in the Queen River at Lynchford following mine closure in the period 12/12/94 to 16/4/95 (Koehnken, DELM, unpub data)

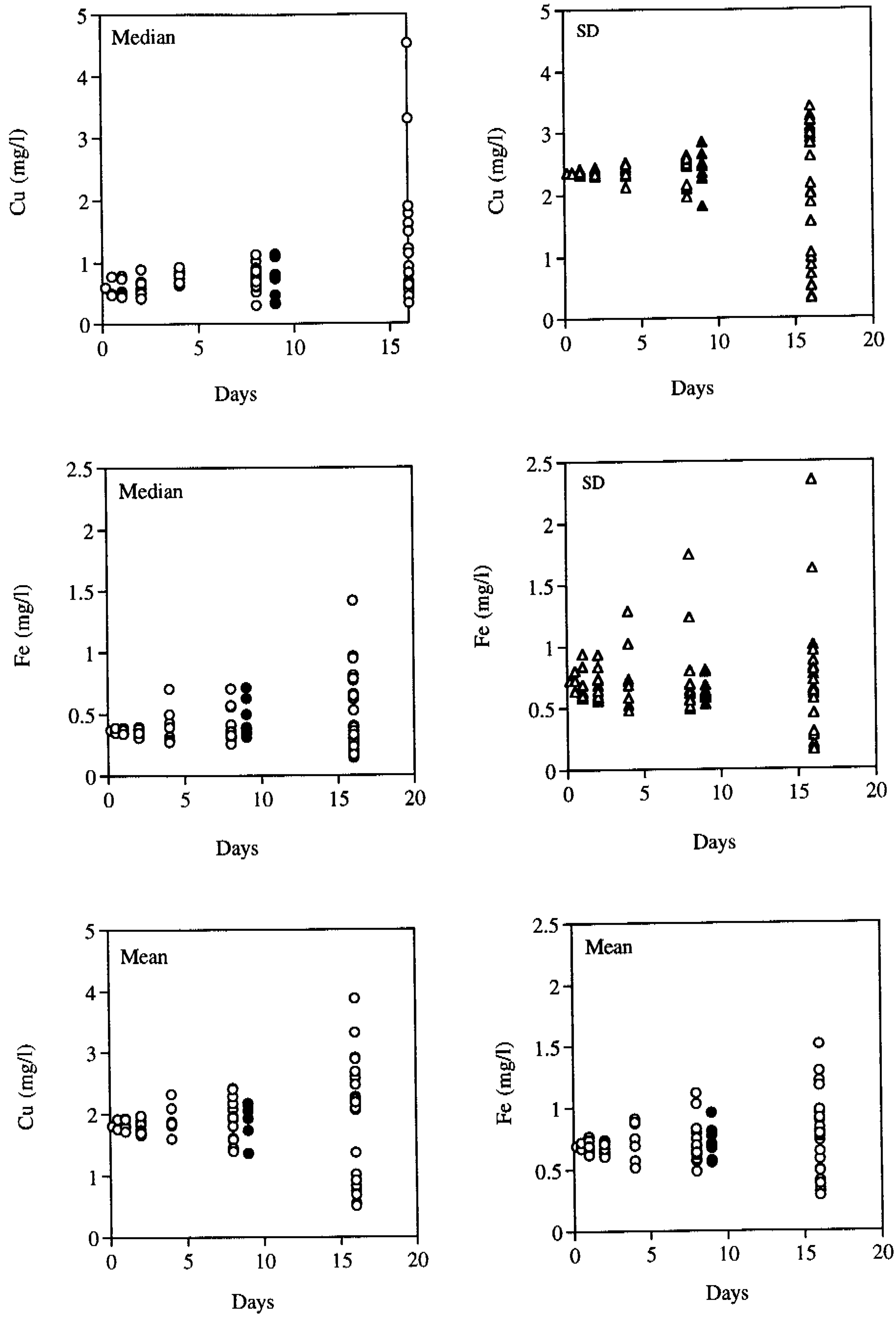


Figure 37 Mean, median and standard deviation of copper and iron in the King River (site 18) against sampling frequency (original data from Koehnken, DELM). White symbols are for frequencies with fixed sampling times, filled symbols are for 8 daily sampling at random times (offset from white symbols)

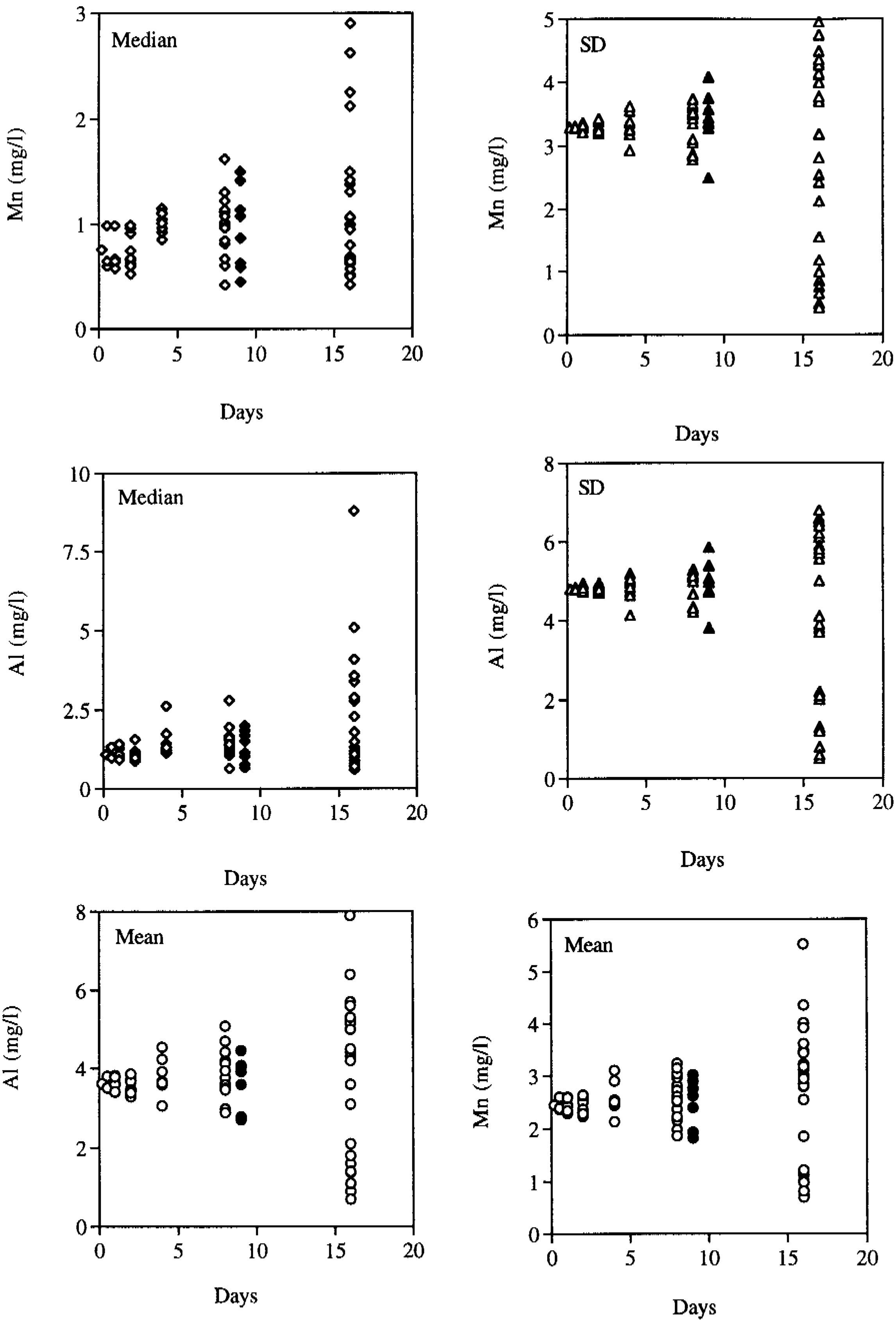


Figure 38 Mean, median and standard deviation of manganese and aluminium in King River (site 18) against sampling frequency (original data from Koehnken, DELM). White symbols are for frequencies with fixed sampling times, filled symbols are for 8 daily sampling at random times (offset from white symbols)

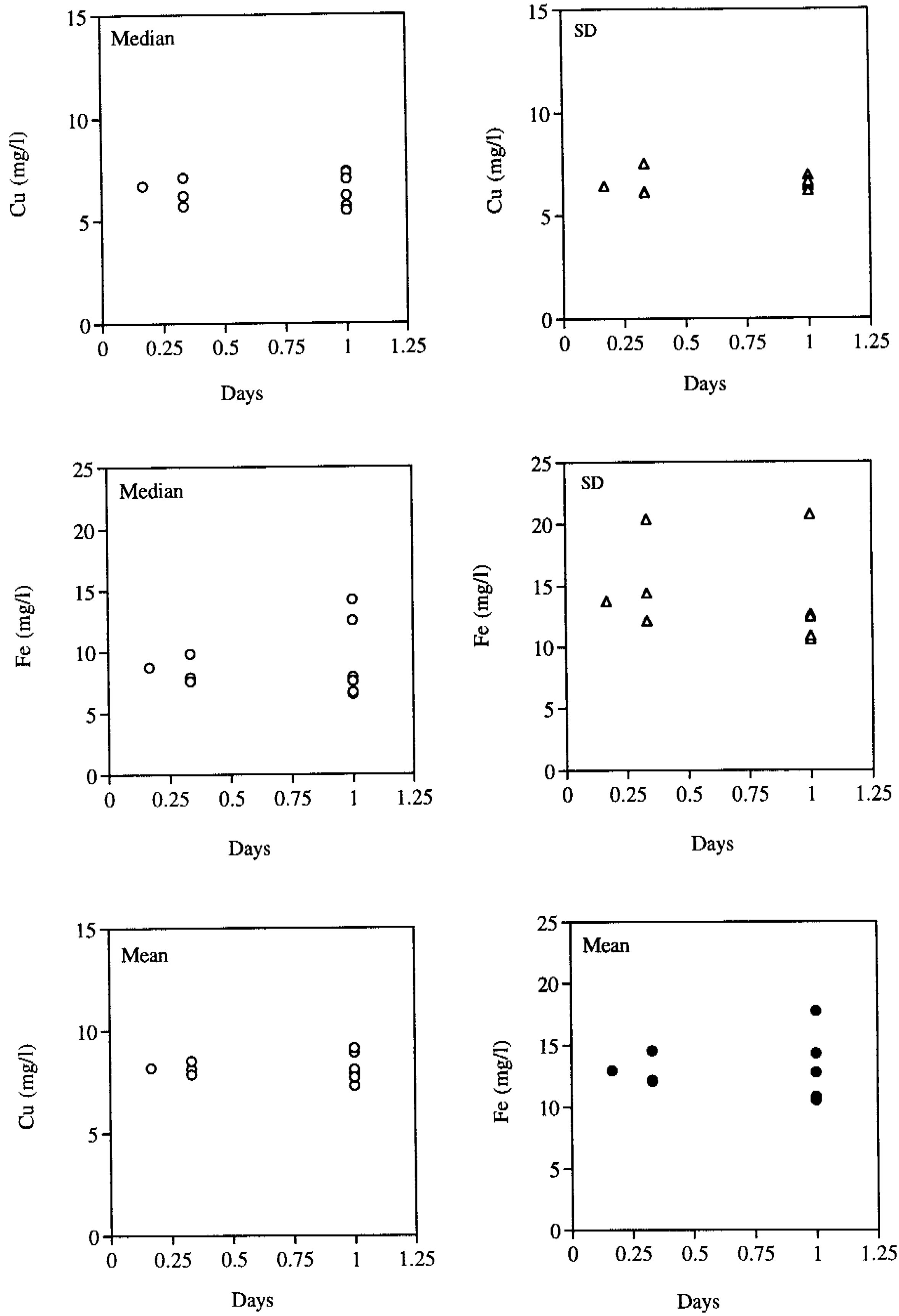


Figure 39 Mean, median and standard deviation of copper and iron in the Queen River (at Lynchford) against sampling frequency at fixed daily sampling times (original data from Koehnken, DELM)

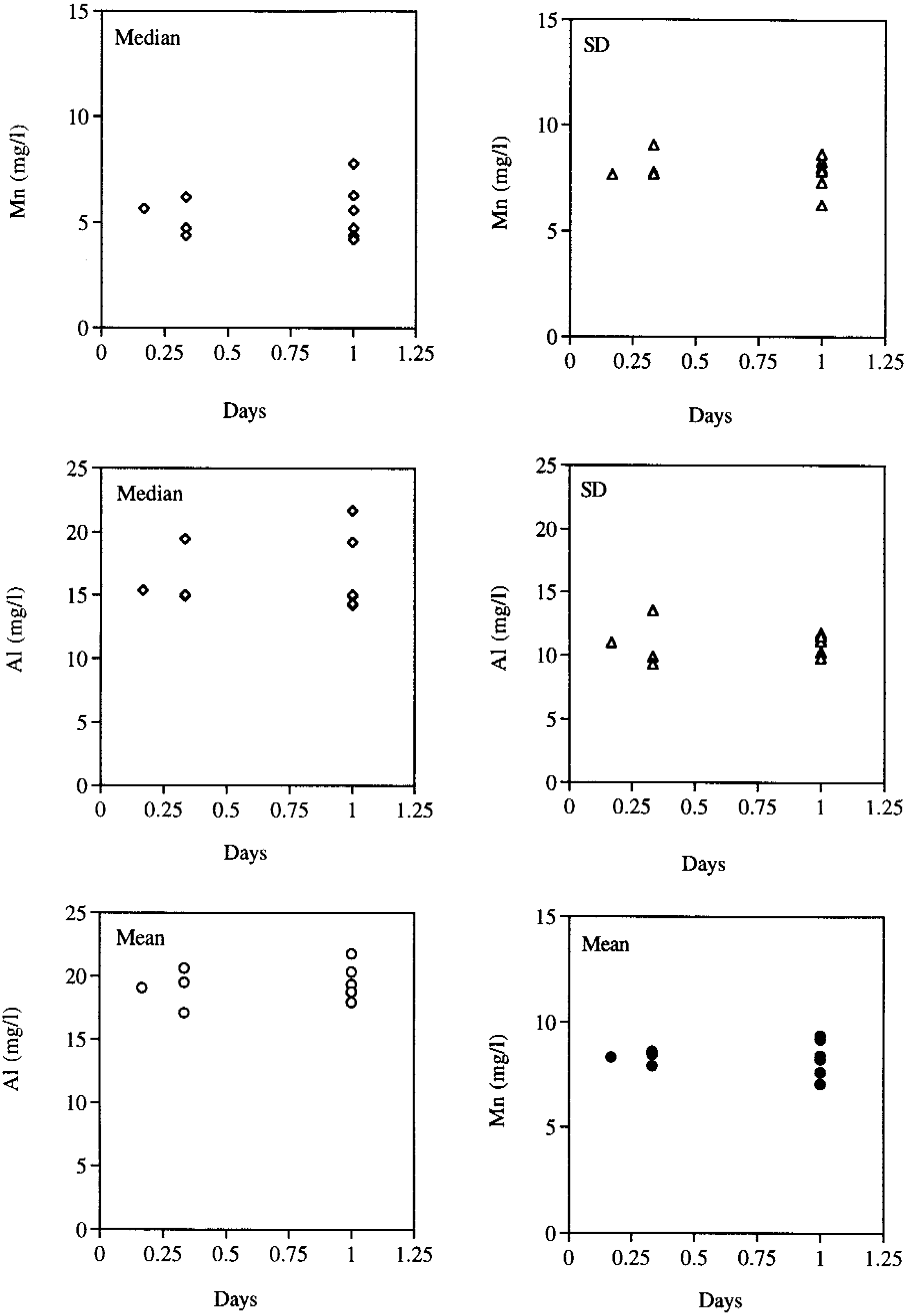


Figure 40 Mean, median and standard deviation of manganese and aluminium in Queen River (at Lynchford) against sampling frequency at fixed daily times (original data from Koehnken, DELM)

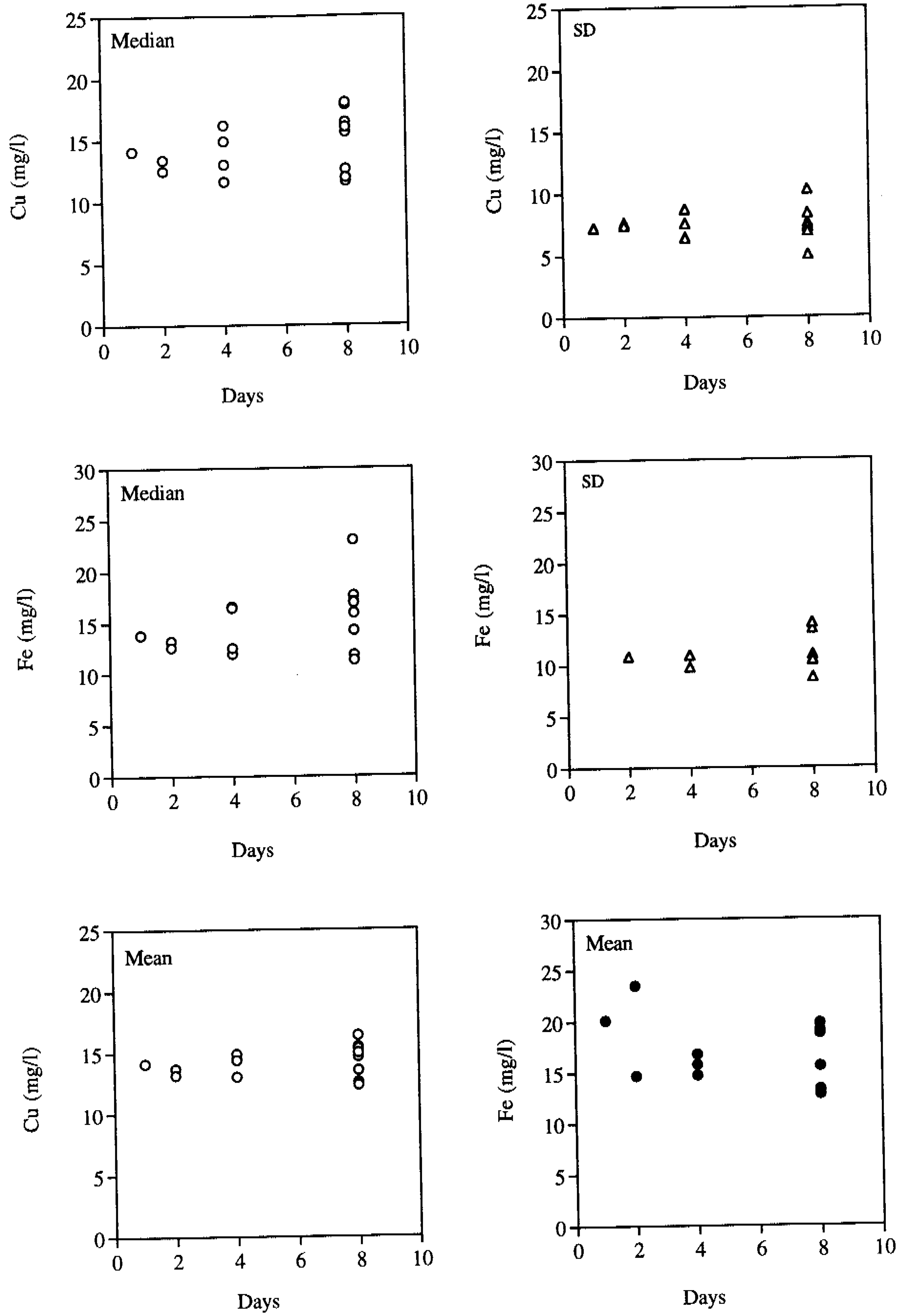


Figure 41 Mean, median and standard deviation of copper and iron in the Queen River (at Lynchford) against sampling frequency at fixed daily times
(original data from Koehnken, DELM)

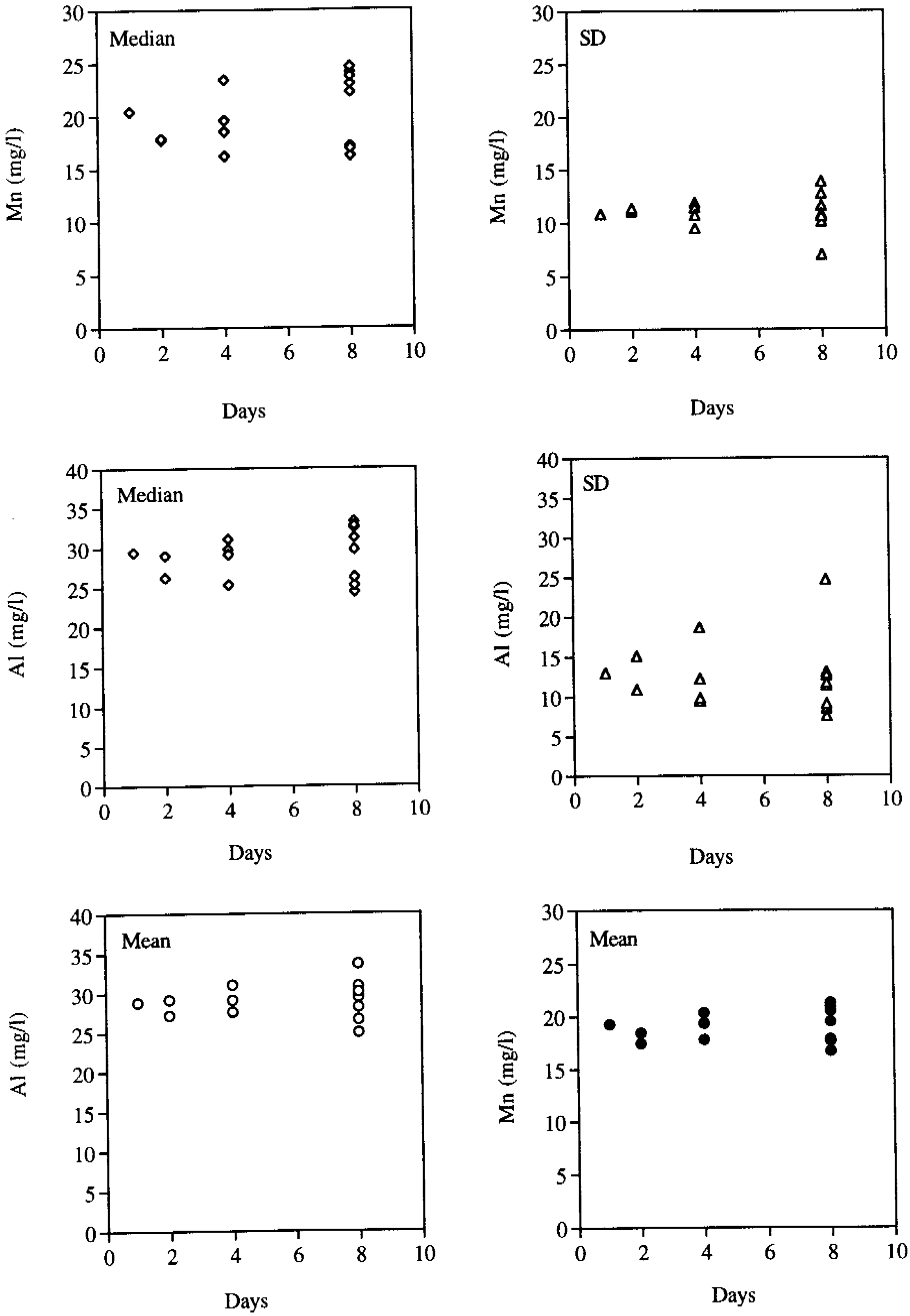


Figure 42 Mean, median and standard deviation of manganese and aluminium in Queen River (at Lynchford) against sampling frequency (original data from Koehnken, DELM)

Such high floods are associated with improved water quality in the lower King River (Koehnken 1996, pers comm) due to dilution of Queen River inflows. Such floods are recognised as being responsible for stimulating the migration of juvenile galaxiids (Pavuk & Fulton 1989) during the late winter–early summer months. Figure 43 also shows the 'windows of opportunity' for galaxiid migration into the King River from Macquarie Harbour. The last major sequence of floods > 2.0 m in height at the Cutten gauge was in 1989. The year preceding and all the years following dam closure have been essentially devoid of flows > 2.0 m height during the critical 'windows'.

It is likely, therefore, that these changes in river hydrology, interacting with the concentrations of toxic metals primarily by dilution, are causing inhibition of migration and hence loss of recruitment of native fish into the catchment of the lower King River. This needs to be confirmed by an experimental evaluation of avoidance thresholds of juvenile galaxiids to King River waters, combined with a more rigorous examination of relationships between metal concentrations, water toxicity and discharge in the lower King River.

Improvement in water quality in the Queen River, by reduction of AMD inputs at Mount Lyell and/or enhancement of flood flows in spring, is therefore likely to stimulate more regular and extensive migrations of galaxiid fish into the lower King River and its tributaries. The complex relationships between total and dissolved metal concentrations and river flow conditions (Koehnken 1996) preclude a simplistic estimation of the reduction in mass loading through site remediation that would be required to do this, particularly as galaxiid migration is at least partially dependent on the timing and magnitude of floods (Pavuk & Fulton 1989).

Pollution with AMD from the Mount Lyell lease area results in elevated levels of toxic metals, particularly copper and aluminium, low pH values and elevated levels of associated anions (eg sulphate). While natural DOC levels are high, the low pH and high ionic content of the main receiving streams mitigates against effective complexation of copper and zinc. Relationships between total and dissolved metal indicate that most metal is either in ionic form or in fine (< 0.45 μm) colloidal form. The forms of metals and their relative toxicities to macroinvertebrates require further examination over a range of pH values relevant to ambient conditions.

Although conductivities correlated highly both with sulphate and copper concentrations in the extensive survey of RAP sampled sites, this simplistic relationship does not hold for the Queen River with time. Conductivity-metal concentration relationships for the Queen River are complex due to the high sulphate input from rock dump sources compared with the high copper input from the Price Lyell mine-water pumpout (McQuade et al 1995). Thus, continuous monitoring of conductivity will not, on its own, allow adequate assessment of metal loads in the Queen and King Rivers for monitoring purposes. Monitoring must be supplemented by sampling and analysis for metals specifically.

Streams receiving AMD from point or diffuse sources in the Mount Lyell area have a very low abundance and diversity of stream fauna and have been assessed as heavily or extremely impacted using the MLRIVPACS model. No fish and few macroinvertebrates are found in the Queen, East Queen and King Rivers, Comstock and Linda Creeks. Those streams in poor biological condition all have anomalous water quality characteristics, typified by low pH, high sulphate and high dissolved metal concentrations. The biota of the lower King River is impacted by a combination of AMD pollution and deleterious changes to stream bed substrate characteristics, combined with marked changes to the flow regime. Macroinvertebrate diversities (at both 'family' and 'species' level) are among the lowest published in Australia and the lowest known in Tasmania, even from streams receiving heavily polluted mine waters that have been sampled with comparable techniques (Chilcott et al 1991, Davies 1995). For example, Growns & Growns (1995) cited 34 Australian freshwater macroinvertebrate studies (including eight polluted site studies), none of which had sites with diversities as low as found in the Queen and King Rivers in this study. Sites in the East Branch of the Finniss River have macroinvertebrate faunas approaching those found in the Queen and King Rivers, but a direct comparison is not possible (ANSTO 1993). Some evidence of recovery in a downstream direction was observed in the Queen River and Comstock Creeks, presumably due in part to dilution and active colonisation from tributary stream macroinvertebrate populations.

Though the biological health of the streams polluted by AMD from Mount Lyell continues to be poor, the presence of some invertebrates and evidence of colonisation from tributaries indicates that any significant improvement in water quality and substrate condition resulting from site remediation is likely to be accompanied by rapid responses in stream biological condition.

The lack of a clear relationship between water quality and the number of macroinvertebrate taxa or the RIVPACS scores found for polluted sites in the Queen, King, Linda and Comstock drainages is primarily due to the complex nature of the impact of mining activity on those streams. While current AMD from waste rock dumps and the mine contributes to declines in water quality with associated toxicological responses in the biota, stream habitats have also been structurally impacted. Exposure of stream beds in the Queen, Linda and Comstock drainages has led to deposition of an iron-hydroxide-associated film accompanied by marked cementation of the stream bed and infilling of interstices. Metal rich sediments have been deposited within the stream bed of the Queen River due to two main processes: release of tailings from the mine and deposition of precipitated metal (Fe, Al and Mn) hydroxides under pH values > 4.2 (Taylor et al 1996). Leaching has resulted in cementation of the bed with the insoluble iron hydroxide material, haematite.

Natural stream substrates in the region are dominated by loosely embedded cobble with large numbers of interstices. Such complex bed environments are known to provide diverse microhabitats for macroinvertebrates, often associated with high numbers of taxa (Logan & Brooker 1983, Newcombe & MacDonald 1991). Similarly, bed interstices are traps for coarse particulate organic material (CPOM) such as leaves, and twigs—a major source of food and microhabitat structure for invertebrates (Merritt et al 1984). Observations on all field sampling trips indicated that, while this material was relatively abundant in all reference site riffle kick samples, there was little or no evidence of CPOM storage in AMD-affected stream beds.

Major stream bed alterations have been noted in the lower King River (Locher 1995), with deposition of fine to coarse sediment from mine tailings and slag filling the channel bed and raising the elevation of the bed by around 5 m and up to 7 metres. This has had the effect of significantly altering the nature of the substrate from a gravel-cobble-boulder dominated materials to a hydraulically smooth, finely packed matrix with little interstitial space suitable as macroinvertebrate micro-habitat. These sediments are also associated with elevated metal levels and actively contribute metal and sulphuric acid though groundwater leachate (Taylor et al 1996). Thus, there is also likely to be a latent toxicity problem in stream benthic sediments which may preclude macroinvertebrate colonisation even when water quality conditions have improved. Some assessment of this is necessary, at least for the sediments of the lower King River downstream of Quarter Mile Bridge.

It can be seen, therefore, that the lack of a simple relationship between biological condition and water quality is hardly surprising. Thus, although a response in macroinvertebrate community composition and abundance is likely with any improvements in water quality, a fully representative biological community is unlikely to result without some restoration of the natural physical characteristics of the stream bed.

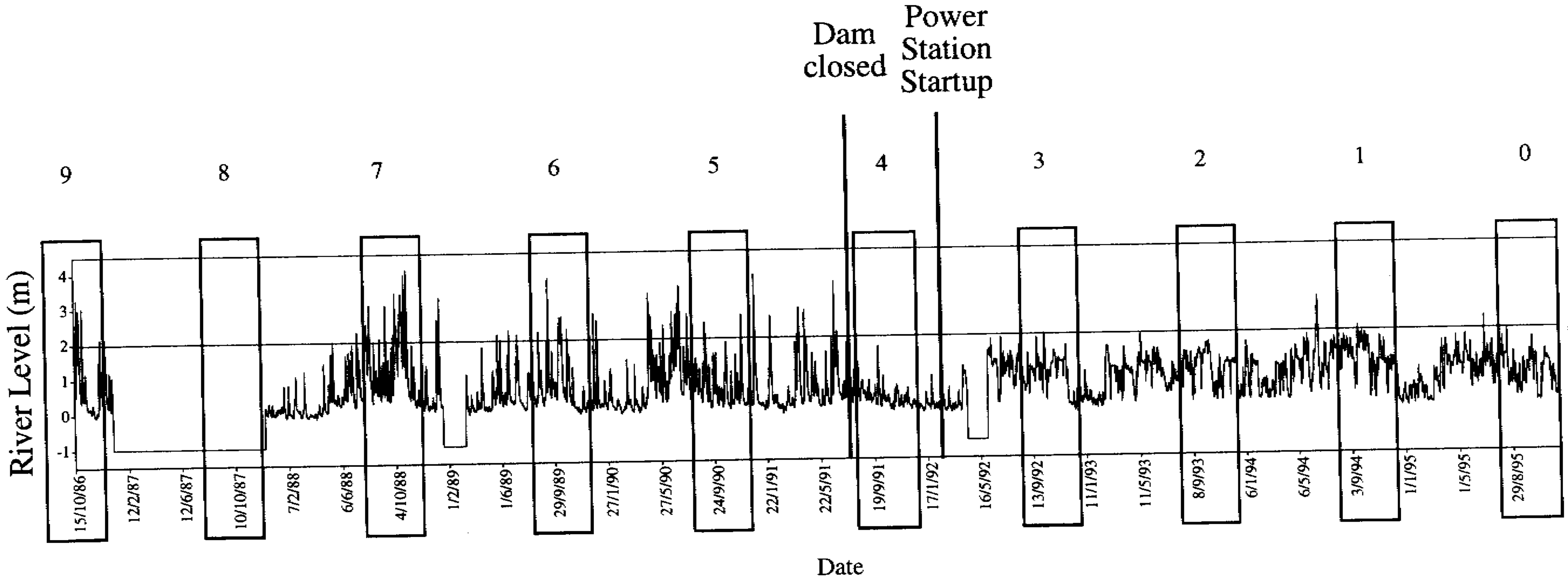


Figure 43 Mean daily King River level below Cutten Creek 1986–1995. Vertical bars indicate dates of Crotty dam closure and start up of John Butters power station. Horizontal line indicates 2.0 m gauge level. Boxes indicate galaxiid recruitment 'windows'. Numbers indicate associated fish ages in 1996.

Despite apparent relationships between copper concentration and macroinvertebrate abundance and number of taxa, such relationships cannot be regarded as causal, due to the high intercorrelation of water quality variables in streams of the Mount Lyell area, and the unknown extent of impact from changes to stream bed characteristics. Experimental assessment is required of the relationships between macroinvertebrate faunal abundance and community composition and water quality, in order to set water quality goals for remediation at Mount Lyell without the confounding factor of stream bed condition, as such goals cannot be identified from field work alone. The use of replicated artificial stream mesocosms, established on-site (continually colonised from a suitable unimpacted stream and dosed with AMD-contaminated water) and experimental manipulations (eg of the AMD input in East Queen River), would allow a much more objective identification of the target water quality required for restoration of the local macroinvertebrate fauna.

Streams in the King and Queen River catchments that are not polluted by AMD typically carry a high diversity and abundance of macroinvertebrates, although RIVPACS assessment indicates that the King River downstream of John Butters hydro power station is less diverse than expected, probably due to the highly fluctuating, unnatural flow regime resulting from HEC operations. Similarly, the macroinvertebrate data suggest that Mount Owen (Cemetery) Creek and Conglomerate Creeks are less diverse than expected. This may be related to changes to catchment hydrology and channel characteristics due to historical loss of vegetation and soil (Wood 1991).

Though many of the monitoring sites affected by AMD had low diversity and abundance, there were several unpolluted reference stream sites that had similar numbers of taxa or abundances. This confirms that a simple assessment of impact based on paired 'control and impact' site is therefore not sufficient to assess the degree of impact of AMD nor to predict the fauna expected in the impacted sites under unpolluted conditions. The use of a RIVPACS approach is therefore seen as a crucial adjunct to quantitative Surber sampling of paired control-impacted sites. The latter data should, in the long term, be subjected to analysis of variance in a paired site approach (eg see Underwood 1992 and references therein).

The MLRIVPACS model, derived from the spring reference site RAP data, predicted that a 'natural' fauna for the King, East Queen and Queen Rivers and for Linda and Comstock Creeks would be dominated by the following taxa :

Taxon	King R	E. Queen R	Queen R	Linda Ck	Comstock Ck
Leptophlebiidae	*	*	*	*	*
Simuliidae	*	*	*	*	*
Hydrobiosidae	*	*	*	*	*
Oligochaetae	*	*	*	*	*
Podonominae	*		*		*
Elmidae (adults)	*		*		
Gripopterygidae	*	*	*	*	*
Chironominae	*		*		
Orthocladiinae	*	*	*	*	*
Hydropsychidae		*	*	*	*
Eusthenidae		*	*	*	*
Conoesucidae		*	*	*	*
Tipulidae			*		
Scirtidae		*	*	*	*

These can be regarded as 'target faunas' for future management actions aimed at restoring biological health to these streams. Any new records of these taxa at the above or adjacent sites that are consistently maintained, along with increases in the O/E50 ratio values predicted by the MLRIVPACS model, should be regarded as indicators of improvement in ecological health at the site. Any positive correlations between improved water quality and increases in ecological health (as measured by O/E values) could be construed (but only by implication or weight of evidence) as being causal. Complete recovery would occur when spring O/E50 values for the sites fall within Band I, and when total spring abundances (as determined from 20% residues of RAP samples) approach those observed in selected reference sites (see below). The exception to this would be the King River sites, which would be anticipated to fall within Band II, due to the recognition of the impact of ongoing disturbance from HEC power station operations.

The MLRIVPACS model was successfully developed using four variables (% moss cover of riffle cobbles, % of site as snag habitat, elevation, distance from source). Both moss cover and snag area could be affected by the impacts of mining or other human disturbance, thus potentially leading to confounding of model predictions in the future. Further modelling should be conducted to:

- develop models for the autumn season data, as well as spring + autumn data combined
- explore the use of predictor variables totally independent of human impact

The occurrence of fish at the monitored sites would also be a major indicator of recovery. This is only likely when major improvements to water quality and physical habitat conditions have occurred in the King and Queen Rivers.

Only major improvements in water quality are likely to result in restoration of fish presence in the King and Queen Rivers. Eels are the most tolerant of the species found in the region and are likely to be the first colonisers of the polluted stream reaches following remediation works, due to their regular recruitment in the Macquarie Harbour drainage and their high tolerance to metals relative to other fish. Lethal and sub-lethal response concentration (eg LC and EC50s) values for eels of copper, zinc and other metals are typically one to two orders of magnitude higher than those of salmonid and galaxiid fish at the same life stages (see data in Mance 1987, Bacher & O'Brien 1990). Salmonid and galaxiid fishes are unlikely to re-establish until free metal levels are reduced to concentrations approaching those indicated in the ANZECC (1992) guidelines (Bacher & O'Brien 1990). Changes in stream bed characteristics may also affect fish abundances, particularly for salmonids whose abundance in a river reach is enhanced in structurally more complex habitats (Shirvell & Dungey 1983).

Recolonisation of the King and Queen Rivers with trout would occur rapidly if water quality conditions improved, as many tributary streams contain significant self-sustaining populations with high quality spawning habitats. Recolonisation of the King and Queen Rivers with native fish (galaxiids, Tasmanian whitebait, eels etc) on restoration of suitable water quality conditions would also be rapid due to the presence of stocks of migrating juveniles in Macquarie Harbour.

5.2 Water quality sampling

High variability in water quality is demonstrated in the King and Queen Rivers at the scale of days and, particularly since MLMRCL mine-closure and commencement of operation of John Butters power station, hours. Similar variability is reflected in the time-series of conductivity found for Linda, Comstock and Idaho Creeks (eg see Mounter 1992, 1993).

The difference in the estimates of means, medians, and standard deviations of analyte concentrations found for fixed vs random sampling times is consistent with the highly variable nature of water quality in the both the King and Queen Rivers. In the King this is dictated by the highly variable flow regime resulting from the operations of the John Butters power station both daily and hourly (see Koehnken 1996 and fig 44). The Queen River, with a more natural hydrology, but smaller catchment, also has considerable variability in discharge at the scale of hours. This variability is enhanced by the presence of denuded hills within the catchment (facilitating a rapid response in storm hydrographs), the influence of pumping operations from the river and variable discharges from mine operations.

This dictates, therefore, a high sampling frequency if estimates of medians or loads (derived from means) are to be calculated with any confidence. As water sampling frequencies greater than daily are impractical and prohibitively expensive, it is recommended that the approach described by Mounter (1992, 1993) be adopted for long-term monitoring of all sites. Thus, sites should be instrumented with stage, conductivity and pH probes and data loggers to record these data at short (eg 5 minute) intervals. Relationships between conductivity and key analytes should be developed by routine and event-driven spot sampling. These relationships would need active inspection and review on a yearly basis.

6 Recommendations

The following recommendations are made:

1 That significant efforts be made to restore water quality in the King and Queen Rivers and in Linda and Comstock Creeks by active remediation of mine and related AMD sources, in order to at least partially restore their ecological health;

2 That the measure of recovery be the value of O/E50 predicted by the MLRIVPACS model and that restoration should aim to achieve Band I status in the long term for all sites with the exception of the King River for which Band II status would be a suitable target (due to the assumed ongoing influence of flow regulation from the John Butters power station);

3 That a routine water quality and biological monitoring program be implemented, according to the design detailed below;

5 That an investigation be implemented into the toxicity of undisturbed stream sediments in the lower King River to macroinvertebrate fauna;

6 That the toxicity of lower King River waters to juvenile galaxiids and eels be evaluated in order to determine threshold concentrations for sub-lethal physiological and avoidance responses and make predictions of water quality-flow conditions suitable for migration in the lower King River as a target for remediation at Mount Lyell;

7 That the direct relationship between improved water quality in the Queen River and macroinvertebrate faunal community composition be evaluated using artificial stream mesocosms on-site and experimental manipulation of the East Queen River in order to set suitable water quality targets for remediation works.

8 That detailed chemical analysis be performed in order to evaluate the form of metals (particularly copper, manganese, aluminium, iron and zinc) in the Queen and King Rivers at a range of locations and under a range of flow conditions. Emphasis should be placed on elucidating the proportion of ionic, colloidal and adsorbed metals under a range of pHs, as well as the degree of complexation by natural dissolved organic materials. The

results should be integrated with the toxicological evaluations to define the toxic nature of Queen and King River waters.

9 That specific water quality targets (concentration means/medians and/or loads) should be developed as an aid for remediation management.

10 That a comprehensive water and chemical balance be developed for the Mount Lyell lease site.

11 That a fundamental evaluation of water sampling procedures be conducted to evaluate sample treatment requirements—timing of filtration, filter size, sample preservation, timing of analysis. This should be done for all key analytes at three sites (Haulage Creek, Queen at Lynchford, lower King).

7 Proposed monitoring program

7.1 Background

The following section describes an extensive (as opposed to intensive) monitoring program for assessing the recovery of water quality and biota in the streams of the Mount Lyell region. Any design of a monitoring program is dependent on the questions that it is supposed to address. This proposed program is specifically designed to address the following questions:

- what is the current state of water quality and biota in the streams?
- is the water quality and biological health recovering?
- how close is the biological health to a recovery target?

The proposed program does not address questions relating to licence conditions or intensive assessments of localised changes in water quality associated with sub-catchment remediation works. Its principal aim is to address the overall environmental condition of the streams of the region in relation to changes in overall water quality and physical conditions.

A 'routine' sampling program is recommended, with regular sampling of a standard set of analytes in order to describe a mean and a median water quality condition in terms of *concentrations*.

Reduction in contaminant loads is the primary objective of site-specific remedial activity in the vicinity of Mount Lyell. Assessment of changes in loads will require additional intense, high frequency sampling of several flood events a year (at a minimum of sites Queen 1 and King 2).

By contrast, environmental condition is responsive to pollutant concentrations. The description of percentiles of the 'population' of pollutant concentrations at a site is best achieved by a regular, routine sampling program where sampling is random in respect of flood events. It is also consistent with the desire to assess the exceedance of any threshold guideline concentrations deemed relevant to ecosystem protection (eg ANZECC 1992, but preferably those derived from mesocosm toxicological and manipulative experimental work on-site).

7.2 Water quality

7.2.1 Sites to be sampled

A principal aim of this program should be to provide continuity with previous sampling to allow detection of trends with time. Two sites are to be used as controls—the upper East Queen and the King River below John Butters power station. The key sites for assessing temporal trends in water quality are in the upper and lower Queen, the lower East Queen, the lower King, upper Linda Creek and Idaho Creek.

The following sites should have data-logged stage, conductivity and pH probes established. Control structures should be built where practicable to ensure reasonable quality flow ratings at low flows (advice to be sought from HEC Water Resources staff). All probes should be rated regularly and the data logged at 5–20 min intervals.

Water sampling and analysis are required to develop relationships between conductivity, pH and key water quality analytes. This should comprise routine, fortnightly spot sampling at each station, as well as automatic sampling at hourly intervals, of a minimum of three flood events per year.

Stream	Site no.	Old site names	Grid refs	Notes*
East Queen R	A	MLMRCL 4	381800 5345850	
	B	MLMRCL 11 / CMT EQWQ/ HEC 664	380675 5342150	1
Queen R	A	MLMRCL 14 / CMT QRQ	380550 5340450	
	B	Lynchford	378000 5334020	2
King R	A	MLMRCL 30	378500 5331670	3
	B	MLMRCL 28	370000 5327850	
	C	MLMRCL 29	364850 5327300	
Idaho Ck	A	HEC 775 / MLMRCL 25	384250 5342200	4
Linda Ck	A	HEC 774	387050 5341000	

*Notes: 1 stage recorder operating from 6/96; 2 pH, stage recorders operating from 6/96; 3 stage recorder operating; 4 conductivity, stage recorder operating from 6/96

The key water quality variables to be analysed (with associated detection limits) are:

Analyte	Detection limit
pH	0.1 units
sulphate	0.1 mg/L
chloride	0.1 mg/L
TSS	0.1 mg/L
conductivity	1 µS/cm
total and dissolved copper	1 µg/L
total and dissolved aluminium	1 µg/L
total and dissolved manganese	1 µg/L
total and dissolved zinc	1 µg/L
total arsenic	1 µg/L
total and dissolved calcium	0.1 mg/L
dissolved organic carbon	0.1 mg/L

Standard procedures are to be used for the collection and analysis of all samples as described in DOE (1989). Filtration should be conducted as soon as is practicable, within four hours of sample collection or the collection of a set of automatic water samples. This is a critical aspect of quality control for differentiating soluble and total metals. All laboratory analyses should conform to NATA registration requirements where possible.

A rating curve should be developed for the existing station at King R. C (King at Cutten Creek) to allow flows to be estimated at discharges above those significantly influenced by tidal action. If this is not feasible, the station should be relocated upstream to a point uninfluenced by tidal action.

Periodic (biennial) assessment of water quality in Lake Burbury should be conducted, taken in profile near the dam wall in mid summer, to assess long term changes in water chemistry associated with stratification.

7.3 Biological health

The aim of the biological sampling program is to address the questions cited above by providing biological data collected in a standard manner for assessing the taxonomic composition and abundance of the macroinvertebrate fauna at each site, the O/E50 value using the spring MLRIVPACS model, and the abundance of fish. Sampling of selected reference as well as monitoring sites is required to confirm the 'calibration' of the MLRIVPACS model by checking that reference site O/E50 values fall within the bounds of Band I.

7.3.1 Macroinvertebrate sampling

RAP sampling

RAP sampling for macroinvertebrates is required in both spring (Sept–Nov) and autumn (Mar–May) each year at the following sites:

Monitoring sites	Grid references	Surber?
King R. 1	378600 5331500	
King R. 2	370600 5327700	
King R. 3 *	370200 5327800	
Queen R. 1	380700 5341800	Y
Queen R. 2	379200 5338200	Y
Queen R. 4	378300 5332200	
East Queen R. 2	381700 5344500	
East Queen R. 3	342200 5380700	Y
Linda Ck 1	386700 5341200	
Comstock Ck 3	383600 5345500	
Comstock Ck 4	387400 5345100	Y

* (requiring a shutdown of John Butters power station)

Reference sites	Grid references	Surber?	Site group (MLRIVPACS)
Yolande R	376500 5347100	1	
East Queen 1	381800 5344800	1	
Collingwood R.	411300 5331500	Y	2
Nelson R.	395100 5237700	Y	2
Franklin 2	398500 5291200	3	
Franklin 3	397900 5297100	3	
Halls Ck	377300 5334300	Y	4
West Queen	380500 5342200	Y	4

All sampling is to be done at riffles. A 10 m kick sample is to be collected from a single riffle habitat at each site, using a 250 μm mesh standard kick net (dimensions 25 x 35 x approx 70 cm, height x width x depth). All samples are to be picked live. The contents of the kick net must be emptied into a sorting tray and the sample picked for a total of 30 min using forceps and a pipette into a vial of 100% ethanol, attempting to collect as many taxa as possible. The preserved picked material is then identified and counted in the laboratory. The sample residue should also be preserved and stored in 100% ethanol or 10% formalin. All live-pick samples are to be preserved in 100% ethanol and identified to family level (with the exception of oligochaetes, nemerteans and mites, which are not identified further) and sub-family level (in the case of chironomids).

At all sites the following environmental data should be obtained:

- % moss cover of riffle cobbles
- % of site as snag habitat
- elevation
- distance from source (on a 1:100,000 map)
- conductivity

Quantitative sampling

In the autumn (March–May) of every second year commencing in 1998, 10 Surber samples are to be taken from riffles at each of the sites indicated in the site list above. The 10 Surber samples are to be pooled to form a single sample at each site. These samples are to be preserved in ethanol, floated using a saturated solution of $CaCl_2$, and sub-sampled to 20% as described by Marchant (1989). The resulting sub-sample should then be sorted and identified to the same taxonomic levels as for the RAP samples.

7.3.2 Fish

Two-pass backpack electrofishing surveys should be conducted over a 100–200 m distance in summer (January-February) at each of the following sites every two years starting in 1998:

Site	Grid reference
Queen River 4	378300 5332200
Princess Creek	377400 5335300
Linda Creek	386700 5341200
Newall Creek	378700 5331500
Nelson River	395100 5237700
Manuka River	361300 5333700
Botanical Ck	362800 533200
Kingfisher Ck	367500 5327200
Lower Landing Ck	370500 5327500
Virginia Ck	370100 5327900
Swift Ck	371000 5326700
Open Ck	375400 5328400

All fish captured should be measured, and a single specimen from each major size class preserved (in lignocaine and 90% ethanol) for later age determination.

Every four years, commencing in 2000, a single electrofishing survey should be conducted by electrofishing boat of the lower King River (from the delta to Teepookana, grid references 364900 5327300–369900 5327800) and Henty Rivers (from the Zeehan Rd bridge to approximately 0.9 km upstream, grid references 356600 5346900–369900 5327800). All fish observed should be identified and counted and a subsample caught for measurement (fork length to nearest mm). Fishing effort should be recorded as both generator and shock time and distance fished.

7.4 Data analysis

7.4.1 Water quality

Temporal trends in water analyte concentrations should be examined graphically and by regression after combination of new data with previous data from the same sites. Medians and means should be calculated for each analyte and compared with accepted guideline and remediation target values.

Relationships should be developed and updated annually between conductivity and all ions at these sites.

Annual loads of metals and acid should be calculated from the relationships between conductivity, metals, pH and discharge at each site (see Mounter 1993 for examples). Where data gaps exist in logger records, a combination of regressions (on data from the same site and between sites) should be used to synthesise missing data (advise to be sought from HEC Water Resources staff).

7.4.2 Macroinvertebrates

RAP samples

The total number of taxa and abundance found for all sites should be reported and compared with previous years' data for trends. Any trends in these variables should be compared between monitoring and reference sites by either a repeated measures analysis of variance on differences and on dissimilarities (as Bray Curtis values) between reference site and monitoring site values or by analysis of covariance (for $n \geq 4$ years data only).

The raw spring sample data should be transformed to presence/absence and assessed using the relevant environmental data (appropriately transformed) with the spring MLRIVPACS model (all sites). The list of taxa found in the spring and autumn samples should be combined and assessed for long-term trends by regression and/or intervention analysis.

If all reference site O/E50 values fall within Band I bounds, the O/E50 values for the monitoring sites can be derived using the MLRIVPACS model and reported. If a significant number (> 2) of the reference sites fall outside their Band I bounds, the bound limits should be shifted to accommodate what may be natural shifts in community composition not accounted for in the original model. In the unlikely event that this persists over 2 or more years, re-sampling of all reference sites used in the original model (spring 1995 sampling sites), once in spring, will be necessary to re-calibrate the MLRIVPACS model.

Quantitative data

Total abundance and number of taxa data should be derived from the sub sampled, pooled sample of ten Surbers at each site. These data should be assessed for trends by either a repeated measures analysis of variance on differences and on dissimilarities (as Bray Curtis values) between reference site and monitoring site values or by analysis of covariance (for $n \geq 4$ years data only).

7.4.3 Fish data

Length frequency and age data for *G truttaceus* and *A australis* should be compared amongst all sites on tributaries of the lower King River with those in Botanical Ck and Manuka River (at Grid Refs 361300 5333700 and 362800 533200 respectively). Data for the tributaries of the lower King River should be examined for increasing diversity and abundance of native fish in Virginia, Lower Landing, Open and Swift Creeks, by comparison with the data collected in previous years (commencing in 1996) in a two factor analysis of variance with year and location (King vs control catchments) as factors. If significant increases in fish abundance and diversity or changes in age structure are detected in these creeks, relative to the two control streams, then flow and water quality data collected in the lower King (at Cutten Ck station) should be examined for significant improvement.

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Appendixes

Appendix 1

Environmental data recorded for all rapid assessment protocol (RAP) sampling sites

Table 1.1 Values of environmental variables determined for RAP sites in winter 1995, Mount Lyell region

Site	Variable																			
	Easting	Northing	Elevat	Bedslope	StmClass	Distsour	Catchsiz	Subedrck	subould	subcoble	subpeble	subgrav	subsand	subsilt	subclay	covsilt	covalgae	covdetri	covmoss	Flow
MTOWEN	384900	5241600	260	0.25	2	2.8	3.07	0	20	70	0	10	10	0	0	0	0	0	0	4
HENTY	373300	5249700	76	0.65	4	20.8	115.28	0	85	10	5	0	0	0	0	0	20	0	0	3
HALLS	377300	5234300	65	0.25	3	4	6.44	0	0	80	5	10	5	0	0	0	0	0	0	3
GOVERN	393200	5230400	230	0.4	4	8.8	27.60	5	50	40	5	0	0	0	0	0	35	0	0	4
STHELDON	391700	5247800	237	3.25	4	22	116.01	0	5	75	15	5	0	0	0	0	0	0	0	3
EQUENONE	381700	5245500	263	0.25	1	1.6	1.43	0	0	80	10	5	5	0	0	0	0	0	0	4
ELDON	391700	5247900	237	3.7	4	20.1	96.82	0	0	60	40	0	0	0	0	0	5	0	0	4
PEARL	379200	5242800	262	0.275	1	1.8	1.90	10	5	50	15	10	10	0	0	0	0	0	25	4
NEWALL	378700	5231500	39	2.65	3	6.7	8.80	5	15	50	5	5	20	0	0	10	5	0	15	4
COMSTTWO	383500	5245500	318	1.25	3	2.65	3.94	0	60	30	5	5	0	0	0	0	10	5	0	4
COMSTHRE	383600	5245500	315	1.25	3	2.7	4.04	0	70	20	5	5	0	0	0	25	0	10	0	4
QUENFOUR	378300	5232200	92	1.55	4	18.2	75.54	0	40	60	0	0	0	0	0	10	0	0	0	4
LINDA	386700	5241200	238	0.7	3	4.2	13.68	0	10	70	10	10	0	0	0	90	0	0	0	3
KINGTHRE	370200	5227800	0	20.8	5	18.5	230.35	0	0	0	0	0	0	30	70	0	0	0	0	2
EQUENTHR	342200	5280700	211	0.4	4	5.5	6.76	0	10	70	10	5	5	0	0	0	0	0	0	3
NELSON	395100	5237700	318	0.78	3	8.5	20.15	0	25	60	10	5	0	0	0	0	0	0	20	4
KINGONE	378600	5231500	39	3.6	4	4.7	28.96	0	5	45	50	0	0	0	0	0	25	0	0	2
QUEENTWO	379200	5238200	106	1.15	4	11.5	39.35	0	20	50	5	5	5	15	0	0	0	0	0	4
PRINCESS	377400	5235300	73	0.75	3	5.3	12.86	0	5	70	10	5	10	0	0	0	0	0	75	4
COMSTFOR	387400	5245100	234	1.25	3	7.25	18.73	0	5	85	10	0	0	0	0	0	10	0	0	3
KINGTWO	370600	5227700	0	20.8	5	17.7	229.22	0	0	20	5	5	0	20	50	0	0	0	0	2
QUEENONE	380700	5241800	154	0.875	4	6.7	14.56	0	30	60	0	5	5	0	0	0	0	0	0	4
QUEENTHR	377500	5334200	55	2.3	4	15.5	70.70	10	70	20	0	0	0	0	0	60	0	0	0	4
EQUENTWO	381700	5244400	260	0.25	1	2.5	1.53	0	20	75	0	5	0	0	0	0	0	0	0	3
YOLANDE	376500	5247100	145	0.65	4	10.6	58.22	0	30	40	10	10	10	0	0	0	0	0	10	3
WESTQUEN	380500	5242200	161	0.5	3	6.2	7.46	0	10	80	5	5	0	0	0	0	25	0	0	4
COMSTONE	383500	5245500	320	0.1	3	2.6	3.44	0	40	35	20	5	0	0	0	0	10	0	20	4
CONGLOM	381300	5240800	160	0.2	3	4.8	6.70	0	40	30	10	10	10	0	0	0	30	0	0	4

Table 1.1 (cont'd)

Site	Variable																					
	Visib	Ttlcopp	Disscopp	pH	Conduct	Sulphate	Colour	folin	TSS	stvelmax	stvelmin	overbank	traibank	Ripleft	Ripright	Distcat	Stdepth	stwidth	Temp	Conductm	periffle	perpool	persnag
MTOWEN	1	40	39	5.47	32.8	2	90	1.6	1			2	2	3	3	2	2	5	6.3	32.2	100	0	0
HENTY	1	3	3	6.64	59.6	1.92	70	1.4	0.34			2	1	4	4	1	2	22	6.6	51.9	80	20	0
HALLS	2	3	4	6.32	64	3.25	140	2.4	2	0.95	0.83	4	3	4	4	1	2	3.7	7.11	58	80	20	0
GOVERN	1									1.02	0.63	2	3	4	4	1	2	14	5.2	36.5	90	10	0
STHELDON	1									1.6	1.23	2	2	4	3	1	2	18.3	4.8	41.6	80	10	10
EQUENONE	1	15	16	6.02	46.7	2.81	35	0.75	0.5	1.48	0.39	4	3	4	3	2	2	3.3	6.3	41.3	100	0	0
ELDON	1									1.37	0.7	2	3	4	4	1	2	14.3	4.9	39.2	90	5	5
PEARL	2	22	22	4.61	41.8	1.32	50	2	0.5	0.63	0.4	4	3	4	4	1	2	2.7	5.7	38.7	75	25	0
NEWALL	2	3	5	5.29	45	2.11	50	3.6	0.5	0.5	0.25	4	3	4	4	2	2	6.25	6.5	47.5	80	15	5
COMSTTWO	2	22	24	4.29	44.1	1.72	120	2.3	0.5	0.5	0.33	2	2	3	4	2	2	6.3	6.5	4.6	95	0	5
COMSTHRE	4	890	900	3.5	215	47.21	10	1	28	-	-	3	2	4	4	3	2	6.2	6.5	170	100	0	0
QUENFOUR	4	13500	13200	3.08	1237	560	480	4.3	94	1.03	0.4	3	2	4	3	3	3	15	7.1	1000	100	0	0
LINDA	4	720	690	3.58	246	69	130	1.2	21	0.61	0.23	3	2	4	4	3	2	7	4.7	203	100	0	0
KINGTHRE	4	530	510	4.33	113	26	120	1.6	18	1.5		1	1	3	1	3	3	15	8	144.3	75	25	0
EQUENTHR	4	1170	1200	3.36	303	62.23	5	0.27	22	-	-	3	2	3	3	3	2	5.7	6.5	260	100	0	0
NELSON	1	2	4	6.89	60	2	60	1.1	4	1.25	0.7	4	3	3	4	1	2	5.3	5.5	59.1	85	15	0
KINGONE	1	9	10	6.15	44	39	90	1.7	3	0.43	0.14	0	0	2	2	2	2	21.5	6.2	47	75	25	0
QUEENTWO	4	4120	4120	3.07	738	208.6	ND	0.92	66	1.33	1.01	1	1	3	2	3	2	11.7	6.5	551	95	5	0
PRINCESS	4	24	26	4.8	53	3.82	120	2	9	1	0.5	3	2	4	4	2	2	5.8	6.5	50.4	50	50	0
COMSTFOR	3	160	160	4.19	66.1	10.1	65	1.4	7	1.07	0.14	2	1	4	4	3	1	7.7	5.4	64.8	70	25	5
KINGTWO	4	530	510	4.33	113	26	120	1.6	18	1		1	1	3	1	3	3	15	7.9	109.8	70	25	5
QUEENONE	4	510	510	3.81	144	30.59	35	0.94	17			1	1	1	1	1	2	8.3	6.3	93.7	100	0	0
QUEENTHR	4	13200	13200	3.02	1167	500.12	10	2.7	96	0.66	0.33	2	2	4	3	3	3	11.7	7.8	1000	70	30	0
EQUENTWO	3	1340	1330	3.55	203	37.6	50	0.37	18	0.727	0.398	2	3	3	2	3	1	3.67	6.4	1500	90	10	0
YOLANDE	2	2	2	4.77	38.1	2.3	90	1.7	0.5	955805	0.33	0	1	3	3	1	2	10	6.5	35	80	20	0
WESTQUEN	2	6	7	5.75	38	1.31	70	1.4	1	0.5	0.33	2	2	4	3	2	2	5.5	6.7	38.7	100	0	0
COMSTONE	1	8	9	4.33	39.2	1	110	2.5	0.54	1.55	0.3	3	4	4	4	1	2	5.3	6.5	40	70	20	10
CONGLOM	1	43	42	4.36	45	3.5	40	0.86	0.5	0.66	0.33	1	2	2	2	2	2	8	5.9	46.5	100	0	0

Table 1.2 Values of environmental variables determined for RAP sites in spring 1995, Mount Lyell region

	Variable																		
Site	Easting	Northing	Elevat	Bedslope	StmClass	Distsour	Catchsiz	Subedrck	subould	subcoble	subpeble	subgrav	subsand	subsilt	subclay	covsilt	covalgae	covdetri	covmoss	Flow
MTOWEN	384900	5241600	260.00	0.25	2.00	2.80	3.07	0	10	70	15	5	0	0	0	0	5	0	0	2
HENTY	373300	5249700	76.00	0.65	4.00	20.80	115.28	0	20	60	15	5	0	0	0	0	50	0	0	2
HALLS	377300	5234300	65.00	0.25	3.00	4.00	6.44	0	0	20	60	5	15	5	0	0	0	2	0	2
GOVERN	393200	5230400	230.00	0.40	4.00	8.80	27.60	0	60	20	10	5	5	0	0	0	0	0	0	2
STHELDON	391700	5247800	237.00	3.25	4.00	22.00	116.01	0	0	15	75	5	55	0	0	0	0	0	0	3
EQUENONE	381700	5245500	263.00	0.25	1.00	1.60	1.43	0	10	70	20	0	0	0	0	0	10	0	0	2
ELDON	391700	5247900	237.00	3.70	4.00	20.10	96.82	0	0	55	43	2	0	0	0	0	0	0	0	3
PEARL	379200	5242800	262.00	0.28	1.00	1.80	1.90	10	30	40	20	0	0	0	0	0	0	5	30	2
NEWALL	378700	5231500	39.00	2.65	3.00	6.70	8.80	0	20	50	10	5	5	0	0	0	50	0	5	2
COMSTTWO	383500	5245500	318.00	0.13	3.00	2.65	3.94	0	45	45	10	0	0	0	0	0	10	0	20	2
COMSTHRE	383600	5245500	315.00	0.13	3.00	2.70	4.04	0	60	35	5	0	0	0	0	90	0	3	2	1
QUENFOUR	378300	5232200	92.00	1.55	4.00	18.20	75.54	0	30	60	10	0	0	0	0	5	0	0	0	3
LINDA	386700	5241200	238.00	0.70	3.00	4.20	13.68	0	15	65	20	0	0	0	0	80	0	0	0	1
KINGTHRE	370200	5227800	0.00	20.80	5.00	18.50	230.35	0	10	30	5	5	25	25	0	100	0	0	0	2
EQUENTHR	342200	5280700	211.00	0.40	4.00	5.50	6.76	0	10	60	20	10	0	0	0	10	10	0	0	2
NELSON	395100	5237700	318.00	0.78	3.00	8.50	20.15	0	15	60	25	0	0	0	0	0	15	0	10	3
KINGONE	378600	5231500	39.00	3.60	4.00	4.70	28.96	0	5	90	5	0	0	0	0	1	10	0	0	1
QUEENTWO	379200	5238200	106.00	1.15	4.00	11.50	39.35	0	15	75	10	0	0	0	0	90	0	0	0	2
PRINCESS	377400	5235300	73.00	0.75	3.00	5.30	12.86	0	20	55	15	10	0	0	0	0	0	0	20	3
COMSTFOR	387400	5245100	234.00	1.25	3.00	7.25	18.73	0	0	60	40	0	0	0	0	0	10	0	0	2
KINGTWO	370600	5227700	0.00	20.80	5.00	17.70	229.22	0	0	0	0	0	100	0	0	100	0	0	0	2
QUEENONE	380700	5241800	154.00	0.88	4.00	6.70	14.56	0	40	45	15	0	0	0	0	80	0	0	0	2
EQUENTWO	381700	5244400	260.00	0.25	1.00	2.50	1.53	0	30	55	15	0	0	0	0	0	0	10	0	2
YOLANDE	376500	5247100	145.00	0.65	4.00	10.60	58.22	0	25	65	10	0	0	0	0	0	25	0	2	3
WESTQUEN	380500	5242200	161.00	0.50	3.00	6.20	7.46	0	30	55	10	3	2	0	0	0	50	0	10	2
COMSTONE	383500	5245500	320.00	0.10	3.00	2.60	3.44	15	40	35	10	0	0	0	0	0	10	2	5	2
CONGLOM	381300	5240800	160.00	0.20	3.00	4.80	6.70	0	15	70	10	5	0	0	0	40	15	0	0	2
LYNCHS	378600	5336700	89.00	1.15	2.00	4.30	4.88	10	25	50	5	5	5	0	0	0	25	0	5	3
CROTTY	386000	5321400	188.00	0.95	3.00	4.80	9.57	0	0	40	50	5	5	0	0	0	0	0	30	2
ALLANS	385800	5323100	188.00	0.60	2.00	3.00	3.00	0	5	75	10	5	5	0	0	0	5	0	0	2
CARDIGAN	403400	5335400	410.00	1.15	3.00	5.50	14.31	0	10	75	10	3	2	0	0	0	35	0	10	2
COLLINGW	411300	5331500	335.00	3.20	5.00	20.60	267.19	0	0	40	40	10	10	0	0	0	0	0	0	1

Table 1.2 (cont'd)

Site	Variable																						
	wclarity	Ttlcopp	Disscopp	pH	Conduct	Sulphate	Colour	folin	TSS	stvelmax	stvelmin	overbank	traibank	Ripleft	Ripright	Distcat	Stdepth	stwidth	Temp	Conductm	periffle	perpool	persnag	aqpltsub
MTOWEN	0	49.00	32.00	5.07	45.80	2.00	69.00	1.43	2.00	0.50	0.25	0.00	0.00	2.00	2.00	2	1.00	4.33	9.20	45.60	95.00	5.00	0.00	0.00
HENTY	2	35	10	6.16	53.3	2	113	2.34	2	1.11	0.67	0.00	3.00	3.00	3.00	1	2.00	25.00	9.40	51.90	85.00	10.00	5.00	0.00
HALLS	1	345.00	10.00	6.91	102.00	3.00	76.00	1.14	0.50	0.83	0.63	3.00	3.00	3.00	3.00	1	2.00	2.50	9.00	102.40	100.00	0.00	0.00	0.00
GOVERN	0									1.09	0.32	1.00	1.00	3.00	3.00	1	2.00	15.00			80.00	20.00	0.00	0.00
STHELDON	0	0.50	0.50	6.13	35.00	1.00	60.00	4.92	0.50	0.67	0.50	1.00	1.00	3.00	3.00	1	1.00	15.00			70.00	10.00	20.00	0.00
EQUENONE	0	34.00	30.00	6.17	52.50	5.00	43.00	0.90	0.50	2.00	1.00	3.00	1.00	3.00	3.00	2	1.00	2.00	9.10	52.60	100.00	0.00	0.00	0.00
ELDON	0	2	0.5	6.45	83.3	1	53	1.47	0.5	1.85	1.01	2.00	1.00	2.00	3.00	1	1.00	22.00	9.40	55.50	85.00	10.00	5.00	0.00
PEARL	2	32.00	20.00	5.40	51.30	2.00	75.00	1.34	3.00	0.67	0.36	2.00	2.00	1.00	2.00	1	2.00	1.00	9.20	51.40	100.00	0.00	0.00	0.00
NEWALL	0	0.50	0.50	6.15	58.00	2.00	139.00	4.92	3.00	0.67	0.50	0.00	0.00	1.00	1.00	2	1.00	6.33	7.70	54.10	85.00	5.00	10.00	0.00
COMSTTWO	1	17.00	12.00	4.10	54.00	2.00	119.00	2.53	0.50	1	0.50	3.00	1.00	3.00	3.00	2	2.00	3.00	8.60	54.90	90.00	10.00	0.00	1.00
COMSTHRE	3	2740.00	2600.00	3.90	560.00	140.00	200.00	1.89	39.00	0.77	0.40	1.00	2.00	1.00	3.00	3	2.00	3.00	9.40	322.50	98.00	0.00	2.00	0.00
QUENFOUR	3	3240.00	3340.00	3.20	540.00	174.00	122.00	2.11	52.00	1.57	0.82	2.00	0.00	3.00	2.00	3	3.00	17.60	8.80	500.00	93.00	7.00	0.00	0.00
LINDA	2	760.00	710.00	3.42	289.00	63.00	214.00	0.73	18.00	0.67	0.33	1.00	2.00	1.00	4.00	3	2.00	8.50	11.30	237.00	100.00	0.00	0.00	0.00
KINGTHRE	3	300	220	4.38	79.7	16	126	1.43	0.5	0.67	0.33	0.00	0.00	1.00	3.00	3	2.00	30.00			40.00	60.00	0.00	0.00
EQUENTHR	1	980.00	950.00	3.41	269.00	54.00	65.00	0.46	9.00			1.00	1.00	3.00	3.00	2	2.00	3.00	9.10	234.00	100.00	0.00	0.00	0.00
NELSON	0	2.00	0.50	6.75	61.20	2.00	62.00	1.03	0.50	1.00	0.67	2.00	1.00	2.00	3.00	1	2.00	5.33	7.00	60.70	88.00	10.00	2.00	0.00
KINGONE	0	22	0.5	5.87	52.5	2	139	2.62	10	0.67	0.33	0.00	0.00	2.00	2.00	2	1.00	20.00			70.00	25.00	5.00	0.00
QUEENTWO	3	9990	9710	2.88	1250	520	34	3.06	100	0.67	0.50	0.00	0.00	0.00	0.00	3	2.00	15.00	11.40	946.00	98.00	0.00	2.00	0.00
PRINCESS	3	14.00	11.00	4.98	62.50	5.00	133.00	2.20	10.00	2.00	1.00	3.00	1.00	3.00	3.00	2	3.00	4.33	8.80	62.20	70.00	25.00	5.00	0.00
COMSTFOR	1	126.00	101.00	4.24	62.20	7.00	98.00	1.61	0.50	0.67	0.50	0.00	1.00	3.00	3.00	3	2.00	3.00			85.00	10.00	5.00	0.00
KINGTWO	3	300	220	4.38	79.7	16	126	1.43	0.5	0.67	0.33	0.00	0.00	0.00	1.00	3	3.00	20.00			35.00	65.00	10.00	0.00
QUEENONE	2	480.00	430.00	3.78	149.80	30.00	129.00	0.49	27.00	0.83	0.29	0.00	1.00	1.00	1.00	3	2.00	6.00	9.70	134.60	100.00	0.00	0.00	0.00
EQUENTWO	2	1060	1060	3.63	175.9	33	68	0.35	10	0.50	0.30	3.00	1.00	3.00	3.00	3	2.00	2.50	9.40	160.00	95.00	5.00	0.00	0.00
YOLANDE	0	0.5	0.5	4.78	38.2	1	100	2.25	0.5	1.33	1.00	1.00	2.00	3.00	2.00	1	3.00	15.00	7.80	38.40	90.00	5.00	5.00	0.00
WESTQUEN	0	2	1	5.89	49.3	2	69	1.28	0.5	0.51	0.09	1.00	2.00	2.00	2.00	2	1.00	5.00	9.40	47.80	95.00	0.00	5.00	0.00
COMSTONE	1	7.00	6.00	4.13	51.00	1.00	118.00	2.45	0.50	1.00	0.31	2.00	3.00	3.00	3.00	1	2.00	3.00	8.40	52.00	95.00	0.00	5.00	0.00
CONGLOM	1	58.00	49.00	4.43	57.00	4.00	53.00	0.79	39.00			1.00	0.00	2.00	1.00	2	2.00	8.30			95.00	5.00	0.00	0.00
LYNCHS	0	6.00	4.00	6.26	59.90	2.00	52.00	0.93	4.00	1.00	0.50	2.00	1.00	2.00	2.00	1	2.00	2.00			100.00	0.00	0.00	0.00
CROTTY	0	12	0.5	6.73	70.9	1	79	1.61	0.5	0.94	0.43	2.00	2.00	2.00	3.00	1	1.00	2.67	6.00	69.30	70.00	20.00	10.00	0.00
ALLANS	0	2	1	5.81	42.3	1	34	1.19	0.5	0.59	0.24	1.00	1.00	3.00	3.00	1	1.00	2.00	6.80	41.60	60.00	40.00	0.00	0.00
CARDIGAN	0	3	0.5	6.67	52.3	1	51	1.14	0.5	0.40	0.35	2.00	1.00	3.00	3.00	1	1.00	6.00	7.70	49.50	95.00	0.00	5.00	0.00
COLLINGW	0	64.00	0.50	6.78	71.10	2.00	38.00	0.81	0.50	0.80	0.78	1.00	2.00	3.00	3.00	1	2.00	21.67	7.40	79.00	90.00	7.00	3.00	0.00

Table 1.3 Values of environmental variables determined for RAP sites in summer 1995, Mount Lyell region

Site	Variable																		
	Easting	Northing	Elevat	Bedslope	StmClass	Distsour	Catchsiz	Subedrck	subould	subcoble	subpeble	subgrav	subsand	subsilt	subclay	covsilt	covalgae	covdetri	covmoss	Flow
MTOWEN	384900	5241600	260	0.25	2	2.8	3.07	0	20	40	35	5	0	0	0	70	15	0	0	1
HENTY	373300	5249700	76	0.65	4	20.8	115.28	0	10	75	10	5	0	0	0	0	10	1	3	2
HALLS	377300	5234300	65	0.25	3	4	6.44	0	2.5	50	50	5	2.5	0	0	0	2.5	0	5	1
GOVERN	393200	5230400	230	0.4	4	8.8	27.60	0	65	15	10	5	5	0	0	0	30	0	15	2
STHELDON	391700	5247800	237	3.25	4	22	116.01	0	0	80	10	5	5	0	0	0	30	0	0	2
EQUENONE	381700	5245500	263	0.25	1	1.6	1.43	0	40	50	8	2	0	0	0	20	5	0	1	2
ELDON	391700	5247900	237	3.7	4	20.1	96.82	0	10	30	25	5	0	0	0	0	10	0	0	2
PEARL	379200	5242800	262	0.275	1	1.8	1.90	0	0	50	45	5	0	0	0	5	0	0	75	2
NEWALL	378700	5231500	39	2.65	3	6.7	8.80	0	20	60	10	5	5	0	0	0	90	0	5	2
COMSTTWO	383500	5245500	318	0.125	3	2.65	3.94	0	55	40	5	0	0	0	0	0	25	3	5	2.5
COMSTHRE	383600	5245500	315	0.125	3	2.7	4.04	0	50	40	10	0	0	0	0	85	10	0	10	2.5
QUENFOUR	378300	5232200	92	1.55	4	18.2	75.54	0	50	50	0	0	0	0	0	90	5	0	0	2
LINDA	386700	5241200	238	0.7	3	4.2	13.68	0	25	68	5	2	0	0	0	85	2	0	0	1
KINGTHRE	370200	5227800	0	20.8	5	18.5	230.35	0	0	70	15	10	5	0	0	0	4	0	0	1
EQUENTHR	342200	5280700	211	0.4	4	5.5	6.76	0	25	65	10	0	0	0	0	0	5	0	0	2
NELSON	395100	5237700	318	0.78	3	8.5	20.15	0	20	55	10	15	0	0	0	0	0	0	5	2
KINGONE	378600	5231500	39	3.6	4	4.7	28.96	0	20	70	10	0	0	0	0	0	30	0	0	2
QUEENTWO	379200	5238200	106	1.15	4	11.5	39.35	0	50	50	0	0	0	0	0	75	0	0	0	2
PRINCESS	377400	5235300	73	0.75	3	5.3	12.86	0	0	80	10	5	5	0	0	0	5	0	10	2
COMSTFOR	387400	5245100	234	1.25	3	7.25	18.73	0	0	70	30	0	0	0	0	95	0	0	0	1.5
KINGTWO	370600	5227700	0	20.8	5	17.7	229.22	0	0	70	15	10	5	0	0	0	0	0	0	2
QUEENONE	380700	5241800	154	0.875	4	6.7	14.56	0	60	40	0	0	0	0	0	0	5	0	2.5	2
EQUENTWO	381700	5244400	260	0.25	1	2.5	1.53	0	20	65	10	5	0	0	0	95	0	0	0	2
YOLANDE	376500	5247100	145	0.65	4	10.6	58.22	0	70	15	7.5	7.5	0	0	0	0	0	0	0	2
WESTQUEN	380500	5242200	161	0.5	3	6.2	7.46	0	30	55	10	5	0	0	0	0	30	0	7.5	2
COMSTONE	383500	5245500	320	0.1	3	2.6	3.44	0	70	20	10	0	0	0	0	0	10	0	30	2
CONGLOM	381300	5240800	160	0.2	3	4.8	6.70	0	50	30	17	3	0	0	0	0	20	0	0	2
LYNCHS	378600	5336700	89	1.15	2	4.3	4.88	5	30	50	10	5	0	0	0	0	10	0	5	2
CROTTY	386000	5321400	188	0.95	3	4.8	9.57	0	4	38	38	5	10	0	0	0	5	0	0	2
ALLANS	385800	5323100	188	0.6	2	3	3.00	0	5	45	40	5	5	0	0	0	0	0	10	1
CARDIGAN	403400	5335400	410	1.15	3	5.5	14.31	0	30	60	10	0	0	0	0	0	35	0	5	2
COLLINGW	411300	5331500	335	3.2	5	20.6	267.19	0	10	25	55	10	0	0	0	0	0	0	0	2

Table 1.3 (cont'd)

Site	Variable																							
	wclarity	Ttlcopp	Disscopp	pH	Sulphate	Colour	folin	TSS	TDS	DOC	stvelmax	stvelmin	overbank	traibank	Ripleft	Ripright	Distcat	Stdepth	stwidth	Temp	Conductm	periffle	perpool	persnag
MTOWEN	1	0.03	0.02	6.4	2.9	100	1.3	4	54	8	0.67	0.67	0	1	2	2	2	1	2.5	15.5	47.6	100	0	0
HENTY	0	0.002	0.002	6.6	3.5	125		3	42		0.67	0.67	0.5	3	3	3	1	1	27.5	11.4	51.5	97	0	3
HALLS	0	0.001	0.001	6.4	5	30		2	92		0.75	0.67	3	1	3	3	1	1	2.5	13.9	134.9	90	10	0
GOVERN	0	0.001	0.001	6.6	2.7	50		0.5	28				1	0	3	3	1	2	7.33	13	38.4	100	0	0
STHELDON	0	0.001	0.001	6.7	3.1	50	0.8	0.5	27	7	0.67	0.67	1	1	3	2	1	1	30	14.8	50	70	25	5
EQUENONE	1	0.016	0.016	5.1	8.6	70	1.3	0.5	59	2.9			1	1	3	2	2	1	3.67	11.2	48.6	95	5	0
ELDON	0	0.001	0.001	6.7	2.3	100		0.5	44				2	2	3	3	1	2	17.5	14.7	50.4	95	0	5
PEARL	1	0.026	0.026	6.4	2.6	85	1.6	2	53	8	0.67	0.5	3	2	2	2	1	2	1.67	17.6	52.1	80	20	0
NEWALL	0	0.002	0.002	6.5	1.9	150	2.7	2	61	13.2			2	1	1	3	2	1	5	9.4	59.8	65	30	5
COMSTTWO	0	0.014	0.013	5.6	1.5	175		0.5	47				2	3	3	3	2	2	3	11.2	51.5	100	0	0
COMSTHRE	3	0.26	0.24	3.9	24	250		12	90				1.5	2	1	2	3	2	4	11.3	147	98	0	2
QUENFOUR	3	2.6	2.5	3.3	170	225	0.8	68	350	2.8	1.5	0.75	2	0	3	2	3	2	15	20	486	83	15	2
LINDA	3	0.48	0.44	3.7	47	125	0.2	19	95		0.67	0.5	1	1	2	2	3	1	4.67	21.2	199.1	85	15	0
KINGTHRE	3	0.79	0.67	3.7	64	150		34	125				0	0	1	1	3	2	30	14.9	217	50	50	0
EQUENTHR	3	0.61	0.54	3.9	32	85		14	96	2.2	1	0.67	2	1	2	3	2	2	6	14	177	99	1	0
NELSON	2	0.002	0.002	6.6	3.3	100		2	52				3	1	3	3	1	2	5	10.7	51.8	95	5	0
KINGONE	1	0.012	0.011	6.5	2.8	100	1.8	3	46	9.4			0	0	3	2	2	1	7.5	14	52.8	40	60	0
QUEENTWO	3	11	11	3.6	760	1500	0.6	420	1150	1.8	1	0.67	0	1	1	0	3	2	10	15	1124	100	0	0
PRINCESS	3	0.038	0.03	5.1	14	125		27	84				2	2	3	3	2	1	5	15	71.5	70	30	0
COMSTFOR	2	0.11	0.11	6	16	70		3	58				0	0	3	3	3	1	4	18.1	83.8	75	20	5
KINGTWO	3	0.78	0.73	3.8	61	200		30	120				0	0	0	0	3	2	15	15	217	50	48	2
QUEENONE	3	0.32	0.005	10.3	140	100		43	300		1	0.5	0	0	1	1	3	2	5	12	477	90	10	0
EQUENTWO	2	0.45	0.35	4	17	125	0.2	17	45				2	1	3	2	3	2	3.33	13.6	111.8	95	5	0
YOLANDE	2	0.002	0.002	6.5	4.7	125		2	64				1	1	3	3	1	3	15	12	34.9	98	0	2
WESTQUEN	1	0.01	0.01	5.4	9	85		1	59		1	0.5	2	2	2	2	2	1	4.33	12	45.2	83	15	2
COMSTONE	1	0.009	0.009	6.3	1.9	200	3.2	0.5	50	3.2			2	2	3	3	1	3	4	11.1	51.2	95	3	2
CONGLOM	0	0.03	0.03	6.8	3.6	50	0.9	2	45	4.1	1	0.67	0	0	1	1	2	2	4.5	12	47.9	100	0	0
LYNCHS	0	0.006	0.005	6.7	47	40		1	58				2	1	2	2	1	1	4	9.2	64	90	10	0
CROTTY	1	0.001	0.001	6.8	1.5	100	1.4	2	51	7.9	0.6	0.6	3	1	3	3	1	1	4	11	70.1	55	35	10
ALLANS	0	0.002	0.002	6.5	2.5	50		0.5	47		0.6	0.6	2	1	1	2	1	1	2.67	12.3	41.7	75	20	5
CARDIGAN	0	0.022	0.002	6.4	2.1	100		1	45	9.4	0.625	0.625	2	3	2	2	1	2	4	12.2	40.3	98	0	2
COLLINGW	1	0.002	0.001	6.5	2.1	100	1.4	5	42	7.8	0.67	0.5	1	2	2	3	1	3	18.33	10.4	42.6	85	10	5

Table 1.4 Values of environmental variables determined for RAP sites in autumn 1995, Mount Lyell region

	Variable														
Site	Easting	Northing	Elevat	Bedslope	StmClass	Distsour	Catchsiz	Subedrck	subould	subcoble	subpeble	subgrav	subsand	subsilt	subclay	Flow
MTOWEN	384900	5241600	260	0.02632	2	2.8	3.07	0	10	65	15	5	5	0	0	2
HENTY	373300	5249700	76	0.00344	4	20.8	115.28	0	30	30	20	10	10	0	0	3
HALLS	377300	5234300	65	0.01980	3	4	6.44	0	0	50	30	10	10	0	0	2
GOVERN	393200	5230400	230	0.00687	4	8.8	27.60	0	70	20	5	5	0	0	0	2
STHELDON	391700	5247800	237	0.00597	4	22	116.01	0	10	70	20	0	0	0	0	1
EQUENONE	381700	5245500	263	0.01370	1	1.6	1.43	0	20	50	20	2	2	0	0	2
ELDON	391700	5247900	237	0.00399	4	20.1	96.82	0	5	90	5	0	0	0	0	2
PEARL	379200	5242800	262	0.02273	1	1.8	1.90	20	0	5	10	20	25	20	0	1
NEWALL	378700	5231500	39	0.01980	3	6.7	8.80	0	20	50	15	10	5	0	0	2
COMSTTWO	383500	5245500	318	0.02469	3	2.65	3.94	0	70	20	5	5	0	0	0	2
COMSTHRE	383600	5245500	315	0.02469	3	2.7	4.04	0	70	20	5	5	0	0	0	2
QUENFOUR	378300	5232200	92	0.00525	4	18.2	75.54	0	30	50	10	5	5	0	0	2
LINDA	386700	5241200	238	0.00781	3	4.2	13.68	0	25	70	5	0	0	0	0	2
KINGTHRE	370200	5227800	0	0.00587	5	18.5	230.35	0	10	55	30	5	0	0	0	1
EQUENTHR	342200	5280700	211	0.01418	4	5.5	6.76	0	25	50	15	10	0	0	0	2
NELSON	395100	5237700	318	0.01105	3	8.5	20.15	0	10	60	20	5	5	0	0	2
KINGONE	378600	5231500	39	0.00399	4	4.7	28.96	0	10	80	5	5	0	0	0	1
QUEENTWO	379200	5238200	106	0.01370	4	11.5	39.35	0	2	?	?	0	0	0	0	2
PRINCESS	377400	5235300	73	0.01282	3	5.3	12.86	0	5	70	15	5	5	0	0	1
COMSTFOR	387400	5245100	234	0.00935	3	7.25	18.73	0	0	50	50	0	0	0	0	2
KINGTWO	370600	5227700	0	0.00059	5	17.7	229.22	0	0	0	0	0	50	50	0	1.5
QUEENONE	380700	5241800	154	0.02198	4	6.7	14.56	0	50	30	10	5	5	0	0	2
EQUENTWO	381700	5244400	260	0.01370	1	2.5	1.53	0	10	70	10	10	0	0	0	2
YOLANDE	376500	5247100	145	0.00797	4	10.6	58.22	0	30	40	20	10	0	0	0	2
WESTQUEN	380500	5242200	161	0.00499	3	6.2	7.46	0	30	50	15	5	0	0	0	2
COMSTONE	383500	5245500	320	0.02469	3	2.6	3.44	0	40	50	10	0	0	0	0	2
CONGLOM	381300	5240800	160	0.03279	3	4.8	6.70	0	45	35	10	5	5	0	0	1
LYNCHS	378600	5336700	89	0.07696	2	4.3	4.88	5	25	50	15	5	5	0	0	2
CROTTY	386000	5321400	188	0.02326	3	4.8	9.57	0	5	40	30	15	10	0	0	2
ALLANS	385800	5323100	188	0.02083	2	3	3.00	0	5	70	20	5	0	0	0	2
CARDIGAN	403400	5335400	410	0.01980	3	5.5	14.31	0	40	40	10	10	0	0	0	2
COLLINGW	411300	5331500	335	0.00518	5	20.6	267.19	0	15	60	15	5	5	0	0	2

Table 1.4 (cont'd)

	Variable																		
Site	covsilt	covalgae	covdetri	covmoss	wclarity	Ttlcopp	pH	Sulphate	Colour	TSS	DOC	stvelmax	stvelmin	overbank	traibank	Ripleft	Ripright	Stdepth	stwidth	Temp
MTOWEN	0	40	0	0	0	0.045	5.7	2	100	<1	1.9	344	234	1	0	2	2	1	4	10.1
HENTY	0	20	0	5	2	0.001	6.8	2.7	70	<1	1.5	0.66		1	1	3	3	2	10	8.7
HALLS	0	2.5	0	2.5	0	0.004	6.1	3	125	<1	2.6	92	80	3	2	3	3	1		9
GOVERN	0	0	0	5	0	<0.001	6	2	60	<1	1.5	0.88		1	1	3	3	0	10	9
STHELDON	0	0	0	0	0	0.002	3.6	21	250	3	1	4	1	0	0	3	3	0	10	7.6
EQUENONE	0	30	0	2	0	0.013	6.7	2	85	<1	6.4	118	86	2	1	3	3	1	4	8.5
ELDON	0	2.5	0	0	0	0.002	6.4	1.5	85	<1	1.5	1		2	2	3	3	0	25	7.8
PEARL	0	10	0	50	0	0.015	5.1	6.2	70	1	1.4	1	0.5	3	2	3	3	0	1.5	10.9
NEWALL	0	60	0	15	0	0.01	6.2	2	175	<1	3.9	0.71		2	2	2	3	0	5	9.2
COMSTTWO	0	10	0	10	1	0.014	4.4	1.1	150	<1	2.5	146	52	3	2	3	3	1	4	7.9
COMSTHRE	0	2.5	0	15	3	0.33	3.9	21	250	3	0.5	118	68	2	2	3	1	1		7.9
QUENFOUR	0	0	0	0	3	4.8	3.2	230	225	67	2	124	64	2	1	3	3		20	9.8
LINDA	100	0	0	0	2	0.97	3.4	83	125	11	0.3	0.4	0.14	1	1	3	3	1	2.5	11.9
KINGTHRE	100	0	0	0	3	0.38	5	22	150	13	0.8	0.83		0	0	1	2	1		12.9
EQUENTHR	100	15	0	0	2	2.4	3.5	58	100	10	1.3	70	24	1	1	2	3	1	4	9.4
NELSON	0	5	0	20	0	0.028	6.8	3.6	70	<1	1.8	1010	650	3	2	2	3	1	5	8.6
KINGONE	0	60	0	0	0	0.009	6.2	2.2	100	1	6.7			0	0	3	3	0	20	11.7
QUEENTWO	100	0	0	0	3	5.1	3.1	260	250	57	2.5	140	11	0	0	1	0	2	10	8.6
PRINCESS	50	50	0	20	3	0.19	6.8	6.1	125	<1	2.4	0.33	0.25	2	1	3	3	0	4.3	12.3
COMSTFOR	0	10	0	0	2	0.24	4.8	18	85	6	0.3	1	0.5	1	1	3	3	0	4	9.3
KINGTWO	0	5	0	0	3	0.45	4.4	23	150	14	0.7			0	0	1	0	1	20	12.7
QUEENONE	0	0	0	0	3	0.26	4.8	4.7	125	5	2.6	132	98	0	0	1	1	2		9.9
EQUENTWO	0	0	10	0	2	0.58	4	17	150	11	2.1	128	72	3	2	3	3	0	3	8.8
YOLANDE	0	10	0	0	2	0.002	5.1	1.6	85	<1	1.9	1		2	2	3	3	3	12	9.6
WESTQUEN	0	40	0	5	0	0.007	6.1	2	85	<1	1.5	90	50	2	2	3	3	1	5	9.5
COMSTONE	0	15	0	5	1	0.008	4.4	1.1	150	<1	2.1	102	36	2	1	3	3	1	4	8
CONGLOM	0	20	0	0	0	0.037	4.6	5.9	30	<1	0.3	1	0.05	0	0	1	1		8	10.7
LYNCHS	0	40	0	20	0	0.005	6.5	2.7	40	<1	0.9	0.5		2	2	2	2	0	4	8.7
CROTTY	2.5	0	0	0	0	0.008	5.9	2.1	125	5	3.3	152	74	3	2	3	3	1		7.7
ALLANS	0	30	0	0	0	0.003	5	5.1	70	1	1.2	96	92	2	2	3	3	0		6.9
CARDIGAN	0	20	0	0	0	0.001	6.1	1.4	85	<1	2	1.42		2	2	3	3	1	4	8.2
COLLINGW	0	2.5	0	0	0	0.005	6.5	2.7	40	<1	1.4	0.77		1	2	3	3	1	25	8.1

Appendix 2

Biological data recorded for all rapid assessment protocol (RAP) sampling sites

Includes:

- All four seasonal RAP site riffle data
- All duplicate riffle and operator comparison RAP data
- RAP residue data
- RAP data for edge habitats

Table 2.1 Raw data from winter 1995 RAP sampling, Mount Lyell

			Site	MTOWEN	HENTY	HALLS	GOVERN	STHELDON	EQUENONE	ELDON	PEARL	NEWALL	COMSTTWO
			Date	19/7/95	20/7/95	19/7/95	21/7/95	21/7/95	20/7/95	21/7/95	19/7/95	19/7/95	20/7/95
			Kicker	LC	LC	LC	LC	LC	LC	PD	JJ	JJ	JJ
			Picker	LC	LC	LC	LC	LC	LC	PD	JJ	JJ	JJ
		TAXA											
Code	**Order**	**Class**	**Family**										
HYDROZOA	Cnidaria	Hydrozoa											
TURBEL	Platyhelminthes	Turbellaria											
NEMATODA	Nematoda												
BIVALVIA	Mollusca	Bivalvia											
GASTROP		Gastropoda											23
HIRUDIN	Annelida	Hirudinea											
OLIGOCH		Oligochaeta			7	9	12	1	3	9		15	20
HYDRACAR	Arachnida	Hydracarina									9	1	
AMPHIPOD	Crustacea	Amphipoda	Paramelitidae			2			3		28		
COPEPODA		Copepoda											
DECAPODA		Decapoda											
ISOPODA		Isopoda											
OSTRACOD		Ostracoda											
SYNCARID		Syncarida											5
COLLEMB	Insecta	Collembola											
EUSTHEN		Plecoptera	Eusthenidae		4	4			1	3		2	92
AUSTROP			Austroperlidae					2					
GRIPOPT			Gripopterygidae	14	35	2	30	17	9	26	63	27	15
NOTONEM			Notonemouridae										
LEPTOPHL		Ephemeroptera	Leptophlebiidae		24	8	13	23	2	21	23	62	
ONISCIG			Oniscigastridae										
CAENIDAE			Caenidae										
BAETIDAE			Baetidae		21					1			
SIPHLON			Siphlonuridae						1				
ZYGOPT		Odonata	Zygoptera										
ANISOPT			Anisopotera										
HEMIPT		Hemiptera											8
MECOPT		Mecoptera											11
CHIRONOM		Chironomidae	Chironominae		2			3				1	21
OTHOCLAD			Orthocladiinae	28	19		2	1	9	4	1	14	
PODOMIN			Podonominae	1	3	1	2	21	1	24		19	1
TANYPOD			Tanypodinae										
DIAMESIN			Diamesinae	2	3		1					10	
SIMULID			Simuliidae	1	5	4	6	26	2	9			
TUPULID			Tipulidae						1			1	
BLEPHER			Blephericeridae				5	3		1			
ATHERIC			Athericidae								5	1	
HYDROCH			Hydrochidae									1	
SCIOMYZ			Sciomyzidae										
NYMPHOM			Nymphomyiidae										
DOLICHOP			Dolichopodidae										4
TABANID			Tabanidae									1	
CALUCPUP			Calucid pupae									1	
DUNIDPUP			Unid. pupae							1			
ATRIPLEC		Trichoptera	Atriplectrididae										
CALAMOC			Calamoceratidae										20
CALOCID			Calocidae						1				
CONOESUC			Conoesucidae	3	7		3			2	17	7	
ECNOMID			Ecnomidae										16
GLOSSOM			Glossomatidae										
HELICOPH			Helicophidae			1			2		10		3
HELICOPS			Helicopsychidae										2
HYDROBIO			Hydrobiosidae	20	12	9	6	7	7	15	2	23	
HYDROPSY			Hydropsychidae		2		3		2		38		
HYDROPTI			Hydroptilidae							1			
KOKIRIID			Kokiriidae										
LEPTOCER			Leptoceridae		1					11			
LIMNEPH			Limnephilidae										1
OECONES			Oeconesidae										
PHILOPOT			Philopotamidae	1			1				2	4	
PHILORHE			Philorheithridae	1									
PLECTROT			Plectrotarsidae										
POLYCENT			Polycentropodidae										
TASIMIID			Tasimiidae										
TUNIDPUP			Unid. pupae		1								
ADTELMID		Coleoptera	Adult Elmidae			1				1	1		
COLADOTH			Other										9
LARELMID			Larvae Elmidae										
SCIRTID			Scirtidae	12		1	8			6		3	
PSEPHEN			Psephenidae								1	1	
COLARVOTH			Other										

Table 2.1 (cont'd)

				Site	COMSTHRE	QUENFOUR	LINDA	KINGTHRE	EQUENTHRE	NELSON	KINGONE	QUEENTWO	PRINCESS
				Date	20/7/95	27/7/95	26/7/95	27/7/95	20/7/95	27/7/95	26/7/95	19/7/95	19/7/95
				Kicker	LC	PD	NM	PD	JJ	NM	PD	LC	JJ
				Picker	LC	PD	NM	PD	JJ	NM	NM	LC	JJ
		TAXA											
Code	**Order**	**Class**	**Family**										
HYDROZOA	Cnidaria	Hydrozoa											
TURBEL	Platyhelminthes	Turbellaria											
NEMATODA	Nematoda												
BIVALVIA	Mollusca	Bivalvia											
GASTROP		Gastropoda											
HIRUDIN	Annelida	Hirudinea											
OLIGOCH		Oligochaeta					1				106	2	12
HYDRACAR	Arachnida	Hydracarina					1		1				3
AMPHIPOD	Crustacea	Amphipoda	Paramelitidae							1			13
COPEPODA		Copepoda											
DECAPODA		Decapoda											
ISOPODA		Isopoda											
OSTRACOD		Ostracoda											
SYNCARID		Syncarida											
COLLEMB	Insecta	Collembola					2					2	
EUSTHEN		Plecoptera	Eusthenidae							7			13
AUSTROP			Austroperlidae										
GRIPOPT			Gripopterygidae				1			26	2		11
NOTONEM			Notonemouridae										
LEPTOPHL		Ephemeroptera	Leptophlebiidae							60	2		17
ONISCIG			Oniscigastridae										
CAENIDAE			Caenidae										
BAETIDAE			Baetidae							3			
SIPHLON			Siphlonuridae										
ZYGOPT		Odonata	Zygoptera										
ANISOPT			Anisopotera										
HEMIPT		Hemiptera											
MECOPT		Mecoptera											
CHIRONOM		Chironomidae	Chironominae										
OTHOCLAD			Orthocladiinae				2	1	2		4	5	
PODOMIN			Podonominae						1	1			2
TANYPOD			Tanypodinae										
DIAMESIN			Diamesinae								3		
SIMULID			Simuliidae								1		
TUPULID			Tipulidae										
BLEPHER			Blephericeridae							2			
ATHERIC			Athericidae					1					
HYDROCH			Hydrochidae										
SCIOMYZ			Sciomyzidae						1				
NYMPHOM			Nymphomyiidae						1				
DOLICHOP			Dolichopodidae										
TABANID			Tabanidae										
CALUCPUP			Calucid pupae					6	4		3		
DUNIDPUP			Unid. pupae										
ATRIPLEC		Trichoptera	Atriplectrididae										
CALAMOC			Calamoceratidae										
CALOCID			Calocidae										2
CONOESUC			Conoesucidae										11
ECNOMID			Ecnomidae										
GLOSSOM			Glossomatidae										
HELICOPH			Helicophidae										
HELICOPS			Helicopsychidae										
HYDROBIO			Hydrobiosidae				1			6	2		18
HYDROPSY			Hydropsychidae										
HYDROPTI			Hydroptilidae										
KOKIRIID			Kokiriidae										
LEPTOCER			Leptoceridae										13
LIMNEPH			Limnephilidae										
OECONES			Oeconesidae										
PHILOPOT			Philopotamidae							2			
PHILORHE			Philorheithridae										
PLECTROT			Plectrotarsidae										
POLYCENT			Polycentropodidae										
TASIMIID			Tasimiidae										
TUNIDPUP			Unid. pupae										
ADTELMID		Coleoptera	Adult Elmidae					1					26
COLADOTH			Other										
LARELMID			Larvae Elmidae										1
SCIRTID			Scirtidae			1	3					4	1
PSEPHEN			Psephenidae										12
COLARVOTH			Other										

Table 2.1 (cont'd)

				COMSTFOR	KINGTWO	QUEENONE	QUEENTHRE	EQUENTWO	YOLANDE	WESTQUEN	COMSTONE	CONGLOM
			Site	COMSTFOR	KINGTWO	QUEENONE	QUEENTHRE	EQUENTWO	YOLANDE	WESTQUEN	COMSTONE	CONGLOM
			Date	21/7/95	27/7/95	19/7/95	20/7/95	20/7/95	20/7/95	19/7/95	20/7/95	19/7/95
			Kicker	NM	PD	NM	NM	NM	NM	JJ	NM	NM
			Picker	NM	NM	NM	NM	NM	NM	JJ	LC	NM
		TAXA										
Code	**Order**	**Class**	**Family**									
HYDROZOA	Cnidaria	Hydrozoa										
TURBEL	Platyhelminthes	Turbellaria										
NEMATODA	Nematoda											
BIVALVIA	Mollusca	Bivalvia										
GASTROP		Gastropoda										
HIRUDIN	Annelida	Hirudinea										
OLIGOCH		Oligochaeta					4		25	42	2	13
HYDRACAR	Arachnida	Hydracarina								1	3	
AMPHIPOD	Crustacea	Amphipoda	Paramelitidae						1	6	12	
COPEPODA		Copepoda										
DECAPODA		Decapoda										
ISOPODA		Isopoda										
OSTRACOD		Ostracoda										
SYNCARID		Syncarida										
COLLEMB	Insecta	Collembola					1					
EUSTHEN		Plecoptera	Eusthenidae				1		2	7	1	
AUSTROP			Austroperlidae									
GRIPOPT			Gripopterygidae	3					3	14	37	87
NOTONEM			Notonemouridae									
LEPTOPHL		Ephemeroptera	Leptophlebiidae				2		18	43	15	7
ONISCIG			Oniscigastridae									
CAENIDAE			Caenidae									
BAETIDAE			Baetidae							16		
SIPHLON			Siphlonuridae									
ZYGOPT		Odonata	Zygoptera									
ANISOPT			Anisopotera									
HEMIPT		Hemiptera										
MECOPT		Mecoptera										
CHIRONOM		Chironomidae	Chironominae				1			6		
OTHOCLAD			Orthocladiinae			1	6			49		45
PODOMIN			Podonominae							7	6	3
TANYPOD			Tanypodinae				1		2		1	
DIAMESIN			Diamesinae							3		25
SIMULID			Simuliidae			1			1	1	2	
TUPULID			Tipulidae							1	1	
BLEPHER			Blephericeridae						1			
ATHERIC			Athericidae									
HYDROCH			Hydrochidae									
SCIOMYZ			Sciomyzidae									
NYMPHOM			Nymphomyiidae									
DOLICHOP			Dolichopodidae			1						
TABANID			Tabanidae									
CALUCPUP			Calucid pupae		10	1				1		2
DUNIDPUP			Unid. pupae									
ATRIPLEC		Trichoptera	Atriplectrididae									
CALAMOC			Calamoceratidae									
CALOCID			Calocidae				1			1		
CONOESUC			Conoesucidae								18	
ECNOMID			Ecnomidae									
GLOSSOM			Glossomatidae									
HELICOPH			Helicophidae	1							5	
HELICOPS			Helicopsychidae	1								
HYDROBIO			Hydrobiosidae				3	1	9	31	9	3
HYDROPSY			Hydropsychidae						1			
HYDROPTI			Hydroptilidae									
KOKIRIID			Kokiriidae									
LEPTOCER			Leptoceridae						1	2		
LIMNEPH			Limnephilidae									
OECONES			Oeconesidae									
PHILOPOT			Philopotamidae							3	1	
PHILORHE			Philorheithridae						2			
PLECTROT			Plectrotarsidae									
POLYCENT			Polycentropodidae							1		
TASIMIID			Tasimiidae									
TUNIDPUP			Unid. pupae								1	1
ADTELMID		Coleoptera	Adult Elmidae								1	
COLADOTH			Other									
LARELMID			Larvae Elmidae									
SCIRTID			Scirtidae				2		1	4	3	2
PSEPHEN			Psephenidae							2	2	
COLARVOTH			Other									

Table 2.2 Raw data from spring 1995 RAP sampling, Mount Lyell

			Site	MTOWEN	HENTY	HALLS	GOVERN	STHELDON	EQUENONE	ELDON	PEARL
			Date	10/10/95	11/10/95	10/10/95	12/10/95	11/10/95	10/10/95	1/11/95	10/10/95
			Kicker	WE	NM	NM	NM	LC	WE	LC	JJ
			Picker	WE	NM	NM	NM	LC	WE	LC	JJ
		TAXA									
Code	Order	Class	Family								
HYDROZOA	Cnidaria	Hydrozoa									
TURBEL	Platyhelminthes	Turbellaria							1		
NEMATODA	Nematoda				1						
BIVALVIA	Mollusca	Bivalvia									
GASTROP		Gastropoda									
HIRUDIN	Annelida	Hirudinea									
OLIGOCH		Oligochaeta		2	6		12	3		6	
HYDRACAR	Arachnida	Hydracarina			1				2		6
PARAMEL	Crustacea	Amphipoda	Paramelitidae								17
CEINIDAE			Ceinidae								
EUSIRID			Eusiridae								
COPEPODA		Copepoda									
DECAPODA		Decapoda									
ISOPODA		Isopoda									
OSTRACOD		Ostracoda									
SYNCARID		Syncarida									
COLLEMB	Insecta	Collembola									
EUSTHEN		Plecoptera	Eusthenidae	1	1	4	3	1		8	1
AUSTROP			Austroperlidae				1	2			
GRIPOPT			Gripopterygidae	9	9	10	88	6	19	46	83
NOTONEM			Notonemouridae	2	1		1	1		1	
LEPTOPHL		Ephemeroptera	Leptophlebiidae		28	61	24	74	9	54	15
ONISCIG			Oniscigastridae								
CAENIDAE			Caenidae								
BAETIDAE			Baetidae		14						
SIPHLON			Siphlonuridae								
AESHNID		Odonata	Aeshnidae								1
HEMIPT		Hemiptera									
MECOPT		Mecoptera									
CHIRONOM	Diptera	Chironomidae	Chironominae		2	1		2			
OTHOCLAD			Orthocladiinae	39	20	1		3	3		4
PODOMIN			Podonominae		1	3	3	12		12	
TANYPOD			Tanypodinae					3			
DIAMESIN			Diamesinae		6						
SIMULID			Simuliidae		2	4	6	1	3	17	6
TUPULID			Tipulidae		3		2	3		1	
BLEPHER			Blephericeridae				6			4	
ATHERIC			Athericidae					1			2
EMPIDAD			Empididae		1						
HYDROCH			Hydrochidae								
MUSCIDAE			Muscidae								
SCIOMYZ			Sciomyzidae								
NYMPHOM			Nymphomyiidae								
DOLICHOP			Dolichopodidae								
SYRPHID			Syrphidae								
TABANID			Tabanidae								
CHAOBOR			Chaoboridae								
CERATOPG			Ceratopogonidae					1			
DUNIDPUP			Unid. pupae	1	3					1	
ATRIPLEC		Trichoptera	Atriplectrididae								
CALAMOC			Calamoceratidae								
CALOCID			Calocidae			1					
CONOESUC			Conoesucidae	17	12		4	1			27
ECNOMID			Ecnomidae								1
GLOSSOM			Glossomatidae			4					
HELICOPH			Helicophidae			2			2		1
HELICOPS			Helicopsychidae								
HYDROBIO			Hydrobiosidae	31	18	11	17	2	18	31	2
HYDROPSY			Hydropsychidae	1	4		1		1		79
HYDROPTI			Hydroptilidae								
KOKIRIID			Kokiriidae								
LEPTOCER			Leptoceridae	1		4		8		1	1
LIMNEPH			Limnephilidae								
OECONES			Oeconesidae								
ODONTOCR			Odontoceridae		3						
PHILOPOT			Philopotamidae	11			2				
PHILORHE			Philorheithridae		16	6		2			
PLECTROT			Plectrotarsidae								
POLYCENT			Polycentropodidae	2							
TASIMIID			Tasimiidae								
TUNIDPUP			Unid. pupae		1						2
ADTELMID		Coleoptera	Adult Elmidae		32	1		5		5	1
COLADOTH			Adult Heterocidae								
ADSCIRT			Adult Scirtidae								
COLUNIDA			Unident. A								
LARELMID			Larvae Elmidae		4	1	1	3			
SCIRTID			Scirtidae	4	1		14		1	1	
PSEPHEN			Psephenidae		2	1					2
DYTISCID			Dytiscidae								
HYDROPH			Hydrophildae								
GORDIID	Nematomorpha		Gordiidae								

Table 2.2 (cont'd)

			Site	NEWALL	COMSTTWO	COMSTHRE	QUENFOUR	LINDA	KINGTHRE	EQUENTWO	NELSON
			Date	10/10/95	10/10/95	10/10/95	11/10/95	10/10/95	6/10/95	10/10/95	10/10/95
			Kicker	LC	WE	JJ	WE	NM	WE	WE	WE
			Picker	LC	WE	JJ	NM	NM	WE	WE	WE
		TAXA									
Code	**Order**	**Class**	**Family**								
HYDROZOA	Cnidaria	Hydrozoa									
TURBEL	Platyhelminthes	Turbellaria									
NEMATODA	Nematoda										
BIVALVIA	Mollusca	Bivalvia									
GASTROP		Gastropoda									
HIRUDIN	Annelida	Hirudinea									
OLIGOCH		Oligochaeta		6			5	3		2	5
HYDRACAR	Arachnida	Hydracarina		2				1			
PARAMEL	Crustacea	Amphipoda	Paramelitidae		3						4
CEINIDAE			Ceinidae								
EUSIRID			Eusiridae								
COPEPODA		Copepoda									
DECAPODA		Decapoda									
ISOPODA		Isopoda									
OSTRACOD		Ostracoda									
SYNCARID		Syncarida									
COLLEMB	Insecta	Collembola					4				
EUSTHEN		Plecoptera	Eusthenidae	2	6						5
AUSTROP			Austroperlidae								
GRIPOPT			Gripopterygidae	26	120		1	1		1	76
NOTONEM			Notonemouridae	1							
LEPTOPHL		Ephemeroptera	Leptophlebiidae	80	9			1			39
ONISCIG			Oniscigastridae								
CAENIDAE			Caenidae								
BAETIDAE			Baetidae								2
SIPHLON			Siphlonuridae								
AESHNID		Odonata	Aeshnidae	2							
HEMIPT		Hemiptera									
MECOPT		Mecoptera									
CHIRONOM	Diptera	Chironomidae	Chironominae			1	1				
OTHOCLAD			Orthocladiinae	3	1	1	1	1		4	3
PODOMIN			Podonominae	2	1				1	1	2
TANYPOD			Tanypodinae			1					
DIAMESIN			Diamesinae								1
SIMULID			Simuliidae		1						1
TUPULID			Tipulidae				1				1
BLEPHER			Blephericeridae								2
ATHERIC			Athericidae								
EMPIDAD			Empididae								
HYDROCH			Hydrochidae								
MUSCIDAE			Muscidae								
SCIOMYZ			Sciomyzidae								
NYMPHOM			Nymphomyiidae								
DOLICHOP			Dolichopodidae								
SYRPHID			Syrphidae								
TABANID			Tabanidae								
CHAOBOR			Chaoboridae								
CERATOPG			Ceratopogonidae								
DUNIDPUP			Unid. pupae				2	2			1
ATRIPLEC		Trichoptera	Atriplectrididae								
CALAMOC			Calamoceratidae								
CALOCID			Calocidae								
CONOESUC			Conoesucidae	4	16						3
ECNOMID			Ecnomidae								
GLOSSOM			Glossomatidae	1							5
HELICOPH			Helicophidae	1	5						
HELICOPS			Helicopsychidae								2
HYDROBIO			Hydrobiosidae	34	7						5
HYDROPSY			Hydropsychidae		2						
HYDROPTI			Hydroptilidae								
KOKIRIID			Kokiriidae								
LEPTOCER			Leptoceridae				1				
LIMNEPH			Limnephilidae								
OECONES			Oeconesidae								
ODONTOCR			Odontoceridae								
PHILOPOT			Philopotamidae		1						
PHILORHE			Philorheithridae								
PLECTROT			Plectrotarsidae								
POLYCENT			Polycentropodidae								
TASIMIID			Tasimiidae								
TUNIDPUP			Unid. pupae	1	1						
ADTELMID		Coleoptera	Adult Elmidae	1							
COLADOTH			Adult Heterocidae								
ADSCIRT			Adult Scirtidae								
COLUNIDA			Unident. A								
LARELMID			Larvae Elmidae	2							
SCIRTID			Scirtidae	4	3		4				3
PSEPHEN			Psephenidae	3							1
DYTISCID			Dytiscidae					1			
HYDROPH			Hydrophildae								
GORDIID	Nematomorpha		Gordiidae								

Table 2.2 (cont'd)

Code	Order	Class	Family	KINGONE	QUEENTWO	PRINCESS	COMSTFOR	KINGTWO	QUEENONE	EQUENTHR	YOLANDE
			Date	6/10/95	11/10/95	11/10/95	11/10/95	6/10/95	10/10/95	10/10/95	11/10/95
			Kicker	LC	NM	WE	JJ	LC	JJ	WE	WE
			Picker	LC	NM	WE	JJ	LC	JJ	WE	WE
		TAXA									
HYDROZOA	Cnidaria	Hydrozoa									
TURBEL	Platyhelminthes	Turbellaria									
NEMATODA	Nematoda										
BIVALVIA	Mollusca	Bivalvia									
GASTROP		Gastropoda									
HIRUDIN	Annelida	Hirudinea									
OLIGOCH		Oligochaeta		62	2						4
HYDRACAR	Arachnida	Hydracarina			1	1	5				
PARAMEL	Crustacea	Amphipoda	Paramelitidae			18					
CEINIDAE			Ceinidae								
EUSIRID			Eusiridae								
COPEPODA		Copepoda									
DECAPODA		Decapoda									
ISOPODA		Isopoda									
OSTRACOD		Ostracoda									
SYNCARID		Syncarida									
COLLEMB	Insecta	Collembola			1						
EUSTHEN		Plecoptera	Eusthenidae			15					2
AUSTROP			Austroperlidae								
GRIPOPT			Gripopterygidae	3		6	1				22
NOTONEM			Notonemouridae	3			3				
LEPTOPHL		Ephemeroptera	Leptophlebiidae	1		6					23
ONISCIG			Oniscigastridae								
CAENIDAE			Caenidae								
BAETIDAE			Baetidae								
SIPHLON			Siphlonuridae								
AESHNID		Odonata	Aeshnidae			1					
HEMIPT		Hemiptera									
MECOPT		Mecoptera									
CHIRONOM	Diptera	Chironomidae	Chironominae			1					
OTHOCLAD			Orthocladiinae	13	4		33				
PODOMIN			Podonominae						1		
TANYPOD			Tanypodinae				7				
DIAMESIN			Diamesinae	94							
SIMULID			Simuliidae	2							33
TUPULID			Tipulidae								
BLEPHER			Blephericeridae								5
ATHERIC			Athericidae								
EMPIDAD			Empididae								
HYDROCH			Hydrochidae								
MUSCIDAE			Muscidae								
SCIOMYZ			Sciomyzidae								
NYMPHOM			Nymphomyiidae								
DOLICHOP			Dolichopodidae								
SYRPHID			Syrphidae								
TABANID			Tabanidae								
CHAOBOR			Chaoboridae					1			
CERATOPG			Ceratopogonidae								
DUNIDPUP			Unid. pupae							1	
ATRIPLEC		Trichoptera	Atriplectrididae								
CALAMOC			Calamoceratidae								
CALOCID			Calocidae	1							
CONOESUC			Conoesucidae	2		2					
ECNOMID			Ecnomidae								
GLOSSOM			Glossomatidae								
HELICOPH			Helicophidae			1					
HELICOPS			Helicopsychidae			1					
HYDROBIO			Hydrobiosidae	5	1	5	1				7
HYDROPSY			Hydropsychidae			1					1
HYDROPTI			Hydroptilidae								
KOKIRIID			Kokiriidae								
LEPTOCER			Leptoceridae			8					
LIMNEPH			Limnephilidae								
OECONES			Oeconesidae								
ODONTOCR			Odontoceridae								
PHILOPOT			Philopotamidae	7							
PHILORHE			Philorheithridae	2		2					1
PLECTROT			Plectrotarsidae								
POLYCENT			Polycentropodidae								
TASIMIID			Tasimiidae								
TUNIDPUP			Unid. pupae								
ADTELMID		Coleoptera	Adult Elmidae		1	6	1		1		
COLADOTH			Adult Heterocidae								
ADSCIRT			Adult Scirtidae								
COLUNIDA			Unident. A			2					
LARELMID			Larvae Elmidae								
SCIRTID			Scirtidae						1		5
PSEPHEN			Psephenidae			9					
DYTISCID			Dytiscidae				1				
HYDROPH			Hydrophildae								
GORDIID	Nematomorpha		Gordiidae								

Table 2.2 (cont'd)

Code	Order	TAXA Class	Family	WESTQUEN	COMSTONE	CONGLOM	COLLINGW	CARDIGAN	LYNCH	CROTTY	TOWNSHIP
			Site	WESTQUEN	COMSTONE	CONGLOM	COLLINGW	CARDIGAN	LYNCH	CROTTY	TOWNSHIP
			Date	12/10/95	10/10/95	10/10/95	31/10/95	31/10/95	13/10/95	1/11/95	1/11/95
			Kicker	LC	JJ	LC	LC	NM	LC	LC	NM
			Picker	LC	JJ	LC	LC	NM	LC	LC	NM
HYDROZOA	Cnidaria	Hydrozoa									
TURBEL	Platyhelminthes	Turbellaria									
NEMATODA	Nematoda					1					
BIVALVIA	Mollusca	Bivalvia									
GASTROP		Gastropoda									
HIRUDIN	Annelida	Hirudinea									
OLIGOCH		Oligochaeta		24	18		24	15	2	27	9
HYDRACAR	Arachnida	Hydracarina		2	1			1			1
PARAMEL	Crustacea	Amphipoda	Paramelitidae	10	11				8	1	
CEINIDAE			Ceinidae								
EUSIRID			Eusiridae								
COPEPODA		Copepoda									
DECAPODA		Decapoda									
ISOPODA		Isopoda									
OSTRACOD		Ostracoda									
SYNCARID		Syncarida									
COLLEMB	Insecta	Collembola									
EUSTHEN		Plecoptera	Eusthenidae	4	1		3	8	31	5	8
AUSTROP			Austroperlidae				3	7		16	7
GRIPOPT			Gripopterygidae	10	99	31	20	10	53	9	38
NOTONEM			Notonemouridae								
LEPTOPHL		Ephemeroptera	Leptophlebiidae	44	30	1	110	77	41	68	40
ONISCIG			Oniscigastridae								
CAENIDAE			Caenidae								
BAETIDAE			Baetidae	5					2		
SIPHLON			Siphlonuridae								
AESHNID		Odonata	Aeshnidae						1	1	3
HEMIPT		Hemiptera									
MECOPT		Mecoptera									
CHIRONOM	Diptera	Chironomidae	Chironominae	10	12			8	2	4	5
OTHOCLAD			Orthocladiinae	40	20	77	1		2	2	6
PODOMIN			Podonominae		5		9	3	1	2	3
TANYPOD			Tanypodinae	1		2					1
DIAMESIN			Diamesinae		1	6			1		
SIMULID			Simuliidae		4	4	55	6	2	33	6
TUPULID			Tipulidae				2	4	1	3	6
BLEPHER			Blephericeridae				14			1	2
ATHERIC			Athericidae	2	1						
EMPIDAD			Empididae	1							
HYDROCH			Hydrochidae								
MUSCIDAE			Muscidae								
SCIOMYZ			Sciomyzidae								
NYMPHOM			Nymphomyiidae								
DOLICHOP			Dolichopodidae								
SYRPHID			Syrphidae								
TABANID			Tabanidae								
CHAOBOR			Chaoboridae								
CERATOPG			Ceratopogonidae								
DUNIDPUP			Unid. pupae			4	3	2			
ATRIPLEC		Trichoptera	Atriplectrididae								
CALAMOC			Calamoceratidae								
CALOCID			Calocidae						1		
CONOESUC			Conoesucidae	2	38	1	1	1	2	1	26
ECNOMID			Ecnomidae								
GLOSSOM			Glossomatidae							1	1
HELICOPH			Helicophidae		5						1
HELICOPS			Helicopsychidae								
HYDROBIO			Hydrobiosidae	12	21	15	44	23	5	14	64
HYDROPSY			Hydropsychidae	4	3	4					
HYDROPTI			Hydroptilidae	3							1
KOKIRIID			Kokiriidae								
LEPTOCER			Leptoceridae	16			1				
LIMNEPH			Limnephilidae								
OECONES			Oeconesidae								
ODONTOCR			Odontoceridae					1			
PHILOPOT			Philopotamidae	25			5	1	7	2	1
PHILORHE			Philorheithridae					2	2		
PLECTROT			Plectrotarsidae								
POLYCENT			Polycentropodidae								1
TASIMIID			Tasimiidae								
TUNIDPUP			Unid. pupae	1	2					1	3
ADTELMID		Coleoptera	Adult Elmidae				10			12	8
COLADOTH			Adult Heterocidae		1						
ADSCIRT			Adult Scirtidae								
COLUNIDA			Unident. A								
LARELMID			Larvae Elmidae	1			5				
SCIRTID			Scirtidae	1	6	6		13		1	14
PSEPHEN			Psephenidae	4							2
DYTISCID			Dytiscidae								
HYDROPH			Hydrophildae								
GORDIID	Nematomorpha		Gordiidae								

Table 2.3 Raw data from summer 1995 RAP sampling, Mount Lyell

			Site	MTOWEN	HENTY	HALLS	GOVERN	STHELDON	EQUENONE	ELDON	PEARL
			Date	23/1/96	26/1/96	24/1/96	24/1/96	24/1/96	25/1/96	24/1/96	24/1/96
			Kicker	NM	JJ	NM	LC	LC	LC	LC	JJ
			Picker	NM	JJ	NM	LC	LC	LC	LC	JJ
Code	Order	TAXA Class	Family								
HYDROZOA	Cnidaria	Hydrozoa									
TURBEL	Platyhelminthes	Turbellaria									
NEMATODA	Nematoda			2							
BIVALVIA	Mollusca	Bivalvia									
GASTROP		Gastropoda									
HIRUDIN	Annelida	Hirudinea									
OLIGOCH		Oligochaeta		1	18	4	26	9		5	3
HYDRACAR	Arachnida	Hydracarina		3	6		2	8	4	1	13
PARAMEL	Crustacea	Amphipoda	Paramelitidae			1	1		2		18
CEINIDAE			Ceinidae			2					
EUSIRID			Eusiridae								
COPEPODA		Copepoda									
DECAPODA		Decapoda									
ISOPODA		Isopoda									
OSTRACOD		Ostracoda									
SYNCARID		Syncarida									
COLLEMB	Insecta	Collembola		1							
EUSTHEN		Plecoptera	Eusthenidae		2	1	5	14	10	47	
AUSTROP			Austroperlidae		1			2		3	
GRIPOPT			Gripopterygidae	1	23	1	38	7	4	26	24
NOTONEM			Notonemouridae	22	2	1	5	14			
LEPTOPHL		Ephemeroptera	Leptophlebiidae	19	66	28	31	59	11	58	27
ONISCIG			Oniscigastridae								
CAENIDAE			Caenidae								
BAETIDAE			Baetidae		4		3	3		8	
SIPHLON			Siphlonuridae								
AESHNID		Odonata	Aeshnidae			1	2				1
HEMIPT		Hemiptera									
MECOPT		Mecoptera									
CHIRONOM	Diptera	Chironomidae	Chironominae		19	3	5	2		6	
OTHOCLAD			Orthocladiinae	44	9		15	5	7	5	2
PODAMIN			Podonominae		4	2	1	1	1	1	1
TANYPOD			Tanypodinae	25			3	3	2		1
DIAMESIN			Diamesinae								
SIMULID			Simuliidae		2		1	3	1	23	9
TUPULID			Tipulidae	1		4	6	1	3		
BLEPHER			Blephericeridae								
ATHERIC			Athericidae								3
EMPIDAD			Empididae								
HYDROCH			Hydrochidae								
MUSCIDAE			Muscidae								
SCIOMYZ			Sciomyzidae								
NYMPHOM			Nymphomyiidae								
DOLICHOP			Dolichopodidae								
SYRPHID			Syrphidae								
TABANID			Tabanidae								
CHAOBOR			Chaoboridae								
CERATOPG			Ceratopogonidae		8			1			
DUNIDPUP			Unid. pupae	1		4	1	1	1	1	
ATRIPLEC		Trichoptera	Atriplectrididae								
CALAMOC			Calamoceratidae								
CALOCID			Calocidae	3	1	18			3		
CONOESUC			Conoesucidae	2			3	2			20
ECNOMID			Ecnomidae		1						
GLOSSOM			Glossomatidae								
HELICOPH			Helicophidae						1		4
HELICOPS			Helicopsychidae								
HYDROBIO			Hydrobiosidae	20	25	13	25	13	49	7	7
HYDROPSY			Hydropsychidae	1		1	1		2		30
HYDROPTI			Hydroptilidae				2				
KOKIRIID			Kokiriidae								
LEPTOCER			Leptoceridae	2	14	4	11	20	1	66	2
LIMNEPH			Limnephilidae								
OECONES			Oeconesidae								
ODONTOCR			Odontoceridae								
PHILOPOT			Philopotamidae	3			2	18	3	16	
PHILORHE			Philorheithridae	1	5		1	1	2	2	
PLECTROT			Plectrotarsidae								
POLYCENT			Polycentropodidae	5					1		
TASIMIID			Tasimiidae								
TUNIDPUP			Unid. pupae	6			6	1	2	1	1
ADTELMID		Coleoptera	Adult Elmidae	1	3	15		16	1	9	1
COLADOTH			Adult Heterocidae								
ADSCIRT			Adult Scirtidae								
COLUNIDA			Unident. A								
LARELMID			Larvae Elmidae	1	2	1		1		1	
SCIRTID			Scirtidae				2		3	1	
PSEPHEN			Psephenidae	1	6	1				1	1
DYTISCID			Dytiscidae								
HYDROPH			Hydrophildae								
GORDIID	Nematomorpha		Gordiidae								

Table 2.3 (cont'd)

				NEWALL	COMSTTWO	COMSTHRE	QUENFOUR	LINDA	KINGTHRE	EQUENTWO	NELSON
			Site	NEWALL	COMSTTWO	COMSTHRE	QUENFOUR	LINDA	KINGTHRE	EQUENTWO	NELSON
			Date	23/1/96	25/1/96	25/1/96	25/1/96	23/1/96	23/1/96	25/1/96	22/1/96
			Kicker	JJ	LC	NM	JJ	WE	JJ	JJ	JJ
			Picker	JJ	LC	NM	JJ	WE	JJ	JJ	JJ
		TAXA									
Code	**Order**	**Class**	**Family**								
HYDROZOA	Cnidaria	Hydrozoa									
TURBEL	Platyhelminthes	Turbellaria		1							
NEMATODA	Nematoda										
BIVALVIA	Mollusca	Bivalvia									
GASTROP		Gastropoda									
HIRUDIN	Annelida	Hirudinea									
OLIGOCH		Oligochaeta		10	2						5
HYDRACAR	Arachnida	Hydracarina		5	1					2	
PARAMEL	Crustacea	Amphipoda	Paramelitidae	1	16						1
CEINIDAE			Ceinidae								
EUSIRID			Eusiridae	1							
COPEPODA		Copepoda									
DECAPODA		Decapoda									
ISOPODA		Isopoda									
OSTRACOD		Ostracoda									
SYNCARID		Syncarida									
COLLEMB	Insecta	Collembola									
EUSTHEN		Plecoptera	Eusthenidae	4	3						5
AUSTROP			Austroperlidae								
GRIPOPT			Gripopterygidae	32	9				2		19
NOTONEM			Notonemouridae			1	1	1		4	
LEPTOPHL		Ephemeroptera	Leptophlebiidae	57	18						73
ONISCIG			Oniscigastridae								
CAENIDAE			Caenidae								
BAETIDAE			Baetidae								14
SIPHLON			Siphlonuridae								
AESHNID		Odonata	Aeshnidae	1							
HEMIPT		Hemiptera									
MECOPT		Mecoptera									
CHIRONOM	Diptera	Chironomidae	Chironominae	2	1				1		7
OTHOCLAD			Orthocladiinae	8	3	2			2		4
PODAMIN			Podonominae	17					1		4
TANYPOD			Tanypodinae	1	2	3				1	
DIAMESIN			Diamesinae								
SIMULID			Simuliidae	14	3						1
TUPULID			Tipulidae							1	
BLEPHER			Blephericeridae	1							
ATHERIC			Athericidae								
EMPIDAD			Empididae		1						
HYDROCH			Hydrochidae								
MUSCIDAE			Muscidae								
SCIOMYZ			Sciomyzidae								
NYMPHOM			Nymphomyiidae								
DOLICHOP			Dolichopodidae								
SYRPHID			Syrphidae								
TABANID			Tabanidae								
CHAOBOR			Chaoboridae								
CERATOPG			Ceratopogonidae								
DUNIDPUP			Unid. pupae			1	1		1		
ATRIPLEC		Trichoptera	Atriplectrididae								
CALAMOC			Calamoceratidae								
CALOCID			Calocidae								
CONOESUC			Conoesucidae	2	42	1			1		
ECNOMID			Ecnomidae	1							
GLOSSOM			Glossomatidae	2							
HELICOPH			Helicophidae		6						
HELICOPS			Helicopsychidae								
HYDROBIO			Hydrobiosidae	34	9					3	
HYDROPSY			Hydropsychidae		2						
HYDROPTI			Hydroptilidae								
KOKIRIID			Kokiriidae								
LEPTOCER			Leptoceridae								
LIMNEPH			Limnephilidae							1	
OECONES			Oeconesidae								
ODONTOCR			Odontoceridae								
PHILOPOT			Philopotamidae	10							
PHILORHE			Philorheithridae							3	
PLECTROT			Plectrotarsidae								
POLYCENT			Polycentropodidae	1							
TASIMIID			Tasimiidae								
TUNIDPUP			Unid. pupae	3							
ADTELMID		Coleoptera	Adult Elmidae	17	2			2		1	
COLADOTH			Adult Heterocidae								
ADSCIRT			Adult Scirtidae								
COLUNIDA			Unident. A								
LARELMID			Larvae Elmidae	5			1				
SCIRTID			Scirtidae	7			1				
PSEPHEN			Psephenidae								
DYTISCID			Dytiscidae					2			
HYDROPH			Hydrophildae								
GORDIID	Nematomorpha		Gordiidae								

Table 2.3 (cont'd)

		TAXA	Site	KINGONE	QUEENTWO	PRINCESS	COMSTFOR	KINGTWO	QUEENONE	EQUENTHR	YOLANDE
			Date	23/1/96	25/1/96	25/1/96	24/1/96	23/1/96	25/1/96	25/1/93	26/1/96
			Kicker	JJ	NM	WE	WE	LC	JJ	NM	WE
			Picker	JJ	NM	WE	WE	LC	JJ	NM	WE
Code	**Order**	**Class**	**Family**								
HYDROZOA	Cnidaria	Hydrozoa									
TURBEL	Platyhelminthes	Turbellaria		1							
NEMATODA	Nematoda										
BIVALVIA	Mollusca	Bivalvia									
GASTROP		Gastropoda									
HIRUDIN	Annelida	Hirudinea									
OLIGOCH		Oligochaeta		37	2	5		2		1	12
HYDRACAR	Arachnida	Hydracarina		7	1	4					
PARAMEL	Crustacea	Amphipoda	Paramelitidae	1		28					4
CEINIDAE			Ceinidae								
EUSIRID			Eusiridae								
COPEPODA		Copepoda									
DECAPODA		Decapoda									
ISOPODA		Isopoda									
OSTRACOD		Ostracoda									
SYNCARID		Syncarida									
COLLEMB	Insecta	Collembola			1					2	
EUSTHEN		Plecoptera	Eusthenidae			12					4
AUSTROP			Austroperlidae								2
GRIPOPT			Gripopterygidae	29		15					2
NOTONEM			Notonemouridae						2		
LEPTOPHL		Ephemeroptera	Leptophlebiidae	18	2	39		2	2		77
ONISCIG			Oniscigastridae								
CAENIDAE			Caenidae								
BAETIDAE			Baetidae								
SIPHLON			Siphlonuridae								
AESHNID		Odonata	Aeshnidae			1					
HEMIPT		Hemiptera									
MECOPT		Mecoptera									
CHIRONOM	Diptera	Chironomidae	Chironominae	27	2	4			5	3	
OTHOCLAD			Orthocladiinae	69	8	1		5	5	3	1
PODAMIN			Podonominae					1			
TANYPOD			Tanypodinae	2	1			1	1		2
DIAMESIN			Diamesinae	2							
SIMULID			Simuliidae	7							3
TUPULID			Tipulidae	1	·1						6
BLEPHER			Blephericeridae								
ATHERIC			Athericidae			1					1
EMPIDAD			Empididae								
HYDROCH			Hydrochidae								
MUSCIDAE			Muscidae		1						
SCIOMYZ			Sciomyzidae								
NYMPHOM			Nymphomyiidae								
DOLICHOP			Dolichopodidae								
SYRPHID			Syrphidae						1		
TABANID			Tabanidae								
CHAOBOR			Chaoboridae					1			
CERATOPG			Ceratopogonidae								
DUNIDPUP			Unid. pupae	5					1	4	1
ATRIPLEC		Trichoptera	Atriplectrididae								
CALAMOC			Calamoceratidae								
CALOCID			Calocidae			3					1
CONOESUC			Conoesucidae								2
ECNOMID			Ecnomidae	1							
GLOSSOM			Glossomatidae								
HELICOPH			Helicophidae								
HELICOPS			Helicopsychidae								
HYDROBIO			Hydrobiosidae	22		9		1	2		27
HYDROPSY			Hydropsychidae								3
HYDROPTI			Hydroptilidae	12					1		
KOKIRIID			Kokiriidae								
LEPTOCER			Leptoceridae			25			1		20
LIMNEPH			Limnephilidae								
OECONES			Oeconesidae								
ODONTOCR			Odontoceridae								
PHILOPOT			Philopotamidae					2			
PHILORHE			Philorheithridae			5				1	3
PLECTROT			Plectrotarsidae								
POLYCENT			Polycentropodidae								
TASIMIID			Tasimiidae								
TUNIDPUP			Unid. pupae	2							
ADTELMID		Coleoptera	Adult Elmidae			22					
COLADOTH			Adult Heterocidae								
ADSCIRT			Adult Scirtidae								
COLUNIDA			Unident. A								
LARELMID			Larvae Elmidae			2					
SCIRTID			Scirtidae								1
PSEPHEN			Psephenidae			29					1
DYTISCID			Dytiscidae		1				1		
HYDROPH			Hydrophildae		1						
GORDIID	Nematomorpha		Gordiidae								

Table 2.3 (cont'd)

			Site	WESTQUEN	COMSTONE	CONGLOM	COLLINGW	CARDIGAN	LYNCH	CROTTY	TOWNSHIP
			Date	25/1/96	25/1/96	25/1/96	23/1/96	23/1/96	23/1/96	24/1/96	24/1/96
			Kicker	JJ	JJ	NM	WE	NM	LC	NM	JJ
			Picker	JJ	JJ	NM	WE	NM	LC	NM	JJ
		TAXA									
Code	**Order**	**Class**	**Family**								
HYDROZOA	Cnidaria	Hydrozoa									
TURBEL	Platyhelminthes	Turbellaria		2	1						
NEMATODA	Nematoda										
BIVALVIA	Mollusca	Bivalvia									
GASTROP		Gastropoda									
HIRUDIN	Annelida	Hirudinea									
OLIGOCH		Oligochaeta		10	17	5	26	2	9	7	7
HYDRACAR	Arachnida	Hydracarina		6	7	15		5	2		14
PARAMEL	Crustacea	Amphipoda	Paramelitidae	7	13				24	1	
CEINIDAE			Ceinidae						1		
EUSIRID			Eusiridae								
COPEPODA		Copepoda									
DECAPODA		Decapoda									
ISOPODA		Isopoda									
OSTRACOD		Ostracoda									
SYNCARID		Syncarida									
COLLEMB	Insecta	Collembola									
EUSTHEN		Plecoptera	Eusthenidae	8	17		1	9	49	1	9
AUSTROP			Austroperlidae				4			11	5
GRIPOPT			Gripopterygidae	6	31	43	3	15	19		22
NOTONEM			Notonemouridae		3	6		3			1
LEPTOPHL		Ephemeroptera	Leptophlebiidae	24	34	2	39	61	41	27	39
ONISCIG			Oniscigastridae								
CAENIDAE			Caenidae								
BAETIDAE			Baetidae	2			7	1	25		
SIPHLON			Siphlonuridae								
AESHNID		Odonata	Aeshnidae		1						10
HEMIPT		Hemiptera									
MECOPT		Mecoptera									
CHIRONOM	Diptera	Chironomidae	Chironominae	32	20			4	11	4	18
OTHOCLAD			Orthocladiinae	17	8	58	1	9	18	1	7
PODAMIN			Podonominae		5		2	3	1		3
TANYPOD			Tanypodinae	2	1	1		1	1		1
DIAMESIN			Diamesinae								
SIMULID			Simuliidae	4	6	5	26	11	1	37	9
TUPULID			Tipulidae				1	1		1	2
BLEPHER			Blephericeridae				1			1	
ATHERIC			Athericidae	1			2				
EMPIDAD			Empididae	1							1
HYDROCH			Hydrochidae								
MUSCIDAE			Muscidae								
SCIOMYZ			Sciomyzidae								
NYMPHOM			Nymphomyiidae								
DOLICHOP			Dolichopodidae								
SYRPHID			Syrphidae								
TABANID			Tabanidae								
CHAOBOR			Chaoboridae								
CERATOPG			Ceratopogonidae								
DUNIDPUP			Unid. pupae	2	1			1		4	
ATRIPLEC		Trichoptera	Atriplectrididae								
CALAMOC			Calamoceratidae								
CALOCID			Calocidae				1				1
CONOESUC			Conoesucidae		34	2			4	4	21
ECNOMID			Ecnomidae								
GLOSSOM			Glossomatidae								
HELICOPH			Helicophidae		2				3	3	1
HELICOPS			Helicopsychidae							1	
HYDROBIO			Hydrobiosidae	35	26	19	24	26	15	24	40
HYDROPSY			Hydropsychidae	7	1	3	1				3
HYDROPTI			Hydroptilidae	21							
KOKIRIID			Kokiriidae								
LEPTOCER			Leptoceridae	16	1		22	1	2	3	2
LIMNEPH			Limnephilidae								
OECONES			Oeconesidae								
ODONTOCR			Odontoceridae								
PHILOPOT			Philopotamidae	9	1			1	20	1	
PHILORHE			Philorheithridae		1	14	1	3			
PLECTROT			Plectrotarsidae								
POLYCENT			Polycentropodidae			1					
TASIMIID			Tasimiidae								
TUNIDPUP			Unid. pupae	2		1		3			1
ADTELMID		Coleoptera	Adult Elmidae	13	2	1	42		9	29	2
COLADOTH			Adult Heterocidae								
ADSCIRT			Adult Scirtidae	1							
COLUNIDA			Unident. A								
LARELMID			Larvae Elmidae	3			2			2	3
SCIRTID			Scirtidae					2		5	2
PSEPHEN			Psephenidae	13					2		4
DYTISCID			Dytiscidae			1					
HYDROPH			Hydrophildae								
GORDIID	Nematomorpha		Gordiidae		1						

Table 2.4 Raw data from autumn 1995 RAP sampling, Mount Lyell

				MTOWEN	HENTY	HALLS	GOVERN	STHELDON	EQUENONE	ELDON	PEARL
			Site	MTOWEN	HENTY	HALLS	GOVERN	STHELDON	EQUENONE	ELDON	PEARL
			Date	10.4.96	18.4.96	18.4.96	11.4.96	18.4.96	17.4.96	12.4.96	11.4.96
			Kicker	L.C.	C.M.	L.C.	L.C.	L.C.		L.C.	C.M.
			Picker	L.C.	C.M.	L.C.	L.C.	L.C.		L.C.	C.M.
		TAXA									
Code	**Order**	**Class**	**Family**								
HYDROZOA	Cnidaria	Hydrozoa									
TURBEL	Platyhelminthes	Turbellaria		1	2						
NEMATODA	Nematoda										
BIVALVIA	Mollusca	Bivalvia									
GASTROP		Gastropoda									
HIRUDIN	Annelida	Hirudinea									
OLIGOCH		Oligochaeta		11	11	34	7	5			2
HYDRACAR	Arachnida	Hydracarina		13		2		1	2	1	3
PARAMEL	Crustacea	Amphipoda	Paramelitidae	1		4	1		2	1	20
CEINIDAE			Ceinidae								
EUSIRID			Eusiridae								
COPEPODA		Copepoda									
DECAPODA		Decapoda									
ISOPODA		Isopoda									
OSTRACOD		Ostracoda									
SYNCARID		Syncarida									
COLLEMB	Insecta	Collembola					1		1		
EUSTHEN		Plecoptera	Eusthenidae		3		4		11	6	
AUSTROP			Austroperlidae		1			1		1	
GRIPOPT			Gripopterygidae		6	2	53	17	9	34	35
NOTONEM			Notonemouridae	18	1				1		1
LEPTOPHL		Ephemeroptera	Leptophlebiidae	9	31	99	48	57	44	81	22
ONISCIG			Oniscigastridae								
CAENIDAE			Caenidae								
BAETIDAE			Baetidae		16	13		1			
SIPHLON			Siphlonuridae								
AESHNID		Odonata	Aeshnidae								
HEMIPT		Hemiptera									
MECOPT		Mecoptera									
CHIRONOM	Diptera	Chironomidae	Chironominae			2			1		1
OTHOCLAD			Orthocladiinae		1	1		1	1	15	3
PODAMIN			Podonominae		18	11	10	6	5		1
TANYPOD			Tanypodinae		1						
DIAMESIN			Diamesinae		2				1		
UNCHIR			Unid. chiron.								
SIMULID			Simuliidae	1	13		4	48	5	41	4
TUPULID			Tipulidae	4	1		1	1	1		
BLEPHER			Blephericeridae				1				
ATHERIC			Athericidae								
EMPIDAD			Empididae					1			1
HYDROCH			Hydrochidae								
MUSCIDAE			Muscidae								
SCIOMYZ			Sciomyzidae								
NYMPHOM			Nymphomyiidae								
DOLICHOP			Dolichopodidae								
SYRPHID			Syrphidae								
TABANID			Tabanidae								
CHAOBOR			Chaoboridae								
CERATOPG			Ceratopogonidae								
DIXIIDAE			Dixiidae						1		
NOTIPHIL			Notiphilidae								
EPHYDRID			Ephydridae								
PSYCHOD			Psychodidae								
DUNIDPUP			Unid. pupae	1			1				
DUNIDLAR			Unid. larvae								
ATRIPLEC		Trichoptera	Atriplectrididae								
CALAMOC			Calamoceratidae								
CALOCID			Calocidae			1					
CONOESUC			Conoesucidae	2	1						14
ECNOMID			Ecnomidae								
GLOSSOM			Glossomatidae								
HELICOPH			Helicophidae			1			5		
HELICOPS			Helicopsychidae			2					
HYDROBIO			Hydrobiosidae	56	16	18	13	16	58	10	8
HYDROPSY			Hydropsychidae		2				3		50
HYDROPTI			Hydroptilidae								
KOKIRIID			Kokiriidae								
LEPTOCER			Leptoceridae		4	1	2		1	2	1
LIMNEPH			Limnephilidae								
OECONES			Oeconesidae								
ODONTOCR			Odontoceridae								
PHILOPOT			Philopotamidae	2							
PHILORHE			Philorheithridae		3	4					1
PLECTROT			Plectrotarsidae								
POLYCENT			Polycentropodidae								
TASIMIID			Tasimiidae								
TUNIDPUP			Unid. pupae			1					
ADTELMID		Coleoptera	Adult Elmidae		9	2		14	3	4	3
COLADOTH			Adult Heterocidae								
ADSCIRT			Adult Scirtidae								
COLUNIDA			Unident. A								
STAPHYLI			Adult Staphylinidae						1		
CHRYSOM			Adult Chrysomelidae								
LARELMID			Larvae Elmidae		3	3					
SCIRTID			Scirtidae	4	14	1	3	2	2	28	
PSEPHEN			Psephenidae	1	1	1					
DYTISCID			Dytiscidae								
HYDROPH			Hydrophildae								
HYDRAEN			Hydraenidae								
UNCOLEO			Unid. coleoptera								
GORDIID	Nematomorpha		Gordiidae						1		

Table 2.4 (cont'd)

			Site	NEWALL	COMSTTWO	COMSTHRE	QUENFOUR	LINDA	KINGTHRE	EQUENTWO	NELSON
			Date	11.4.96	17.4.96	17.4.96	16.4.96	10.4.96	11.4.96	17.4.96	10.4.96
			Kicker	L.C.	L.C.	L.C.	L.C.	C.M.	C.M.	L.C.	L.C.
			Picker	L.C.	L.C.	L.C.	L.C.	C.M.	C.M.	L.C.	L.C.
		TAXA									
Code	**Order**	**Class**	**Family**								
HYDROZOA	Cnidaria	Hydrozoa									
TURBEL	Platyhelminthes	Turbellaria									
NEMATODA	Nematoda										
BIVALVIA	Mollusca	Bivalvia									
GASTROP		Gastropoda									
HIRUDIN	Annelida	Hirudinea									
OLIGOCH		Oligochaeta		5	12		1	2			
HYDRACAR	Arachnida	Hydracarina		5	6				1		1
PARAMEL	Crustacea	Amphipoda	Paramelitidae	2	17	1					1
CEINIDAE			Ceinidae								
EUSIRID			Eusiridae								
COPEPODA		Copepoda									
DECAPODA		Decapoda									
ISOPODA		Isopoda									
OSTRACOD		Ostracoda									
SYNCARID		Syncarida									
COLLEMB	Insecta	Collembola					1	1	6	1	
EUSTHEN		Plecoptera	Eusthenidae	4	15				1		3
AUSTROP			Austroperlidae	1							
GRIPOPT			Gripopterygidae	118	32	3					75
NOTONEM			Notonemouridae		2			2	3		
LEPTOPHL		Ephemeroptera	Leptophlebiidae	55	80	1		5	1		110
ONISCIG			Oniscigastridae								
CAENIDAE			Caenidae								
BAETIDAE			Baetidae						1		7
SIPHLON			Siphlonuridae								
AESHNID		Odonata	Aeshnidae								
HEMIPT		Hemiptera									
MECOPT		Mecoptera									
CHIRONOM	Diptera	Chironomidae	Chironominae	1	2	1		1			
OTHOCLAD			Orthocladiinae	7	4		1				
PODAMIN			Podonominae	21	27						5
TANYPOD			Tanypodinae		2			2		1	
DIAMESIN			Diamesinae	1							
UNCHIR			Unid. chiron.			3					
SIMULID			Simuliidae	5	1				2	1	4
TUPULID			Tipulidae							1	
BLEPHER			Blephericeridae	1							
ATHERIC			Athericidae								
EMPIDAD			Empididae								
HYDROCH			Hydrochidae								
MUSCIDAE			Muscidae								
SCIOMYZ			Sciomyzidae								
NYMPHOM			Nymphomyiidae								
DOLICHOP			Dolichopodidae								
SYRPHID			Syrphidae								
TABANID			Tabanidae								
CHAOBOR			Chaoboridae						1		
CERATOPG			Ceratopogonidae					1			
DIXIIDAE			Dixiidae								
NOTIPHIL			Notiphilidae								1
EPHYDRID			Ephydridae								
PSYCHOD			Psychodidae								
DUNIDPUP			Unid. pupae							2	
DUNIDLAR			Unid. larvae								
ATRIPLEC		Trichoptera	Atriplectrididae								
CALAMOC			Calamoceratidae								
CALOCID			Calocidae		1						3
CONOESUC			Conoesucidae	5	9						
ECNOMID			Ecnomidae								
GLOSSOM			Glossomatidae	1							
HELICOPH			Helicophidae		1						
HELICOPS			Helicopsychidae								
HYDROBIO			Hydrobiosidae	28	7		1	1		2	9
HYDROPSY			Hydropsychidae	1							1
HYDROPTI			Hydroptilidae						1		
KOKIRIID			Kokiriidae								
LEPTOCER			Leptoceridae	1	3						4
LIMNEPH			Limnephilidae								
OECONES			Oeconesidae								
ODONTOCR			Odontoceridae								
PHILOPOT			Philopotamidae		2						
PHILORHE			Philorheithridae					1			4
PLECTROT			Plectrotarsidae		1						
POLYCENT			Polycentropodidae								
TASIMIID			Tasimiidae								
TUNIDPUP			Unid. pupae								
ADTELMID		Coleoptera	Adult Elmidae	5							
COLADOTH			Adult Heterocidae								
ADSCIRT			Adult Scirtidae								
COLUNIDA			Unident. A								
STAPHYLI			Adult Staphylinidae								
CHRYSOM			Adult Chrysomelidae								
LARELMID			Larvae Elmidae				1				
SCIRTID			Scirtidae	6	9			2			1
PSEPHEN			Psephenidae								1
DYTISCID			Dytiscidae					3			1
HYDROPH			Hydrophildae								
HYDRAEN			Hydraenidae					1			
UNCOLEO			Unid. coleoptera								
GORDIID	Nematomorpha		Gordiidae								

Table 2.4 (cont'd)

		TAXA									
			Site	KINGONE	QUEENTWO	PRINCESS	COMSTFOR	KINGTWO	QUEENONE	EQUENTHR	YOLANDE
			Date	11.4.96	17.4.96	28.3.96	12.4.96	11.4.96	17.4.96	18.4.96	11.4.96
			Kicker	D.J.	L.C.	C.M.	C.M.	C.M.	L.C.	L.C.	C.M.
			Picker	D.J.	L.C.	C.M.	C.M.	C.M.	L.C.	L.C.	C.M.
Code	**Order**	**Class**	**Family**								
HYDROZOA	Cnidaria	Hydrozoa									
TURBEL	Platyhelminthes	Turbellaria		6							1
NEMATODA	Nematoda										
BIVALVIA	Mollusca	Bivalvia									
GASTROP		Gastropoda									
HIRUDIN	Annelida	Hirudinea									
OLIGOCH		Oligochaeta		51		4			1	1	12
HYDRACAR	Arachnida	Hydracarina				4					2
PARAMEL	Crustacea	Amphipoda	Paramelitidae			15			1		1
CEINIDAE			Ceinidae								
EUSIRID			Eusiridae								
COPEPODA		Copepoda									
DECAPODA		Decapoda									
ISOPODA		Isopoda									
OSTRACOD		Ostracoda									
SYNCARID		Syncarida									
COLLEMB	Insecta	Collembola			1		1				
EUSTHEN		Plecoptera	Eusthenidae			25	1				7
AUSTROP			Austroperlidae								1
GRIPOPT			Gripopterygidae			16	3			1	3
NOTONEM			Notonemouridae								
LEPTOPHL		Ephemeroptera	Leptophlebiidae	1						1	56
ONISCIG			Oniscigastridae								
CAENIDAE			Caenidae								
BAETIDAE			Baetidae								
SIPHLON			Siphlonuridae								
AESHNID		Odonata	Aeshnidae			2					
HEMIPT		Hemiptera				5					
MECOPT		Mecoptera									
CHIRONOM	Diptera	Chironomidae	Chironominae			1			1		
OTHOCLAD			Orthocladiinae	4		2	1		3	4	
PODAMIN			Podonominae	2							
TANYPOD			Tanypodinae	1							
DIAMESIN			Diamesinae	15							
UNCHIR			Unid. chiron.					1			
SIMULID			Simuliidae	1			1	1			81
TUPULID			Tipulidae		1						1
BLEPHER			Blephericeridae								
ATHERIC			Athericidae			1					1
EMPIDAD			Empididae			4					
HYDROCH			Hydrochidae								
MUSCIDAE			Muscidae								
SCIOMYZ			Sciomyzidae								
NYMPHOM			Nymphomyiidae								
DOLICHOP			Dolichopodidae								
SYRPHID			Syrphidae								
TABANID			Tabanidae								
CHAOBOR			Chaoboridae					1			
CERATOPG			Ceratopogonidae								
DIXIIDAE			Dixiidae								
NOTIPHIL			Notiphilidae								
EPHYDRID			Ephydridae								
PSYCHOD			Psychodidae								
DUNIDPUP			Unid. pupae							2	
DUNIDLAR			Unid. larvae				1				
ATRIPLEC		Trichoptera	Atriplectrididae								
CALAMOC			Calamoceratidae								
CALOCID			Calocidae			1					
CONOESUC			Conoesucidae			13					5
ECNOMID			Ecnomidae								
GLOSSOM			Glossomatidae								
HELICOPH			Helicophidae			3					
HELICOPS			Helicopsychidae								
HYDROBIO			Hydrobiosidae	1	1	1					20
HYDROPSY			Hydropsychidae			3					4
HYDROPTI			Hydroptilidae								
KOKIRIID			Kokiriidae								
LEPTOCER			Leptoceridae			12					
LIMNEPH			Limnephilidae								
OECONES			Oeconesidae								
ODONTOCR			Odontoceridae								
PHILOPOT			Philopotamidae								
PHILORHE			Philorheithridae			1					1
PLECTROT			Plectrotarsidae								
POLYCENT			Polycentropodidae								
TASIMIID			Tasimiidae								
TUNIDPUP			Unid. pupae								
ADTELMID		Coleoptera	Adult Elmidae			51			1		3
COLADOTH			Adult Heterocidae								
ADSCIRT			Adult Scirtidae						1		
COLUNIDA			Unident. A								
STAPHYLI			Adult Staphylinidae						2		
CHRYSOM			Adult Chrysomelidae						1		
LARELMID			Larvae Elmidae				1				2
SCIRTID			Scirtidae		1	12			1		4
PSEPHEN			Psephenidae			16					2
DYTISCID			Dytiscidae			1					
HYDROPH			Hydrophildae								
HYDRAEN			Hydraenidae								
UNCOLEO			Unid. coleoptera								
GORDIID	Nematomorpha		Gordiidae								

Table 2.4 (cont'd)

			Site	WESTQUEN	COMSTONE	CONGLOM	COLLINGW	CARDIGAN	LYNCH	CROTTY	TOWNSHIP
			Date	18.4.96	17.4.96	10.4.96	12.4.96	10.4.96	11.4.96	10.4.96	16.4.96
			Kicker	L.C.	L.C.	C.M.	L.C.	C.M.		L.C.	L.C.
			Picker	L.C.	L.C.	C.M.	L.C.	C.M.		L.C.	L.C.
		TAXA									
Code	**Order**	**Class**	**Family**								
HYDROZOA	Cnidaria	Hydrozoa									
TURBEL	Platyhelminthes	Turbellaria									2
NEMATODA	Nematoda										
BIVALVIA	Mollusca	Bivalvia									
GASTROP		Gastropoda						1			
HIRUDIN	Annelida	Hirudinea									
OLIGOCH		Oligochaeta		18	11	27	35	4			13
HYDRACAR	Arachnida	Hydracarina		3	2	3	1	1	6	18	
PARAMEL	Crustacea	Amphipoda	Paramelitidae	14	14				12		
CEINIDAE			Ceinidae								
EUSIRID			Eusiridae							4	
COPEPODA		Copepoda									
DECAPODA		Decapoda									
ISOPODA		Isopoda									
OSTRACOD		Ostracoda									
SYNCARID		Syncarida									
COLLEMB	Insecta	Collembola				1					
EUSTHEN		Plecoptera	Eusthenidae	16	16	1		2	31	1	17
AUSTROP			Austroperlidae				1			5	12
GRIPOPT			Gripopterygidae	14	23	34		46	38		30
NOTONEM			Notonemouridae	1	1	8					
LEPTOPHL		Ephemeroptera	Leptophlebiidae	41	85	34	50	69	38	66	90
ONISCIG			Oniscigastridae								
CAENIDAE			Caenidae								
BAETIDAE			Baetidae	4			42	4	23		
SIPHLON			Siphlonuridae								
AESHNID		Odonata	Aeshnidae								4
HEMIPT		Hemiptera									
MECOPT		Mecoptera									
CHIRONOM	Diptera	Chironomidae	Chironominae		6			1	9		
OTHOCLAD			Orthocladiinae	16	3	13		1	5	2	1
PODAMIN			Podonominae	2	21	19	19	30	1	3	11
TANYPOD			Tanypodinae	3	1						1
DIAMESIN			Diamesinae	1							
UNCHIR			Unid. chiron.								
SIMULID			Simuliidae	8	1			16	8	36	1
TUPULID			Tipulidae	1	3		2				
BLEPHER			Blephericeridae								
ATHERIC			Athericidae	1							
EMPIDAD			Empididae				1				
HYDROCH			Hydrochidae								
MUSCIDAE			Muscidae								
SCIOMYZ			Sciomyzidae								
NYMPHOM			Nymphomyiidae								
DOLICHOP			Dolichopodidae								
SYRPHID			Syrphidae								
TABANID			Tabanidae								
CHAOBOR			Chaoboridae								
CERATOPG			Ceratopogonidae								
DIXIIDAE			Dixiidae								
NOTIPHIL			Notiphilidae								
EPHYDRID			Ephydridae								
PSYCHOD			Psychodidae	1							
DUNIDPUP			Unid. pupae			1		1			
DUNIDLAR			Unid. larvae								
ATRIPLEC		Trichoptera	Atriplectrididae								
CALAMOC			Calamoceratidae								
CALOCID			Calocidae						4		
CONOESUC			Conoesucidae	9	12	1	1		6		5
ECNOMID			Ecnomidae								
GLOSSOM			Glossomatidae								1
HELICOPH			Helicophidae		3						1
HELICOPS			Helicopsychidae								
HYDROBIO			Hydrobiosidae	17	15	6	22	7	7	5	25
HYDROPSY			Hydropsychidae	6	1	2					2
HYDROPTI			Hydroptilidae								
KOKIRIID			Kokiriidae								
LEPTOCER			Leptoceridae								1
LIMNEPH			Limnephilidae			2					
OECONES			Oeconesidae								
ODONTOCR			Odontoceridae								
PHILOPOT			Philopotamidae	2					1		1
PHILORHE			Philorheithridae	1	1		12	1	1		
PLECTROT			Plectrotarsidae								
POLYCENT			Polycentropodidae			1		1			
TASIMIID			Tasimiidae								
TUNIDPUP			Unid. pupae								
ADTELMID		Coleoptera	Adult Elmidae	2			1		14	8	1
COLADOTH			Adult Heterocidae								
ADSCIRT			Adult Scirtidae								
COLUNIDA			Unident. A								
STAPHYLI			Adult Staphylinidae								
CHRYSOM			Adult Chrysomelidae								
LARELMID			Larvae Elmidae	1			1				
SCIRTID			Scirtidae	3	12	1		1		1	3
PSEPHEN			Psephenidae	13				2	1		2
DYTISCID			Dytiscidae								
HYDROPH			Hydrophildae								
HYDRAEN			Hydraenidae								
UNCOLEO			Unid. coleoptera								
GORDIID	Nematomorpha		Gordiidae								

Table 2.5 Raw data from autumn 1995 RAP sampling of edge habitats, Mount Lyell

			Site	MTOWEN	HENTY	HALLS	GOVERN	STHELDON	EQUENONE	ELDON	PEARL
			Date	10.4.96	7.5.96	18.4.96	11.4.96	12.4.96	17.4.96	12.4.96	11.4.96
			Kicker	D.J.	C.M.	J.J.	D.J.	J.J.	J.J.	D.J.	J.J.
			Picker	D.J.	L.C.	J.J.	D.J.	J.J.	J.J.	D.J.	J.J.
		TAXA									
Code	**Order**	**Class**	**Family**								
HYDROZOA	Cnidaria	Hydrozoa									
TURBEL	Platyhelminthes	Turbellaria									
NEMATODA	Nematoda										
BIVALVIA	Mollusca	Bivalvia									
GASTROP		Gastropoda									
HIRUDIN	Annelida	Hirudinea									
OLIGOCH		Oligochaeta				1		19	2	21	3
HYDRACAR	Arachnida	Hydracarina				9		7	8	9	11
PARAMEL	Crustacea	Amphipoda	Paramelitidae			7			1		25
CEINIDAE			Ceinidae								
EUSIRID			Eusiridae								
COPEPODA		Copepoda									
DECAPODA		Decapoda									
ISOPODA		Isopoda									
OSTRACOD		Ostracoda									
SYNCARID		Syncarida									
COLLEMB	Insecta	Collembola		1							
EUSTHEN		Plecoptera	Eusthenidae					6	1	2	
AUSTROP			Austroperlidae					2			
GRIPOPT			Gripopterygidae	1			5	14	3	5	26
NOTONEM			Notonemouridae	10		3		16	11	9	
LEPTOPHL		Ephemeroptera	Leptophlebiidae	4		62	20	66	19	21	34
ONISCIG			Oniscigastridae				2	2		24	
CAENIDAE			Caenidae								
BAETIDAE			Baetidae								
SIPHLON			Siphlonuridae								
AESHNID		Odonata	Aeshnidae								2
HEMIPT		Hemiptera		2					4	1	
MECOPT		Mecoptera					1			2	
CHIRONOM	Diptera	Chironomidae	Chironominae	1		1	2	2	2	5	
OTHOCLAD			Orthocladiinae	2		2	2	1	3		3
PODAMIN			Podonominae			1					
TANYPOD			Tanypodinae			3	2	2	2	4	
DIAMESIN			Diamesinae				1				
UNCHIR			Unid. chiron.								
SIMULID			Simuliidae								5
TUPULID			Tipulidae	1		1		2	2	9	1
BLEPHER			Blephericeridae								
ATHERIC			Athericidae					1		1	4
EMPIDAD			Empididae								
HYDROCH			Hydrochidae								
MUSCIDAE			Muscidae								
SCIOMYZ			Sciomyzidae								
NYMPHOM			Nymphomyiidae								
DOLICHOP			Dolichopodidae								
SYRPHID			Syrphidae								
TABANID			Tabanidae								
CHAOBOR			Chaoboridae								
CERATOPG			Ceratopogonidae							4	
DIXIIDAE			Dixiidae					1			
NOTIPHIL			Notiphilidae								
EPHYDRID			Ephydridae								
PSYCHOD			Psychodidae								
DUNIDPUP			Unid. pupae							1	1
DUNIDLAR			Unid. larvae								
DIPUNIDA			Unid. Adult						1		
ATRIPLEC		Trichoptera	Atriplectrididae							1	
CALAMOC			Calamoceratidae								
CALOCID			Calocidae			15		1	2		
CONOESUC			Conoesucidae	7							1
ECNOMID			Ecnomidae							1	5
GLOSSOM			Glossomatidae								
HELICOPH			Helicophidae			1					2
HELICOPS			Helicopsychidae								2
HYDROBIO			Hydrobiosidae			8		3	4	1	1
HYDROPSY			Hydropsychidae								
HYDROPTI			Hydroptilidae							1	
KOKIRIID			Kokiriidae								
LEPTOCER			Leptoceridae			24		10		10	6
LIMNEPH			Limnephilidae							1	
OECONES			Oeconesidae								
ODONTOCR			Odontoceridae								
PHILOPOT			Philopotamidae								
PHILORHE			Philorheithridae	2		1			2	1	3
PLECTROT			Plectrotarsidae								
POLYCENT			Polycentropodidae								
TASIMIID			Tasimiidae								
TUNIDPUP			Unid. pupae								
ADTELMID		Coleoptera	Adult Elmidae			1				4	1
COLADOTH			Adult Heterocidae								
ADSCIRT			Adult Scirtidae								
COLUNIDA			Unident. A								
STAPHYLI			Adult Staphylinidae								
CHRYSOMA			Adult Chrysomelidae								
DYTISCAD			Adult Dytiscidae	2						2	1
LARELMID			Larvae Elmidae								1
SCIRTID			Scirtidae	1		5		5	3	3	1
PSEPHEN			Psephenidae	1		1					
DYTISCID			Dytiscidae				1				
CARABID			Carabidae	2							
CHRYSOM			Chrysomelidae					1			
HYDROPH			Hydrophildae								
HYDRAEN			Hydraenidae								
LIMNICH			Limnichidae					1			
UNCOLEO			Unid. coleoptera								
GORDIID	Nematomorpha		Gordiidae								

Table 2.5 (cont'd)

Code	Order	TAXA Class	Family / Site	NEWALL	COMSTTWO	COMSTHRE	QUEENFOUR	LINDA	KINGTHRE	EQUENTWO	NELSON
			Date	17.4.96	6.5.1996	17.4.96	16.4.96	10.4.96	11.4.96	17.4.96	10.4.96
			Kicker	D.J.	J.J.	J.J.	J.J.	J.J.	J.J.	J.J.	D.J.
			Picker	D.J	J.J.	J.J.	J.J.	J.J.	J.J.	J.J.	D.J.
HYDROZOA	Cnidaria	Hydrozoa									
TURBEL	Platyhelminthes	Turbellaria									
NEMATODA	Nematoda										
BIVALVIA	Mollusca	Bivalvia									
GASTROP		Gastropoda									
HIRUDIN	Annelida	Hirudinea									
OLIGOCH		Oligochaeta		7	22			9		2	
HYDRACAR	Arachnida	Hydracarina		7	3			1			1
PARAMEL	Crustacea	Amphipoda	Paramelitidae	3	13						2
CEINIDAE			Ceinidae								
EUSIRID			Eusiridae								
COPEPODA		Copepoda									
DECAPODA		Decapoda									
ISOPODA		Isopoda									
OSTRACOD		Ostracoda									
SYNCARID		Syncarida									
COLLEMB	Insecta	Collembola					2				
EUSTHEN		Plecoptera	Eusthenidae	5							
AUSTROP			Austroperlidae								
GRIPOPT			Gripopterygidae	5	9	1			1	1	1
NOTONEM			Notonemouridae	4	2			15	2	1	7
LEPTOPHL		Ephemeroptera	Leptophlebiidae	58	21						52
ONISCIG			Oniscigastridae	5							
CAENIDAE			Caenidae								
BAETIDAE			Baetidae								
SIPHLON			Siphlonuridae								
AESHNID		Odonata	Aeshnidae								1
HEMIPT		Hemiptera				1		1	2	4	
MECOPT		Mecoptera		5							
CHIRONOM	Diptera	Chironomidae	Chironominae						4		
OTHOCLAD			Orthocladiinae	3	20	12	1	2	3		
PODAMIN			Podonominae	2	2						
TANYPOD			Tanypodinae	1		1		7			
DIAMESIN			Diamesinae								
UNCHIR			Unid. chiron.								
SIMULID			Simuliidae								
TUPULID			Tipulidae					2		1	3
BLEPHER			Blephericeridae								
ATHERIC			Athericidae								1
EMPIDAD			Empididae								1
HYDROCH			Hydrochidae								
MUSCIDAE			Muscidae								
SCIOMYZ			Sciomyzidae							1	
NYMPHOM			Nymphomyiidae								
DOLICHOP			Dolichopodidae								
SYRPHID			Syrphidae								
TABANID			Tabanidae								
CHAOBOR			Chaoboridae						3		
CERATOPG			Ceratopogonidae								
DIXIIDAE			Dixiidae								
NOTIPHIL			Notiphilidae								
EPHYDRID			Ephydridae								
PSYCHOD			Psychodidae								
DUNIDPUP			Unid. pupae	1		3			1		
DUNIDLAR			Unid. larvae				1				
DIPUNIDA			Unid. Adult		6	7			2		
ATRIPLEC		Trichoptera	Atriplectrididae								
CALAMOC			Calamoceratidae								
CALOCID			Calocidae								2
CONOESUC			Conoesucidae		6	3		2			1
ECNOMID			Ecnomidae	1							
GLOSSOM			Glossomatidae								
HELICOPH			Helicophidae		5						1
HELICOPS			Helicopsychidae								
HYDROBIO			Hydrobiosidae	7	2				1		3
HYDROPSY			Hydropsychidae								
HYDROPTI			Hydroptilidae								
KOKIRIID			Kokiriidae								
LEPTOCER			Leptoceridae	12							14
LIMNEPH			Limnephilidae								
OECONES			Oeconesidae								
ODONTOCR			Odontoceridae							1	
PHILOPOT			Philopotamidae								
PHILORHE			Philorheithridae	1				2	1	1	3
PLECTROT			Plectrotarsidae								
POLYCENT			Polycentropodidae								
TASIMIID			Tasimiidae								
TUNIDPUP			Unid. pupae								
ADTELMID		Coleoptera	Adult Elmidae	2	1			1	4		
COLADOTH			Adult Heterocidae								
ADSCIRT			Adult Scirtidae								
COLUNIDA			Unident. A								
STAPHYLI			Adult Staphylinidae		1						
CHRYSOMA			Adult Chrysomelidae								
DYTISCAD			Adult Dytiscidae					1			
LARELMID			Larvae Elmidae	1							
SCIRTID			Scirtidae	9	7						3
PSEPHEN			Psephenidae								
DYTISCID			Dytiscidae								
CARABID			Carabidae						1		
CHRYSOM			Chrysomelidae								
HYDROPH			Hydrophilidae							1	
HYDRAEN			Hydraenidae								
LIMNICH			Limnichidae			1					
UNCOLEO			Unid. coleoptera								
GORDIID	Nematomorpha		Gordiidae								

Table 2.5 (cont'd)

				KINGONE	QUEENTWO	PRINCESS	COMSTFOR	KINGTWO	QUEENONE	EQUENTHR	YOLANDE
			Site	KINGONE	QUEENTWO	PRINCESS	COMSTFOR	KINGTWO	QUEENONE	EQUENTHR	YOLANDE
			Date	16.4.96	17.4.96	28.3.96	12.4.96	11.4.96	17.4.96	18.4.96	11.4.96
			Kicker	D.J.	J.J.	L.C.	D.J.	J.J.	J.J.	J.J.	J.J.
			Picker	L.C.	J.J.	L.C.	D.J.	J.J.	J.J.	J.J.	J.J.
		TAXA									
Code	**Order**	**Class**	**Family**								
HYDROZOA	Cnidaria	Hydrozoa									
TURBEL	Platyhelminthes	Turbellaria									
NEMATODA	Nematoda										
BIVALVIA	Mollusca	Bivalvia									
GASTROP		Gastropoda									
HIRUDIN	Annelida	Hirudinea						1			
OLIGOCH		Oligochaeta		22	3	2	5				20
HYDRACAR	Arachnida	Hydracarina				9					5
PARAMEL	Crustacea	Amphipoda	Paramelitidae			44				1	4
CEINIDAE			Ceinidae								
EUSIRID			Eusiridae								
COPEPODA		Copepoda									
DECAPODA		Decapoda									
ISOPODA		Isopoda									
OSTRACOD		Ostracoda									
SYNCARID		Syncarida									
COLLEMB	Insecta	Collembola					1				
EUSTHEN		Plecoptera	Eusthenidae								1
AUSTROP			Austroperlidae								
GRIPOPT			Gripopterygidae			2	1				3
NOTONEM			Notonemouridae				4	3		1	1
LEPTOPHL		Ephemeroptera	Leptophlebiidae			5		1			77
ONISCIG			Oniscigastridae								1
CAENIDAE			Caenidae								
BAETIDAE			Baetidae								
SIPHLON			Siphlonuridae								
AESHNID		Odonata	Aeshnidae			1					
HEMIPT		Hemiptera									
MECOPT		Mecoptera									
CHIRONOM	Diptera	Chironomidae	Chironominae			1	10				
OTHOCLAD			Orthocladiinae	5	1	2		4	4	1	3
PODAMIN			Podonominae	1							
TANYPOD			Tanypodinae			2	3		1	1	1
DIAMESIN			Diamesinae								
UNCHIR			Unid. chiron.								
SIMULID			Simuliidae					3			1
TUPULID			Tipulidae			5					3
BLEPHER			Blephariceridae								
ATHERIC			Athericidae								
EMPIDAD			Empididae								
HYDROCH			Hydrochidae								
MUSCIDAE			Muscidae	3							
SCIOMYZ			Sciomyzidae								
NYMPHOM			Nymphomyiidae								
DOLICHOP			Dolichopodidae								
SYRPHID			Syrphidae								
TABANID			Tabanidae	1							
CHAOBOR			Chaoboridae					1			
CERATOPG			Ceratopogonidae								
DIXIIDAE			Dixiidae								
NOTIPHIL			Notiphilidae								
EPHYDRID			Ephydridae								
PSYCHOD			Psychodidae							1	
DUNIDPUP			Unid. pupae						5	3	
DUNIDLAR			Unid. larvae					1			
DIPUNIDA			Unid. Adult								
ATRIPLEC		Trichoptera	Atriplectrididae			2					
CALAMOC			Calamoceratidae								
CALOCID			Calocidae								
CONOESUC			Conoesucidae	3						1	
ECNOMID			Ecnomidae								
GLOSSOM			Glossomatidae			1					
HELICOPH			Helicophidae								
HELICOPS			Helicopsychidae								
HYDROBIO			Hydrobiosidae					3			11
HYDROPSY			Hydropsychidae								
HYDROPTI			Hydroptilidae								
KOKIRIID			Kokiriidae								
LEPTOCER			Leptoceridae	2		24	4	1			13
LIMNEPH			Limnephilidae				1				
OECONES			Oeconesidae								
ODONTOCR			Odontoceridae								
PHILOPOT			Philopotamidae								
PHILORHE			Philorheithridae			2	7				1
PLECTROT			Plectrotarsidae								
POLYCENT			Polycentropodidae			9					
TASIMIID			Tasimiidae								
TUNIDPUP			Unid. pupae								
ADTELMID		Coleoptera	Adult Elmidae			1		2			
COLADOTH			Adult Heterocidae								
ADSCIRT			Adult Scirtidae								
COLUNIDA			Unident. A								
STAPHYLI			Adult Staphylinidae								
CHRYSOMA			Adult Chrysomelidae								
DYTISCAD			Adult Dytiscidae			1	22				
LARELMID			Larvae Elmidae				1	1			2
SCIRTID			Scirtidae	1				1			5
PSEPHEN			Psephenidae								1
DYTISCID			Dytiscidae								
CARABID			Carabidae								1
CHRYSOM			Chrysomelidae								
HYDROPH			Hydrophildae								
HYDRAEN			Hydraenidae								
LIMNICH			Limnichidae								
UNCOLEO			Unid. coleoptera							1	1
GORDIID	Nematomorpha		Gordiidae								

Table 2.5 (cont'd)

			Site	WESTQUEN	COMSTONE	CONGLOM	COLLINGW	CARDIGAN	LYNCH	CROTTY	TOWNSHIP
			Date	18.4.96	17.4.96	10.4.96	12.4.96	7.5.96	11.4.96	16.4.96	16.4.96
			Kicker	J.J.	J.J.	J.J.	D.J.	L.C.	D.J.	J.J.	J.J.
			Picker	J.J.	J.J.	J.J.	D.J.	L.C.	D.J.	J.J.	J.J.
Code	**Order**	**TAXA Class**	**Family**								
HYDROZOA	Cnidaria	Hydrozoa									
TURBEL	Platyhelminthes	Turbellaria									
NEMATODA	Nematoda					1					
BIVALVIA	Mollusca	Bivalvia									
GASTROP		Gastropoda									
HIRUDIN	Annelida	Hirudinea									
OLIGOCH		Oligochaeta		7	1	8	1		3	3	6
HYDRACAR	Arachnida	Hydracarina		2		44	2		5	2	13
PARAMEL	Crustacea	Amphipoda	Paramelitidae	4	33			1	9	3	2
CEINIDAE			Ceinidae								
EUSIRID			Eusiridae							38	
COPEPODA		Copepoda									
DECAPODA		Decapoda									
ISOPODA		Isopoda									
OSTRACOD		Ostracoda									
SYNCARID		Syncarida									
COLLEMB	Insecta	Collembola			1						
EUSTHEN		Plecoptera	Eusthenidae	2	1						1
AUSTROP			Austroperlidae					1		1	3
GRIPOPT			Gripopterygidae	30	3	29	1	1	1	2	12
NOTONEM			Notonemouridae	14	1	20	24	9	1	6	2
LEPTOPHL		Ephemeroptera	Leptophlebiidae	18	19	49	11	32	55	42	73
ONISCIG			Oniscigastridae				36	1	1	14	1
CAENIDAE			Caenidae								
BAETIDAE			Baetidae								
SIPHLON			Siphlonuridae								
AESHNID		Odonata	Aeshnidae	1				1			
HEMIPT		Hemiptera		6						3	
MECOPT		Mecoptera					4	9	1		
CHIRONOM	Diptera	Chironomidae	Chironominae				1		1		1
OTHOCLAD			Orthocladiinae	5	38	3		1		3	2
PODAMIN			Podonominae						2	1	4
TANYPOD			Tanypodinae	5	1	3		1	1		3
DIAMESIN			Diamesinae								
UNCHIR			Unid. chiron.								
SIMULID			Simuliidae	1					1		
TUPULID			Tipulidae			5	3				
BLEPHER			Blephericeridae								
ATHERIC			Athericidae								
EMPIDAD			Empididae	1							
HYDROCH			Hydrochidae								
MUSCIDAE			Muscidae								
SCIOMYZ			Sciomyzidae								
NYMPHOM			Nymphomyiidae								
DOLICHOP			Dolichopodidae								
SYRPHID			Syrphidae								
TABANID			Tabanidae								
CHAOBOR			Chaoboridae								
CERATOPG			Ceratopogonidae								
DIXIIDAE			Dixiidae							1	
NOTIPHIL			Notiphilidae								
EPHYDRID			Ephydridae								
PSYCHOD			Psychodidae								
DUNIDPUP			Unid. pupae			1					2
DUNIDLAR			Unid. larvae								
DIPUNIDA			Unid. Adult		4						
ATRIPLEC		Trichoptera	Atriplectrididae								
CALAMOC			Calamoceratidae								
CALOCID			Calocidae		4			1		1	
CONOESUC			Conoesucidae	1				1		1	
ECNOMID			Ecnomidae				1				
GLOSSOM			Glossomatidae								
HELICOPH			Helicophidae			2					
HELICOPS			Helicopsychidae								
HYDROBIO			Hydrobiosidae	3		4	1	8	5	1	
HYDROPSY			Hydropsychidae	1							
HYDROPTI			Hydroptilidae	32							
KOKIRIID			Kokiriidae								
LEPTOCER			Leptoceridae	24	1		2	14	1	3	10
LIMNEPH			Limnephilidae				2			6	1
OECONES			Oeconesidae								
ODONTOCR			Odontoceridae				4*				
PHILOPOT			Philopotamidae								
PHILORHE			Philorheithridae		1	2		6		2	4
PLECTROT			Plectrotarsidae								
POLYCENT			Polycentropodidae			1					
TASIMIID			Tasimiidae								
TUNIDPUP			Unid. pupae		1						
ADTELMID		Coleoptera	Adult Elmidae						1		
COLADOTH			Adult Heterocidae								
ADSCIRT			Adult Scirtidae								
COLUNIDA			Unident. A								1
STAPHYLI			Adult Staphylinidae								
CHRYSOMA			Adult Chrysomelidae								
DYTISCAD			Adult Dytiscidae			1					
LARELMID			Larvae Elmidae	1				1	1		
SCIRTID			Scirtidae	1	2		2	12		2	8
PSEPHEN			Psephenidae	1		2				1	
DYTISCID			Dytiscidae								
CARABID			Carabidae								
CHRYSOM			Chrysomelidae								
HYDROPH			Hydrophildae								
HYDRAEN			Hydraenidae								
LIMNICH			Limnichidae								
UNCOLEO			Unid. coleoptera								
GORDIID	Nematomorpha		Gordiidae								

Table 2.6 Raw 'species' data from winter 1995 RAP sampling, Mount Lyell

	Sites														
Species	MTOWEN	HENTY	HALLS	GOVERN	STHELDON	EQUENONE	ELDON	PEARL	NEWALL	COMSTTWO	COMSTHRE	QUENFOUR	LINDA	KINGTHRE	EQUENTHR
ESPECTAB		4	2			1	2		2	5					
ECOSTALIS		1	2				1								
LVARIA		1						16							
LEPTOSPI		8						37	1						
TZWICKI				28	7		18		22	22					
TCOMPRIN					1										
TINOPIN					5				1						
TTHALIA					2										
THARDYI					1										
TTASMANI								1	2						
CARDIOSP	14	18		4	4	5	11	6	1	71			1		
RTRILOSP			1												
DINOTSP1						2									
UNGENII															
GENYSPI				7					49	6					
GENYSPII										1					
GNYSPIII						1			2	1					
GENDSP		7													
GENZ										1					
NOVSPII		8		4		1	12		8	5					
BAESPIII		18													
AUSPAIII		1			22		9								
ULEPHLEB								23							
UNLPTCER															
PNIGRITA			1						1	2					
SMISPIII				3				38		2					
MORUYASP	5			2		1									
URIBICON	9	2	1						3						
TASCHSPI		5	4	1	5		4		12						
TAPOBAMU		2		2	3				3						
TASMANUM			2				8			1					
TFERULUM						4									
THESPERI									1						
TKIMMIN															
TRUGULU	2	2													
HEIGHTEEN				1					4	1					
HWADDAMA															
ASMICSPI		1													
CADCASTO										9					
CDIGITIF				1				2		9					
CEBENINA									2						
CFROMUS	3							1							
CNEPOTUL				1			1		4						
CNORELUS		5					1								
CLUXUTA				1				11							
CPLICATA						3									
CRAMKREN															
DIPSPSIX						2									
EHESPERI															
ENESYDRI	1					1			3						
NOTALISP							9					1			
APILOSA								1		14					
AOBLIQUA															
APEDIGIO													1		
PHILORHE								2							
KCLIVICO								1							
GLOSSOSO								1							
GENBSPII			1												
CHEAMATO												1			
OLIGOCH		7	9	12	1	3	9		15	23			1		
HYDRACAR								9	1				1		1
AMPHIPOD			2			3		28		2					
COLLEMB													2		
SIPHLON						1									
CHIRONOM	31	24	1	5	25	1	28	1	44	41			2	1	3
SIMULID	1	5	4	6	26	2	9								
TUPULID						1			1						
BLEPHER				5	3		1								
ATHERIC								5	1					1	
HYDROCH									1						
SCIOMYZ															1
NYMPHOM															1
DOLICHOP															
TABANID									1						
ADTELMID			1				1	1						1	
LARELMID															
SCIRTID	12		1	8			6		3	9		1	3		
PSEPHEN								1	1						

Table 2.6 (cont'd)

Species	Sites												
	NELSON	KINGONE	QUEENTWO	PRINCESS	COMSTFOR	KINGTWO	QUEENONE	QUEENTHR	EQUENTWO	YOLANDE	WESTQUEN	COMSTONE	CONGLOM
ESPECTAB	4			3				1		2	2	1	
ECOSTALIS	3			1									
LVARIA											8		
LEPTOSPI													56
TZWICKI	21	2		9	1					1		6	5
TCOMPRIN													
TINOPIN										1			1
TTHALIA													
THARDYI													
TTASMANI													
CARDIOSP				1	2						5	31	27
RTRILOSP										1			
DINOTSP1	3										1		
UNGENII												4	
GENYSPI	29									5		9	
GENYSPII				4									7
GNYSPIII											4		
GENDSP											7		
GENZ											1		
NOVSPII	9	1		12				2		13	24		
BAESPIII	3										16		
AUSPAIII	23	1											
ULEPHLEB													
UNLPTCER				1									
PNIGRITA				2				1		3			
SMISPIII										1			
MORUYASP													
URIBICON				1							1		
TASCHSPI	3							2		1	2	2	
TAPOBAMU									1				
TASMANUM		1								1		2	
TFERULUM													
THESPERI													
TKIMMIN											15		
TRUGULU													2
HEIGHTEEN												1	
HWADDAMA											3		
ASMICSPI													
CADCASTO													
CDIGITIF												15	
CEBENINA													
CFROMUS													
CNEPOTUL													
CNORELUS				11									
CLUXUTA												4	
CPLICATA								1					
CRAMKREN				1									
DIPSPSIX													
EHESPERI		1											
ENESYDRI	2			13						4	1	3	
NOTALISP				8									
APILOSA												4	
AOBLIQUA	1										2		
APEDIGIO													
PHILORHE				1						1			
KCLIVICO													
GLOSSOSO	2												
GENBSPII												2	
CHEAMATO													
OLIGOCH		16	2	12				4		25	42	2	13
HYDRACAR				3							1	3	
AMPHIPOD	1			13						1	6	12	
COLLEMB			2					1					
SIPHLON													
CHIRONOM	1	7	2	2			1	8		2	65	6	23
SIMULID		1					1			1	1	2	
TUPULID											1	1	
BLEPHER	2									1			
ATHERIC													
HYDROCH													
SCIOMYZ													
NYMPHOM													
DOLICHOP							1						
TABANID													
ADTELMID				26								1	
LARELMID				1									
SCIRTID			4	1				2		1	4	3	2
PSEPHEN				12							2	2	

Appendix 3

Edited SAS® printouts of results of STEPDISC and DISCRIM (Discriminant Function Analysis) conducted on spring RAP data to developing the spring MLRIVPACS model (see Methods)

1 Spring RAP data, stepwise discriminant function analysis output

Output of the SAS® stepdisc routine on the reduced environmental data set derived from HMDS and PCC results (used as the final analysis for preparing MLRIVPACS spring model).

```
                Stepwise Discriminant Analysis

      27 Observations          15 Variable(s) in the Analysis
       4 Class Levels           0 Variable(s) will be included

          The Method for Selecting Variables will be: STEPWISE

          Significance Level to Enter =  0.1500
          Significance Level to Stay  =  0.1500

                        Class Level Information

              GRPNUM     Frequency     Weight          Proportion

                 1           4          4.0000           0.148148
                 2          10         10.0000           0.370370
                 3           7          7.0000           0.259259
                 4           6          6.0000           0.222222


             Stepwise Discriminant Analysis     Simple Statistics

                                  Total-Sample

Variable         N          Sum            Mean        Variance        Std Dev

SLOPE           27       0.40782        0.01510      0.0002361        0.01537
ELEVAT          27     130.71897        4.84144        0.67386        0.82089
STMORDER        27     101.00000        3.74074        2.43020        1.55891
DISTSOUR        27      66.72042        2.47113        1.07355        1.03612
CATCHSIZ        27      42.65281        1.57973        0.47004        0.68559
SUBCOBLE        27      21.02227        0.77860        0.05250        0.22912
SUBPEBLE        27      12.57776        0.46584        0.06547        0.25586
SUBSILT         27       0.22551        0.00835        0.00188        0.04340
COVALGAE        27       7.75848        0.28735        0.08578        0.29289
COVMOSS         27       4.94113        0.18300        0.05415        0.23269
STWIDTH         27     473.12000       17.52296      348.94326       18.68002
RMTCOND         27      41.00000        1.51852        0.33618        0.57981
PERIFFLE        27      33.62460        1.24536        0.07408        0.27218
PERPOOL         27       5.85915        0.21701        0.03872        0.19678
PERSNAG         27       3.42859        0.12698        0.01863        0.13650

----------------------------------------------------------------------------

                                   GRPNUM = 1

Variable         N          Sum           Mean         Variance        Std Dev

SLOPE            4       0.08077        0.02019      0.0001293        0.01137
ELEVAT           4      21.20548        5.30137        0.09800        0.31305
STMORDER         4      10.00000        2.50000        1.66667        1.29099
DISTSOUR         4       6.49938        1.62484        0.41075        0.64090
CATCHSIZ         4       4.24916        1.06229        0.17905        0.42314
SUBCOBLE         4       3.91121        0.97780      0.0007132        0.02671
SUBPEBLE         4       1.50485        0.37621        0.00468        0.06841
SUBSILT          4             0              0              0              0
COVALGAE         4       1.46856        0.36714        0.01584        0.12587
COVMOSS          4       0.14190        0.03547        0.00503        0.07095
STWIDTH          4      29.63000        7.40750       32.38489        5.69077
RMTCOND          4       5.00000        1.25000        0.25000        0.50000
PERIFFLE         4       5.51041        1.37760        0.01865        0.13655
PERPOOL          4       0.67654        0.16914        0.01271        0.11276
PERSNAG          4       0.22551        0.05638        0.01271        0.11276

----------------------------------------------------------------------------
```

GRPNUM = 2

Variable	N	Sum	Mean	Variance	Std Dev
SLOPE	10	0.17736	0.01774	0.0004893	0.02212
ELEVAT	10	53.31496	5.33150	0.29237	0.54071
STMORDER	10	34.00000	3.40000	0.93333	0.96609
DISTSOUR	10	23.55671	2.35567	0.46128	0.67918
CATCHSIZ	10	14.39368	1.43937	0.11584	0.34035
SUBCOBLE	10	7.71821	0.77182	0.04801	0.21912
SUBPEBLE	10	5.34455	0.53445	0.07012	0.26481
SUBSILT	10	0	0	0	0
COVALGAE	10	2.56526	0.25653	0.09364	0.30600
COVMOSS	10	1.44865	0.14487	0.04267	0.20657
STWIDTH	10	116.67000	11.66700	82.99309	9.11005
RMTCOND	10	15.00000	1.50000	0.27778	0.52705
PERIFFLE	10	11.70391	1.17039	0.03871	0.19674
PERPOOL	10	3.16678	0.31668	0.04241	0.20594
PERSNAG	10	1.77792	0.17779	0.02282	0.15107

GRPNUM = 3

Variable	N	Sum	Mean	Variance	Std Dev
SLOPE	7	0.04485	0.00641	0.0000572	0.00756
ELEVAT	7	27.58474	3.94068	0.36104	0.60086
STMORDER	7	41.00000	5.85714	0.14286	0.37796
DISTSOUR	7	26.88850	3.84121	0.22065	0.46974
CATCHSIZ	7	17.65094	2.52156	0.22182	0.47097
SUBCOBLE	7	5.15506	0.73644	0.10389	0.32231
SUBPEBLE	7	3.01569	0.43081	0.12094	0.34777
SUBSILT	7	0	0	0	0
COVALGAE	7	1.83211	0.26173	0.09259	0.30429
COVMOSS	7	1.53451	0.21922	0.10091	0.31767
STWIDTH	7	304.66000	43.52286	263.08033	16.21975
RMTCOND	7	9.00000	1.28571	0.23810	0.48795
PERIFFLE	7	8.41387	1.20198	0.18014	0.42442
PERPOOL	7	1.26671	0.18096	0.03114	0.17647
PERSNAG	7	0.42687	0.06098	0.01090	0.10438

Stepwise Discriminant Analysis Simple Statistics

GRPNUM = 4

Variable	N	Sum	Mean	Variance	Std Dev
SLOPE	6	0.10483	0.01747	0.0000536	0.00732
ELEVAT	6	28.61379	4.76897	0.69398	0.83306
STMORDER	6	16.00000	2.66667	0.66667	0.81650
DISTSOUR	6	9.77584	1.62931	0.16291	0.40362
CATCHSIZ	6	6.35902	1.05984	0.04227	0.20559
SUBCOBLE	6	4.23778	0.70630	0.02087	0.14446
SUBPEBLE	6	2.71268	0.45211	0.04848	0.22018
SUBSILT	6	0.22551	0.03759	0.00848	0.09207
COVALGAE	6	1.89255	0.31542	0.14805	0.38478
COVMOSS	6	1.81606	0.30268	0.04130	0.20323
STWIDTH	6	22.16000	3.69333	3.64471	1.90911
RMTCOND	6	12.00000	2.00000	0.40000	0.63246
PERIFFLE	6	7.99641	1.33274	0.05116	0.22620
PERPOOL	6	0.74911	0.12485	0.04630	0.21517
PERSNAG	6	0.99829	0.16638	0.01800	0.13416

Stepwise Discriminant Analysis

Stepwise Selection: Step 1

Statistics for Entry, DF = 3, 23

Variable	R**2	F	Prob > F	Tolerance
SLOPE	0.1199	1.045	0.3917	1.0000
ELEVAT	0.5113	8.023	0.0008	1.0000
STMORDER	0.7216	19.872	0.0001	1.0000
DISTSOUR	0.7305	20.782	0.0001	1.0000
CATCHSIZ	0.7445	22.345	0.0001	1.0000
SUBCOBLE	0.1487	1.339	0.2860	1.0000
SUBPEBLE	0.0522	0.423	0.7385	1.0000
SUBSILT	0.1346	1.193	0.3346	1.0000
COVALGAE	0.0199	0.155	0.9252	1.0000
COVMOSS	0.1397	1.245	0.3163	1.0000
STWIDTH	0.7310	20.831	0.0001	1.0000
RMTCOND	0.2359	2.367	0.0971	1.0000
PERIFFLE	0.0961	0.815	0.4986	1.0000
PERPOOL	0.1674	1.542	0.2305	1.0000
PERSNAG	0.1766	1.644	0.2067	1.0000

Variable CATCHSIZ will be entered

The following variable(s) have been entered:
CATCHSIZ

Multivariate Statistics

Wilks' Lambda = 0.25545626	F(3, 23) =	22.345	Prob > F = 0.0001
Pillai's Trace = 0.744544	F(3, 23) =	22.345	Prob > F = 0.0001

Average Squared Canonical Correlation = 0.24818125

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Stepwise Selection: Step 7

Statistics for Removal, DF = 3, 20

Variable	Partial R**2	F	Prob > F
ELEVAT	0.3008	2.868	0.0622
DISTSOUR	0.7883	24.817	0.0001
COVMOSS	0.3776	4.045	0.0212
PERSNAG	0.4390	5.218	0.0080

No variables can be removed

Stepwise Selection: Summary

Step	Variable Entered	Variable Removed	Number In	Partial R**2	F Statistic	Prob > F
1	CATCHSIZ		1	0.7445	22.345	0.0001
2	ELEVAT		2	0.3070	3.248	0.0413
3	COVMOSS		3	0.2619	2.484	0.0887
4	PERSNAG		4	0.2461	2.176	0.1225
5	DISTSOUR		5	0.2752	2.404	0.0993
6		CATCHSIZ	4	0.0069	0.044	0.9872

Step	Variable Entered	Variable Removed	Number In	Wilks' Lambda	Prob < Lambda	Average Squared Canonical Correlation	Prob > ASCC
1	CATCHSIZ		1	0.25545626	0.0001	0.24818125	0.0001
2	ELEVAT		2	0.17704086	0.0001	0.35025851	0.0001
3	COVMOSS		3	0.13066748	0.0001	0.39974822	0.0001
4	PERSNAG		4	0.09850868	0.0001	0.44405465	0.0001
5	DISTSOUR		5	0.07140266	0.0001	0.46221459	0.0002
6		CATCHSIZ	4	0.07190201	0.0001	0.46077522	0.0001

2 Spring RAP data, stepwise discriminant function analysis output

Output of the SAS® discrim routine on the reduced environmental data set derived from HMDS and PCC results (used as the final analysis for preparing MLRIVPACS spring model).

Discriminant Analysis

27 Observations	26 DF Total
4 Variables	23 DF Within Classes
4 Classes	3 DF Between Classes

Class Level Information

GROUP	Output SAS Name	Frequency	Weight	Proportion	Prior Probability
1	_1	4	4.0000	0.148148	0.250000
2	_2	10	10.0000	0.370370	0.250000
3	_3	7	7.0000	0.259259	0.250000
4	_4	6	6.0000	0.222222	0.250000

Discriminant Analysis Pooled Covariance Matrix Information

Covariance Matrix Rank	Natural Log of the Determinant of the Covariance Matrix
4	-9.9542426

Discriminant Analysis Pairwise Generalized Squared Distances Between Groups

$$D^2(i|j) = (\bar{X}_i - \bar{X}_j)' \, COV^{-1} (\bar{X}_i - \bar{X}_j)$$

Generalized Squared Distance to GROUP

From GROUP	1	2	3	4
1	0	2.93984	36.04133	3.55550
2	2.93984	0	22.63823	4.53569
3	36.04133	22.63823	0	33.94028
4	3.55550	4.53569	33.94028	0

Discriminant Analysis Linear Discriminant Function

$$\text{Constant} = -.5 \, \bar{X}_j' \, COV^{-1} \bar{X}_j \qquad \text{Coefficient Vector} = COV^{-1} \bar{X}_j$$

GROUP

	1	2	3	4
CONSTANT	-62.86532	-72.80366	-93.92436	-51.80683
ELEV	18.92957	19.42793	17.42054	16.58736
DIST	16.97775	20.51923	30.62786	16.33852
MOSS	7.44843	12.94757	28.61285	13.01925
SNAG	-43.85386	-46.03598	-77.40973	-36.37404

Resubstitution Results using Linear Discriminant Function

Generalized Squared Distance Function: Posterior Probability of Membership in each GROUP:

$$D_j^2(X) = (X-\bar{X}_j)' \, COV^{-1} (X-\bar{X}_j) \qquad Pr(j|X) = \exp(-.5 \, D_j^2(X)) \, / \, SUM_k \exp(-.5 \, D_k^2(X))$$

Posterior Probability of Membership in GROUP:

SITE	From GROUP	Classified into GROUP	1	2	3	4
1	1	1	0.8722	0.0762	0.0000	0.0516
2	2	2	0.0588	0.8313	0.0026	0.1073
3	4	4	0.4240	0.0494	0.0000	0.5266
4	2	2	0.2942	0.6931	0.0001	0.0126
5	2	2	0.0511	0.9109	0.0000	0.0380
6	1	1	0.9122	0.0209	0.0000	0.0669
7	2	2	0.0430	0.9510	0.0002	0.0057
8	4	4	0.2854	0.2057	0.0000	0.5089
9	4	4	0.0083	0.0060	0.0000	0.9857
10	2	2	0.0831	0.8871	0.0001	0.0297
11	4	4	0.0162	0.0354	0.0000	0.9484
12	1	2 *	0.1452	0.6596	0.0000	0.1952
13	4	4	0.1375	0.3268	0.0000	0.5356
14	4	1 *	0.5307	0.0897	0.0000	0.3796
15	1	1	0.6911	0.2122	0.0000	0.0967
16	2	2	0.0303	0.9677	0.0007	0.0012
17	2	2	0.2439	0.6416	0.0000	0.1146
18	2	4 *	0.2770	0.1599	0.0000	0.5631
19	2	4 *	0.0313	0.1251	0.0000	0.8436
20	2	1 *	0.8257	0.0737	0.0000	0.1006
21	3	3	0.0000	0.0000	1.0000	0.0000
22	3	3	0.0000	0.0000	1.0000	0.0000
23	3	3	0.0000	0.0167	0.9832	0.0000
24	3	3	0.0001	0.0050	0.9947	0.0001
25	3	3	0.0000	0.0001	0.9999	0.0000
26	3	3	0.0000	0.0000	1.0000	0.0000
27	3	3	0.0000	0.0000	1.0000	0.0000

* Misclassified observation

Discriminant Analysis   Classification Summary for Calibration Data: RES.CHEM1

Resubstitution Summary using Linear Discriminant Function

Generalized Squared Distance Function: Posterior Probability of Membership in each GROUP:

$$D_j^2(X) = (X-\bar{X}_j)' \, COV^{-1} (X-\bar{X}_j) \qquad Pr(j|X) = \exp(-.5\, D_j^2(X)) \,/\, SUM_k \exp(-.5\, D_k^2(X))$$

Number of Observations and Percent Classified into GROUP:

From GROUP	1	2	3	4	Total
1	3 75.00	1 25.00	0 0.00	0 0.00	4 100.00
2	1 10.00	7 70.00	0 0.00	2 20.00	10 100.00
3	0 0.00	0 0.00	7 100.00	0 0.00	7 100.00
4	1 16.67	0 0.00	0 0.00	5 83.33	6 100.00
Total Percent	5 18.52	8 29.63	7 25.93	7 25.93	27 100.00
Priors	0.2500	0.2500	0.2500	0.2500	

Error Count Estimates for GROUP:

	1	2	3	4	Total
Rate	0.2500	0.3000	0.0000	0.1667	0.1792
Priors	0.2500	0.2500	0.2500	0.2500	

Discriminant Analysis Classification Summary for Calibration Data: RES.CHEM1

Cross-validation Summary using Linear Discriminant Function

Generalized Squared Distance Function:

$$D_j^2(X) = (X-\bar{X}_{(X)j})' \, COV_{(X)}^{-1} (X-\bar{X}_{(X)j})$$

Posterior Probability of Membership in each GROUP:

$$Pr(j|X) = \exp(-.5\, D_j^2(X)) \,/\, SUM_k \exp(-.5\, D_k^2(X))$$

Number of Observations and Percent Classified into GROUP:

From GROUP	1	2	3	4	Total
1	3 75.00	1 25.00	0 0.00	0 0.00	4 100.00
2	1 10.00	7 70.00	0 0.00	2 20.00	10 100.00
3	0 0.00	0 0.00	7 100.00	0 0.00	7 100.00
4	3 50.00	0 0.00	0 0.00	3 50.00	6 100.00
Total Percent	7 25.93	8 29.63	7 25.93	5 18.52	27 100.00
Priors	0.2500	0.2500	0.2500	0.2500	

Error Count Estimates for GROUP:

	1	2	3	4	Total
Rate	0.2500	0.3000	0.0000	0.5000	0.2625
Priors	0.2500	0.2500	0.2500	0.2500	

Discriminant Analysis Classification Summary for Test Data: RES.TESTCHEM

Classification Summary using Linear Discriminant Function

Generalized Squared Distance Function:

$$D_j^2(X) = (X-\bar{X}_j)' \, COV^{-1} (X-\bar{X}_j)$$

Posterior Probability of Membership in each GROUP:

$$Pr(j|X) = \exp(-.5\, D_j^2(X)) \,/\, SUM_k \exp(-.5\, D_k^2(X))$$

Number of Observations and Percent Classified into GROUP:

	1	2	3	4	Total
Total	6	3	3	0	12
Percent	50.00	25.00	25.00	0.00	100.00
Priors	0.2500	0.2500	0.2500	0.2500	

Appendix 4

Macroinvertebrate data recorded for all Surber sampled sites,
Mount Lyell region

Table 4.1 Macroinvertebrate data (family level) from surbers collected in Spring 1995

Site / Taxon (Sample)	Comstock Ck Site 4																			
Sample	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
BIVALVIA								1												
SPHAERII																				
NEMATODE													3							
OLIGOCH	1	1					1													
HYDRACAR																				
PARAMELI										1	1									
EUSTHEN																				
GRIPOPT						1		1			2	1						1		
NOTONEM																				
LEPTOPHL																				
BAETIDAE																				
AESCHNID																				
CHIRONOM	1		3	2		1	2		2	1	1	4		4	1	2			2	
SIMULID										1						1				
TUPULID			1																	
BLEPHER																				
ATHERIC																				
CERATOPG																				
EMPIDAD																				
CALOCID																				
CONOESUC																				
GLOSSOM																				
HELICOPH																				
HYDROBIO																				
HYDROPSY																				
HYDROPTY																				
LEPTOCER																				
ODONTOC																				
PHIILOPOT																				
PHILORHE																				
ADTELMID																				
LARELMID																				
SCIRTID																				
PSEPHEN																				

Site / Taxon (Sample)	Governor R.																			
Sample	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
BIVALVIA																				
SPHAERII																				
NEMATODE									1											
OLIGOCH	17	86	57	61	51	14	78	96	326	65	33	4	28	22	45	27	181	69	36	11
HYDRACAR					1					1										
PARAMELI																				
EUSTHEN	1				2									1	1					
GRIPOPT	1	4	2	2	13	2			2	1	6	3	3	6	1	7	1	3		3
NOTONEM					1															
LEPTOPHL	8	5	2	6	4	4	3	8	3	4	5	9	9	4	8	6	9	11	1	9
BAETIDAE																				
AESCHNID																				
CHIRONOM	1	2		1	1		1					3				1				
SIMULID		3	1	1	2					1	1	1			1	1				
TUPULID									1											
BLEPHER		1	5		2						2	1		1	2	2	1	2		
ATHERIC																				
CERATOPG		1							1						1					
EMPIDAD																				
CALOCID																	1			
CONOESUC					1						1									
GLOSSOM																				
HELICOPH																				
HYDROBIO	1			1						2	1	1		1	1	1	1			3
HYDROPSY		1														1				
HYDROPTY												1								
LEPTOCER		1								1										
ODONTOC																				
PHIILOPOT											1									
PHILORHE																			1	
ADTELMID											1			1						
LARELMID																				
SCIRTID	2	1	6	8	5	14	2	9	8	1	4	12	14	2	5	5	5	4	7	11
PSEPHEN															1					

Site / Taxon (Sample)	Nelson River																			
Sample	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
BIVALVIA																				
SPHAERII					1														1	
NEMATODE																				
OLIGOCH	2	25	27	11	64	33	43	25	65	74	38	5	7	6	2	19	21	28	23	2
HYDRACAR			2							1										
PARAMELI									1			1								
EUSTHEN	1			3			1	1	1	2		2			1		1	1	2	
GRIPOPT	14	4	5	4	6	2		1	4	3		2	1	1	3	1	5		3	3
NOTONEM			1	1																
LEPTOPHL	14	17	23	62	4	28	49	28	46	37	6	8	7	23	6	24	1	37	44	7
BAETIDAE	3					1		1			1	1				1			1	
AESCHNID														1						
CHIRONOM	2	1	4	6	2	4	23		8		1			2		1	2		2	1
SIMULID					1															
TUPULID					1													1		
BLEPHER				1																
ATHERIC				2	3						12					2			1	
CERATOPG																				
EMPIDAD			2													1	1			
CALOCID									1	1							1		1	1
CONOESUC									1					1						1
GLOSSOM	9	13	34	27	24	18	3	8	2	22	6	14	1	17	7	26	14	8	24	12
HELICOPH						2	1		1				1						1	
HYDROBIO				3	1			1	3								1			
HYDROPSY												1								
HYDROPTY																			1	1
LEPTOCER				1			1										1			
ODONTOC							1													
PHIILOPOT			1												1					
PHILORHE		1	1	2	2	2		1		3						2	1	2	1	
ADTELMID	1	1																		
LARELMID		2		1			1			3	1	1							1	
SCIRTID				1	2	2	2	1	5	1						2		1		
PSEPHEN				4	1			1	2				1			1	1	1		

Table 4.2 Macroinvertebrate data (species level) from surbers collected in Spring 1995

Site	Comstock Ck Site 4																			
Sample	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Taxon																				
BIVALVIA								1												
SPHAERII																				
NEMATODE													3							
OLIGOCH	1	1					1													
HYDRACAR																				
PARAMELI										1	1									
ESPECTAB																				
ECOSTALI																				
TZWICKI												1								
TTASMANI																				
CARDIOSP						1		1			2							1		
RPILCHUA																				
KALBOMAC																				
DBASSAE																				
LEPTOSPI																				
ATASMANI																				
ACHRIST																				
GENYSPI																				
GENYSPII																				
GENYSPIII																				
GENDSPI																				
GENZSPI																				
NOUSSPII																				
AUSPAIII																				
BAESPIII																				
AESCHNID																				
CHIRONOM																				
OTHOCLAD	1		3	2		1	2		2	1	1	4		4	1	2			2	
PODONOM																				
TANYPOD																				
DIAMESIN																				
SIMULID										1						1				
TUPULID			1																	
BLEPHER																				

Site	Governor R.																			
Sample	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Taxon																				
BIVALVIA																				
SPHAERII									1											
NEMATODE	17	86	57	61	51	14	78	96	326	65	33	40	28	22	45	27	181	69	36	110
OLIGOCH					1					1										
HYDRACAR																				
PARAMELI	1				2									1	1					
ESPECTAB																				
ECOSTALI	1	4	2		9	1			2	1	3	2	2	5		3	1	2		3
TZWICKI				1														1		
TTASMANI					3	1					3	1	1		1	4				
CARDIOSP																				
RPILCHUA					1															
KALBOMAC					1															
DBASSAE														1						
LEPTOSPI					1															
ATASMANI																				
ACHRIST	6	4	2	6	4	4	2	4	3	3	4	1	7	4	8	5	7	7	1	7
GENYSPI								2					2					1		
GENYSPII																				
GENYSPIII	1	1										1				1	1			1
GENDSPI							1	1												1
GENZSPI										1	1						1	3		
NOUSSPII																				
AUSPAIII																				
BAESPIII																				
AESCHNID	1	2		1	1											1				
CHIRONOM							1													
OTHOCLAD												3								
PODONOM																				
TANYPOD																				
DIAMESIN		3	1	1	2					1	1	1			1	1				
SIMULID									1											
TUPULID		1	5		2						2	1		1	2	2	1	2		
BLEPHER																				

Site	Nelson River																			
Sample	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Taxon																				
BIVALVIA					1														1	
SPHAERII																				
NEMATODE	2	25	27	110	64	33	43	25	65	74	38	5	7	6	2	19	21	28	23	2
OLIGOCH			2							1										
HYDRACAR									1			1								
PARAMELI				1			1		1	2							1			
ESPECTAB	1			2				1				2			1			1	2	
ECOSTALI	13	5	4	4	5	2		1	5	3		2	1		3	1	5		3	2
TZWICKI																				
TTASMANI	1				1									1						1
CARDIOSP			1																	
RPILCHUA																				
KALBOMAC																				
DBASSAE																				
LEPTOSPI			1																	
ATASMANI				1																
ACHRIST	9	12	13	40	24	25	32	25	38	19	5	4	7	11	4	15	9	23	27	5
GENYSPI					1							2						3		
GENYSPII	3	4	1	8	7	1		3	2	6				5		1			4	
GENYSPIII				1	1					8	1					3			2	2
GENDSPI			3	9	5	2	11	1						1	1	4		4	8	
GENZSPI			6	3			6		4	2						1	1	5	2	
NOUSSPII				1	1									1	1					
AUSPAIII	3					1		3			1	1							1	
BAESPIII														1						
AESCHNID		1	2	1	1	2	1		3		1			1		1	2		2	
CHIRONOM	1					1			3					1						1
OTHOCLAD	1		2	5	1	1	1		2											
PODONOM																				
TANYPOD							1													
DIAMESIN					1															
SIMULID					1													1		
TUPULID				1																
BLEPHER																				

Table 4.2 (cont'd)

Site	Comstock Ck Site 4																				Governor R.																				Nelson River																			
Sample	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Taxon																																																												
ATHERIC																																												2	3						12					2			1	
CERATOPG																						1							1						1																									
EMPIDAD																																											2													1	1			
TVARIEG																																																		1							1		1	1
CSANERA																																					1																							
CNORELUS																															1																		1					1						1
GLOSSOM																																									9	13	34	27	24	18	3	8	20	22	6	14	10	17	7	26	14	8	24	12
APILOSA																																														2	1		1				1							
AGRISEA																																																											1	
MORUSPI																														2	1	1		1		1				1				1																
AOBLIQUU																																								1									3								1			
EHESPER																																												1																
ENESYDRI																					1			1																								1												
PNIGRITA																																								1																				
TASCHSPI																																			1																									
KCLIVIC																																												1																
TASMANUM																																					1																							
CHEUSPH																																				1																								
DSIIIIII																						1																																						
MRUPINA																																																											1	1
OECETISP																														1														1																
TRIPLECT																																															1													
RUSSOB?																																																									1			
ODONTOC																																															1													
PHILOPOT																															1												1												1					
HEIGHTEEN																															1																													
HWADDAMA																																											1																	
PHILORHE																																							1			1	1	2	2	2		1		3						2	1	2	1	
ADTELMID																															1			1							1	1																		
LARELMID																																										2		1			1			3	1	1							1	
SCIRTID																					2	10	6	8	5	14	20	9	8	10	4	12	14	2	5	5	5	4	7	11				1	2	2	2	1	5	1						2		1		
PSEPHEN																																			1									4	1			1	2				1			1	1	1		

Appendix 5

Fish capture and length data recorded for all electrofished stream sites

Table 5.1 Fish survey data, Mount Lyell–Macquarie Harbour region, 1996. Number observed and lengths are recorded. Only those sites where fish were quantitatively surveyed are detailed here.

	Site length (m),	S. trutta (Brown trout)		O. mykiss (Rainbow trout)		A. australis (Shortfin eel)		P. urvillii (Sandy)	
Site	No. runs	n	lengths (mm)	n	lengths (mm)	n	lengths (mm)	n	lengths (mm)
West Queen R	80, 2			23	130, 56, 202, 206, 191, 74, 63, 66, 133, 128, 200, 205, 167, 187, 129, 137, 135, 126, 135, 135, 119, 139, 131				
Halls Ck	100, 2			30	112, 175, 173, 115, 132, 135, 121, 190, 148, 115, 168, 180, 170, 180, 170, 170, 168, 145, 175, 108, 113, 118, 170, 113, 130, 120, 123, 106, 114, 195				
Township Ck									
Newall Ck	100, 2	12	194, 213, 184, 137, 127, 132, 112, 108, 52, 131, 224, 176						
Nelson R	100, 2	12	108, 166, 126, 164, 128, 124, 197, 176, 208, 110, 70, 150						
Manuka R	100, 2	8	175, 150, 202, 82, 301, 215, 157, 168			4	162, 166, 126, 111	7	143, 136, 129, 152, 156, 75
Porteus Ck	220, 2					1	220		
Botanical Ck	70, 2					2	480, 395	54	99, 83, 87, 88, 78, 91, 81, 80, 76, 82, 80, 77, 57, 56, 59, 92, 74, 87, 88, 75, 83, 70, 70, 64, 69, 84, 68, 82, 55, 76, 81, 57, 81, 85, 79, 82, 75, 74, 74, 88, 56, 74, 94, 70, 73, 97, 57, 77, 56, 53
Connellys Point Ck	100, 2	2	188, 192			1	750	37	92, 72, 74, 130, 155, 80, 95, 49, 122, 93, 65, 103, 81, 110, 73, 58, 135, 84, 143, 110, 88, 87, 72, 52, 76, 81, 69, 72, 65, 49, 44
Lower Henty R	900, 1	>1				20	750, 550, 750, 400, 45	33	75, 102, 61, 76
Tully R	130, 1	8	189, 196, 182, 170, 228, 240, 273, 71			4	580	39	74, 131, 150, 99, 113, 102, 77, 54, 97, 105, 114, 82, 119, 114, 113, 124, 140, 79, 72, 102, 93, 132, 94, 67, 89, 69, 76
McCutcheon's Ck	150, 2	1	160			1		16	74, 100, 70, 90, 56, 92, 89, 93, 96, 84, 65, 69, 88, 93, 67, 54
Lucky Ck	100, 2								
Kingfisher Ck	150, 2					1	267		
Four mile Ck	150, 2								
Lower Landing Ck	120, 1					4	350, 460, 380, 420		
Virginia Ck	100, 2					1	160		
Swift Ck	230, 2			25	207, 204, 181, 158, 177, 183, 166, 81, 81, 178, 72, 80, 173, 178, 81, 182, 188, 91, 87, 84, 81, 82, 78, 78, 59	11	475, 547, 415, 316, 329, 407, 302, 290, 342, 320, 245		
Open Ck	230, 2	20	184, 175, 139, 210, 187, 169, 179, 154, 183, 150, 168, 195, 142, 124, 188, 198, 159, 164, 194, 143			1	455		
Starting Ck	220, 2			3	156, 163, 125				
Lower Gordon Ck 1	30, 2								
Lower Gordon Ck 2	80, 2							12	113, 75, 97, 64, 61, 90, 65, 75, 63, 65, 51, 55
Little Eagle Ck	100, 2	6	177, 231, 144, 146, 174, 117					3	67, 75, 82

Table 5.1 (cont'd)

Site	Site length (m), No. runs	G. marmoratus (Blackfish) n	G. marmoratus (Blackfish) lengths (mm)	G. australis (Lamprey*) n	G. australis (Lamprey*) lengths (mm)	G. maculatus (Jollytail) n	G. maculatus (Jollytail) lengths (mm)	G. truttaceus (Mountain galaxias) n	G. truttaceus (Mountain galaxias) lengths (mm)	G. brevipinnis (Climbing galaxias) n	G. brevipinnis (Climbing galaxias) lengths (mm)
West Queen R	80, 2										
Halls Ck	100, 2										
Township Ck											
Newall Ck	100, 2										
Nelson R	100, 2									1	67
Manuka R	100, 2	2	185, 79	2	98			10	59, 99, 114, 137, 121, 100, 119, 127, 79, 61	2	64, 112
Porteus Ck	220, 2									5	180, 190, 166, 170, 131
Botanical Ck	70, 2			>50	80, 97, 100, 94, 94, 94, 90, 97, 103, 97, 95, 100, 81, 105, 81, 91, 96			100	789, 63, 62, 118, 64, 102, 101, 92, 97, 105, 93, 68, 64, 64, 92, 59, 59, 92, 69, 70, 102, 55, 78,108, 65, 127, 62, 69, 60, 58, 60, 64, 65, 64, 67, 66, 68, 104, 62, 102, 118, 92, 69, 62, 75, 91, 113, 86, 87, 107, 134, 67, 86, 64, 64, 68, 67, 108, 117, 99, 128, 98, 91, 68, 68, 100, 88, 102, 96, 69, 69, 64, 91, 64, 63, 65, 102, 97, 72, 71, 94, 104, 79, 71, 126, 94, 103, 82, 117, 69, 64, 66, 63, 114, 94	1	51
Connellys Point Ck	100, 2			8	100, 104, 101, 97, 100, 97, 99, 88			87	123, 129, 153, 98, 102, 102, 55, 106, 118, 152, 132, 146, 67, 119, 163, 159, 162, 63, 124, 106, 125, 146, 123, 108, 97, 113, 143, 152, 142, 141, 115, 116, 60, 108, 118, 118, 133, 142, 116, 88, 132, 122, 96, 114, 141, 101, 111, 122, 92, 61, 133, 78, 94, 65, 67, 112, 101, 132, 62, 125, 102, 97, 111, 76, 97, 134, 114, 65, 65, 86, 44, 134, 138, 112, 134, 118, 112, 128, 125, 82, 73, 65, 64	4	111, 97, 118
Lower Henty R	900, 1			> 200	128, 145, 128	122	55, 58, 62, 63, 59, 67, 63, 113, 78, 51, 63, 51, 52, 54, 65, 58, 67, 70	~ 88	68, 64, 76, 68, 94, 74, 73, 103, 68, 66, 83, 92, 67		
Tully R	130, 1			>>10	113, 82, 90, 83, 98, 99, 85, 89, 78, 70			82	64, 103, 66, 69, 66, 67, 112, 111, 106, 91, 81, 66, 96, 64, 75, 97, 66, 75, 61, 75, 63, 71, 71, 71, 71, 73, 69, 69, 70, 69, 73, 69, 155, 81, 86, 71, 111, 96, 68, 70, 73, 76, 66, 64, 79, 133, 111, 92, 67, 92, 70, 77, 68, 74, 71, 64, 62, 89, 73, 70, 68, 65, 68, 67, 100, 113, 71, 68, 67, 71, 70, 71, 71	2	52, 49
McCutcheon's Ck	150, 2			7	96, 92, 94, 98, 93, 93, 87			28	64, 62, 147, 82, 76, 69, 80, 115, 105, 91, 75, 91, 98, 78, 132, 112, 87, 95, 76, 72, 69, 108, 110, 70, 74, 65, 94		
Lucky Ck	100, 2									2	137, 139
Kingfisher Ck	150, 2							11	177, 146, 159, 157, 149, 168, 149, 153, 168, 164, 166	11	168, 139, 147, 163, 124, 159, 112, 168, 148, 169, 138
Four mile Ck	150, 2									14	157, 178, 178, 164, 128, 157, 138, 143, 169, 152, 148
Lower Landing Ck	120, 1										
Virginia Ck	100, 2									4	154, 158, 160, 163, 158
Swift Ck	230, 2										
Open Ck	230, 2										
Starting Ck	220, 2										
Lower Gordon Ck 1	30, 2									3	43,109,135
Lower Gordon Ck 2	80, 2							11	102, 88, 130, 97, 71, 71, 64, 142, 137, 94, 64		
Little Eagle Ck	100, 2							6	125, 104, 77, 144, 82, 101	1	235

* Identification tentative. Some specimens may be Mordacia mordax